ISSN 0853-2982 JURNAL TEKNIK SIPIL eISSN 2549-2659
Jurnal Teoretis dan Terapan Bidang Rekayasa Sipil

Evaluation of The Performance of Hot Mix Asphalt With Natural Rubber (Latex) For Asphalt Concrete - Binder Course (Ac-Bc)

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Abstract

This study aims to measure the performance of the Hot Mix Asphalt for Asphalt Concrete Binder Course (AC-BC) with addition of natural rubber (latex) at variations of 0%, 2% and 3% by weight. The method used in this study is an experimental method in a laboratory that consists of natural aggregate testing, rheology testing for asphalt pen 60/70 and asphalt pen 60/70 plus natural rubber (latex) and AC-BC mixture testing. The method used is Marshall Test to obtain optimum asphalt content (OAC) and another method consists of UMATTA Resilient Modulus Test and strain controlled Four Points Fatigue Test. The addition of natural rubber in the AC-BC mixture reduced the optimum asphalt content (OAC) and increased the Marshall stability value, the optimum percentage is 3% natural rubber (latex) with the lowest OAC of 5.4% and the highest Marshall stability. The UMATTA test with 2% natural rubber (latex) resulted in the highest Resilient Modulus value compared to the other two blends. Fatigue testing at strain 500 με, 600 με, and 700 με resulted that the mixture of AC-BC with 3% natural rubber produced the highest fatigue life value compared to the other two mixes. In general, the result of testing and its analysis concluded that the use of natural rubber (latex) can reduce the use of asphalt in the mixture. This can be relified by decreasing the value of OAC in the mixture with natural rubber. The mixture with 3% natural rubber (latex) gives the highest resistance to fatigue cracks in the laboratory.

Keywords: AC-BC, natural rubber (latex), resilient modulus, fatigue cracking.

Abstrak

Penelitian ini bertujuan untuk mengukur kinerja Campuran Beraspal Panas untuk Aspal Beton Lapis Antara (AC-BC) dengan bahan tambah natural rubber (lateks) pada variasi 0%, 2% dan 3%. Metode yang digunakan dalam penelitian ini adalah metode eksperimental di laboratorium yang terdiri atas pengujian agregat alam, pengujian reologi aspal pen 60/70, pengujian reologi aspal pen 60/70 ditambah natural rubber (lateks) dan pengujian campuran AC-BC. Pengujian campuran Stabilitas Marshall untuk mendapatkan kadar aspal optimum dan pengujian lanjutan campuran dengan kadar aspal optimum yang terdiri dari Modulus Resilien dengan UMATTA dan ketahanan terhadap kelelahan dengan menggunakan metode four points loading kontrol regangan. Penambahan natural rubber (lateks) dalam campuran AC-BC menurunkan kadar optimum aspal (KAO) dan meningkatkan nilai stabilitas Marshall, dimana pada persentase 3% natural rubber (lateks) didapat KAO terendah dan stabilitas Marshall. Pengujian UMATTA pada penambahan 2% natural rubber (lateks) menghasilkan nilai Modulus Resilien yang paling tinggi dibandingkan dengan dua campuran lainnya. Pengujian kelelahan pada regangan 500 με, 600 με, 700 με menunjukan bahwa campuran AC-BC dengan 3% natural rubber (lateks) menghasilkan nilai umur kelelahan yang paling tinggi. Secara umum, dari hasil pengujian maupun analisis dapat disimpulkan bahwa penggunaan natural rubber (lateks) mampu menurunkan penggunaan aspal dalam pembuatan campuran, hal ini dapat dilihat dengan menurunnya nilai KAO pada campuran dengan penambahan natural rubber (lateks). Campuran 3% natural rubber (lateks) lebih mampu menahan retak lelah pada lapisan perkerasaan.

Kata kunci: AC-BC, natural rubber (lateks), modulus resilien, kelelahan retak.

1. Introduction

Rubber-modified asphalt has long been known to improve rheological properties at low and high temperatures and give three times longer durability compared to conventional asphalt. Although the price of rubber-modified asphalt is much higher than the conventional asphalt, the benefits of increasing the life of the modified asphalt make the total price lower.

