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Analysis of Variation of Soaking Duration of Asphalt Concrete Wearing Course (AC-WC) Mixture Using Natural Rubber Modified Asphalt Against Indirect Tensile Strength Value (ITS)

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Abstract. Natural rubber asphalt modification involves the mixing of asphalt with vulcanization chemical additives such as sulfur, mixed together in a heated state. The addition of natural rubber enhances the asphalt's elasticity, increasing its capacity to withstand loads from heavier vehicles, improving heat resistance, and boosting its adhesiveness to aggregates. This results in a road surface that is more resistant to cracking and potholing. The research aims to analyze indirect tensile strength values in asphalt-modified natural rubber. The methodology employed is a laboratory experimental study based on SNI 6753:2015, with immersion variations of ½ hour, 24 hours, 48 hours, and 72 hours. The study's findings indicate indirect tensile strength values at intervals of 12 hours, 24 hours, 48 hours, and 72 hours as follows: 459.752 kPa, 427.571 kPa, 379.771 kPa, and 379.971 kPa, respectively. The tensile strength ratios for each variation were 100%, 92.98%, 82.59%, and 75.52%. The study concluded that the tensile strength ratio at submersion for ½ hours, 24 hours, and 48 hours meet the requirements of the AASTHO T-283 specification.

Keywords: Asphalt Concrete Wearing Course, Indirect Tensile Strength, Tensile Strength Ratio

INTRODUCTION

The asphalt concrete wearing course (AC-WC) serves as the topmost protective layer of road surfaces, shielding the underlying structure from water infiltration [1]. This weakening occurs because the water reduces the adhesive interaction between these components. Consequently, when vehicles traverse these compromised areas and exert pressure, the road surface is prone to cracking and further damage [2].

To mitigate road damage, improvements in the quality of asphalt used are imperative. Modified asphalt, such as polymer asphalt, represents a viable solution [3]. Polymer asphalt is a material produced by modifying either natural or synthetic polymers [4]. Notably, natural rubber stands out as a potential additive in polymer asphalt mixtures.

Indonesia ranks among the world's largest rubber producers, with domestic rubber production accounting for approximately 85% of the total output [5] & [6]. However, rubber prices have plummeted due to a decline in demand for raw rubber exports. One strategy to stabilize rubber values is to encourage domestic consumption. The Ministry of Public Works and Housing (PUPR) supports this approach by utilizing natural rubber in infrastructure projects, including its integration into asphalt mixtures as additives or in the form of modified asphalt from natural rubber. Known as asphalt rubber, this material is created by combining asphalt with natural rubber and chemical additives for vulcanization, mixed together at high temperatures [7]. The Directorate General of Highways (Bina Marga) has issued interim special specifications, SKH-2.M.04, which pertain to asphalt materials that incorporate natural rubber.

According to Yussofb, N. I. M., dkk., (2019), natural rubber is characterized by its elasticity, high tensile strength, and substantial elongation ratio. When used as a modifier in asphalt mixtures, natural rubber enhances the mixture's grinding resistance and flexibility modulus. As a result, natural rubber asphalt exhibits increased elasticity and improved adhesion to aggregates.

The study aimed to assess the elasticity of asphalt modified with natural rubber based on its indirect tensile strength (ITS) values, adhering to the standards of SNI 6753-2015. The research included immersion variations of 12, 24