There are several studies to evaluate pavement performances using additive or filler, such as Subagio

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et. al, 2005 studies about the fatigue performance of Hot rolled asphalt and superpave mixes using Indonesian rock asphalt as fine aggregates and filler; Subagio et al, 2013 studied about: the resilient modulus and plastic deformation performance of hot mix recycling asphalt (HMRA) using modified binder elvaloy; Jahanian et al studied performance evaluation of Hot Mix Asphalt containing bitumen modified with gilsonite; Dulaimi et.al evaluated the performance of HMA containing calcium carbide residue as a filler; Ma et al studied the performance evaluation of temperature effect on hot in place recycling asphalt mixture; and other studies.

The addition of rubber to asphalt can improve several parameters, i.e. the increase in softening point, elasticity, and adhesiveness so that the asphalt is more durable. Rubber-modified asphalt is also superior to conventional asphalt because its melting point is higher, and if exposed to sunlight, it does not melt and is more stable so it; does not break quickly, does not surge quickly and does not erode quickly. Rubber-modified asphalt is also stickier and more flexible so that it can reduce cracking due to overload. The test results also show that rubber asphalt has a durability of 1.5-2 times the durability of conventional asphalt (Prastanto et al., 2015).

According to Siswanto, (2016), compared to conventional asphalt, asphalt mixture modified with natural rubber (latex) produces a higher dynamic stability value, so it can extend the life of pavement with the smallest percentage of natural rubber (latex) of 2%. Based on the phenomenon, a study was conducted to measure the performance of Asphalt Concrete - Binder Course (AC-BC) with natural rubber (latex) modification. The natural rubber (latex) percentage variation used followed the recommendation of the smallest percentage of natural rubber (latex) of 2%. As a comparison, testing was done on increasing the percentage of natural rubber (latex) by 3% and on conventional asphalt with 0% natural rubber (latex).

This study aims to measure the performance of Hot Mix Asphalt for Asphalt Concrete - Binder Course (AC-BC) with addition of natural rubber (latex) at variations of 0%, 2% and 3% by weight.

In this study, advanced testing was carried out to determine the value of Resilient Modulus from asphalt mix modified with natural rubber (latex) with repetitive loading using UMATTA. In addition, testing was carried out using a Four-Point Bending Test to determine the fatigue life of the asphalt mix modified with natural rubber (latex).

2. Materials and Laboratory Tests

2.1 Aggregate

Aggregate is a constituent that has a very important role in transportation infrastructure, especially in this case on road pavement. The aggregate requirement in the mixture ranges from 90% - 95% of the mixture's total weight or 75% - 85% of the mixture's volume (Asphalt Institute, 1989). The aggregate used must be clean from impurities, organic materials or other undesirable substances because they will reduce the mixture's performance (Hardiyatmo, 2011).

2.2 Asphalt

Asphalt in the pavement layer functions as a binding material between aggregate grains to form a dense material so that it can give the mixture strength and durability in supporting vehicle loads. Asphalt is needed in a certain amount to bind aggregate particles, filling voids between aggregates. Low asphalt content in the mixture will reduce durability, flexibility, strength, impermeability, and workability. However, too much asphalt will also result in low mixture stability and stiffness (Hardiyatmo, 2011).

2.3 Rubber asphalt

According to Minister for Public Works and Human Settlements (2018 General Specifications), natural rubber is a natural material obtained from rubber-producing trees including Havea Brasiliensis, by tapping the part between the cambium and tree skin.

The rubber asphalt material is pre-vulcanized latex for liquid natural rubber and solid natural rubber. Asphalt modification with liquid rubber can be done in an asphalt mixing plant (bitumen plant) through the mixing process using a special mixing tool (Minister for Public Works and Human Settlements (2018 General Specifications).

2.4 Marshall and absolute density

Hot mix asphalt planning to determine the performance of asphalt concrete mixture that is commonly done in Indonesia is through the Marshall method. From these tests, stability and flow values are obtained, then the ratio of stability and flow (Marshall Quotient) and other volumetric quantities will be calculated. In this test, the Optimum Asphalt Content (OAC) can also be analyzed later.

Absolute density is the highest (maximum) density that can be achieved by a mixture until the mixture cannot get even denser. The absolute density is a refinement of the conventional Marshall method. For heavy traffic conditions, the conventional Marshall sets the compaction of test specimen with 2 x 75 collisions with void in mix limit of 3% - 5%. The results of the quality control test indicate that the compatibility of control parameters in the field is often not met to achieve the requirements in the specifications so that the performance of road pavement is not achieved.

2.5 Marshall immersion

Marshall immersion test is a test to determine the durability of asphalt mixture, which in this case is shown by examining the susceptibility of the mixture to damage caused by water. Several Marshall specimens were prepared in Optimum Asphalt Content, half of the prepared specimens were tested under normal conditions and their average stability was

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calculated, the remaining specimens were immersed for 24 hours at 60°C and their average stability was calculated. Comparison between the stability of the test specimens after immersion and the stability of the standard test specimens were expressed in percent, called the Marshall Index of Retained Strength.

The Marshall Index of Retained Strength of 90% is the minimum value required in the Bina Marga Specification (Ministry of Public Works, 2014). At this value, the asphalt mixture is considered quite resistant to damage caused by water.

2.6 Stiffness modulus

This test was conducted to determine the value of the asphalt mixture's resilient modulus. Resilient modulus is the level of material elasticity and stiffness that is theoretically obtained from the relationship between stress and strain of a material. Resilient modulus can be used, among others, as an assessment to predict stress, strain and displacement, and can be used as an approach to pavement planning and to evaluate pavement performance.

In this study, the resilient modulus was obtained by using the Universal Material Testing Apparatus (UMATTA), which refers to BS EN 12697-26-2004 Annex F. The test is classified as a non-destructive test that do not damage the test materials as the load given is relatively small. The UMATTA consists of a Control and Data Acquisition System (CDAS) device, a personal computer device and an integrated software.

2.7 Fatigue crack

Fatigue is a phenomenon of crack occurrences due to repeated loads that occur due to repetition of stresses or strains whose limits are still below the material strength limit (Yoder et al.,1975). The stress and strain values depend on the wheel load, stiffness and the basic nature of the pavement.

According to SHRP-A-410 (1994), The laboratory testing methods that are quite good and are possible to be used in measuring the properties of the mixture that affect fatigue performance are:

1. Direct axial tensile
2. Indirect tensile
3. Flexture fatigue test with 2, 3, and 4 flexure points
4. Rotating bending

Test for resistance to fatigue can be carried out using a four-point loading test tool.

3. Research Methodology

The method used in this study is an experimental method in the laboratory. Primary data collection was done through a series of tests on aggregates, asphalt, and mixtures. This research was conducted at the Bandung Institute of Technology laboratory, Balai Besar Pelaksana Jalan dan Jembatan Wilayah V Laboratory, and the Ministry of Public Works and Public Housing Laboratory. In general, this research can be seen from the flowchart in **Figure 1**.

4. Data Presentation and Analysis

4.1 Marshall stability

Stability is an empirical parameter to determine the ability of the pavement layer to withstand permanent deformation when receiving traffic loads without permanent changes in shape such as waves, rut, and bleeding (Asphalt Institute, 1994). The stability value according to the General Specifications of Bina Marga 2018 is limited to a minimum of 800 kg for the AC-BC and according to the Hot Mix Asphalt with Natural Rubber Specifications, it is limited to a minimum of 900 kg. A comparison of the stability values of each mixture is presented in **Figure 2**.

From the Figure 2, the stability of AK0 is the lowest, followed by AK1 and AK2. The optimum asphalt content for AK0, AK1, and AK2 is about 5.50. The

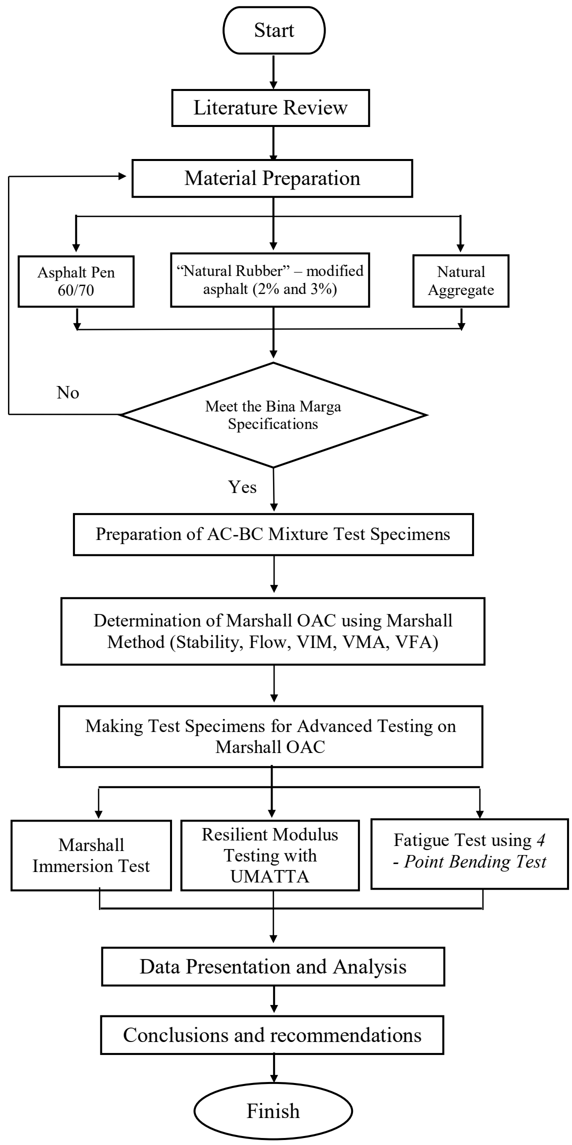

Figure 1. Research flowchart

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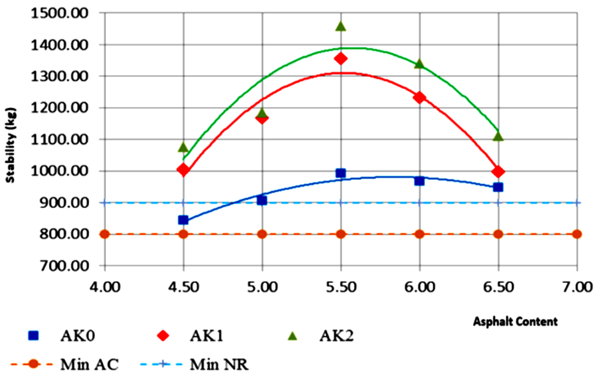


Figure 2. Comparison of stability values

minimum AC shown in orange line with the value of 800kg and minimum NR shown in the blue line which is 900 kg.

Optimum Asphalt Content is the asphalt content that produces a mixture that satisfies all elements of Marshall parameters, including the VIM Refusal. VIM Refusal can reduce the percentage of Optimum Asphalt Content in the mixture because it considers the conditions in which the mixture in the pavement experiences further compaction by the traffic load. A comparison of the Optimum Asphalt Content of each mixture is presented in **Figure 3**.

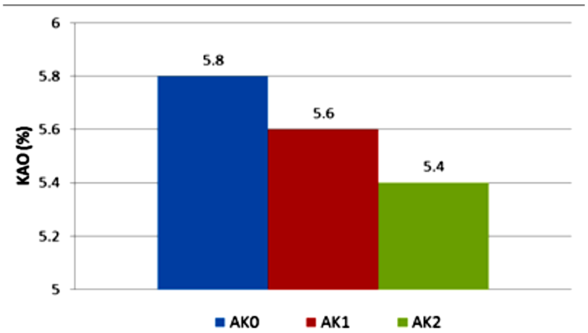


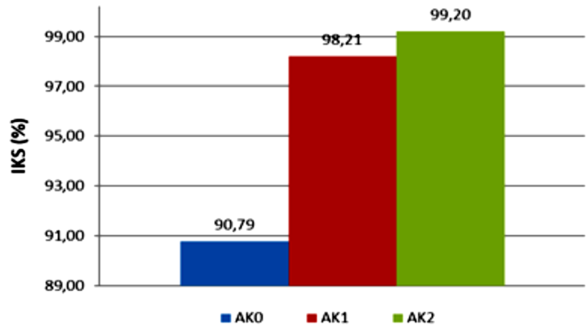
Figure 3. Comparison of OAC values

Based on **Figure 3**, the OAC in the asphalt pen 60/70 mixture is higher than the modified asphalt mixture. This is because the modified asphalt is harder and its ability to flow is better so that after being absorbed by the aggregate, this modified asphalt will not easily get out of the void in aggregate and the required asphalt is less than the requirement for asphalt pen 60/70 content to produce a mixture with optimum strength.

4.2 Marshall stability after immersion

Marshall immersion testing aims to determine the mixture's resistance to water, which is characterized by the loss of bonds between asphalt and aggregate grains. This is important in maintaining stability.

Based on the Marshall immersion test, it was found that the Marshall Index of Retained Strength value in the AK1 mixture was 93.87%, in the mixture with AK1 was 94.98%, and in the AK2 mixture was 95.09%. All types of mixtures meet the requirements as of the 2018 Bina Marga General Specifications that require Marshall Index of Retained Strength to be greater than 90%, as shown in **Figure 4**.



IKS: Marshall Index of Retained Strength

Figure 4. Marshall index of retained strength of each mixture

4.3 Resilient modulus test

Resilient modulus is a modulus of elasticity based on recoverable strain (Huang, 2004). This terminology is used because asphalt mixture is a material that is not perfectly elastic. The visco elastic asphalt mixture causes the resilient modulus to change depending on the temperature and time of loading received. The higher the temperature, the lower the resilient modulus. This is because at high temperatures the asphalt will become a material that is more liquid and no longer solid, so the asphalt's ability to bind will be greatly reduced which makes the bond between the aggregates in the mixture not interlocking.

The test conducted for the temperature of 25°C, 35°C and 45°C with AK0, AK1, and AK2 foe each temperature. The result of resilient modulus can be seen in **Figure 5**.

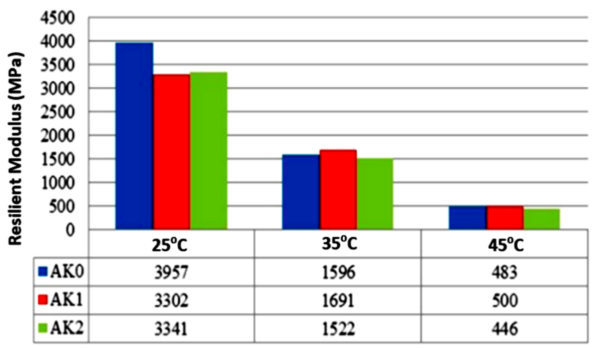


Figure 5. Comparison of mixture's resilient modulus values at variating temperatures

In addition to the test temperature, the hardness of the adhesive (asphalt) and aggregate characteristics also affect the value of the resilient modulus of an asphalt mixture. Resilient modulus testing in this study was conducted at test temperatures of 25°C, 35°C and 45°C.

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Table 1. Summary of results of AC-BC mixture modified with natural rubber (latex)

Parameter		AC-BC NR		
		Asphalt Pen 60/70	Asphalt Pen 60/70 + 2% Latex	Asphalt Pen 60/70+ 3% Latex
Marshall				
OAC	%	5.8	5.6	5.4
Density	t/m^3	2.263	2.284	2.2891
Marshall Stability	kg	980.625	1307.726	1.380.645
Flow	mm	3.843	3.889	3.875
Marshall Quotient	kg/mm	255.532	336.426	355939
Marshall Immersion				
Marshall Index of Retained Strength	%	90.79	98.21	99.20
Dynamic Testing System (UMATTA)				
Resilient Modulus (25°C)	Mpa	3957	3302	3341
Resilient Modulus (35°C)		1596	1691	1522
Resilient Modulus (45°C)		483	500	446
Fatigue test				
Fatigue life (500μ_ε)	cycles	17170	16380	101110
Fatigue life (600μ_ε)	cycles	10100	5790	29890
Fatigue life (700μ_ε)	cycles	6170	3930	15230

Test result at a temperature of 45°C shows a smaller resilient modulus value compared to tests at a temperature of 25°C and at a temperature of 35°C. Test results are shown in **Figure 5**, where the Resilient Modulus value for each mixture type decreases as the temperature increases.

4.4 Fatigue test

This fatigue test was carried out by using strain control. The strain given to the tested mixture consisted of 3 (three) levels: 500 με, 600 με, and 700 με. The relationship between strain and fatigue life for all three types of mixtures can be seen in **Figure 6**.

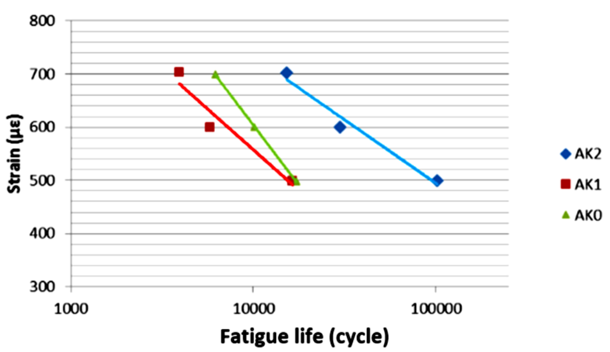

Figure 6. Comparison of fatigue life to strain

Based on **Figure 6**, the strain value is inversely proportional to the fatigue life, where the greater the strain given, the shorter loading cycles. This is because the greater the strain given, the greater the stress produced to maintain the strain. As a result, the load received by the mixture is greater, which impacts on the faster the mixture collapses.

4.5 Analysis

A test using the Marshall method was conducted to determine workability, the UMATTA method was used to determine Resilient Modulus, and the Fatigue Test was carried out to determine the fatigue life of AC-BC mixture with natural rubber (latex) modified asphalt. The results of the research can be seen in **Table 1**.

From the results of the Marshall test, it was found that the value of OAC is decreasing, stability is increasing, and melting is increasing. The stability and melting quality of the mixture increases with the increasing percentage of natural rubber (latex) in the mixture. With a decrease in OAC in the mixture, the use of asphalt is less so it saves the amount of asphalt in the mixture. From the results of the Marshall Immersion test, the stability value and the Marshall Index of Retained Strength increased and met the specifications where the Marshall Index of Retained Strength was greater than 90%. From the UMATTA test, the Resilient Modulus value for mixtures that use natural rubber (latex) modification is lower than the mixture without natural rubber (latex) (conventional). Fatigue resistance test with strain control shows that the use of natural rubber (latex) can increase fatigue life when compared to the mixture without natural rubber (latex) (conventional).

5. Conclusions

Based on the presentation and analysis of the data, the following conclusions were obtained:

1. Evaluation of the characteristics of the hot mix asphalt for Asphalt Concrete - Binder Course (AC-BC) with the addition of natural rubber (latex) can reduce the optimum asphalt content (OAC) and increase the mixture's durability.
2. Evaluation of Resilient Modulus value
   The results of the UMATTA test on the addition of 2% natural rubber (latex) resulted in a higher Resilient Modulus value compared to the other two mixtures although the resilient modulus value did not show a significant increase.
3. The AC-BC mixture with the addition of natural rubber (latex) resulted in a longer fatigue life based on the results of fatigue testing at strains of 500 με, 600 με, and 700 με,.

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6. Recommendations

Based on the results of the study, further testing is proposed for the basic rheological properties of asphalt with natural rubber (latex) modification and further testing for the AC-BC mixture.

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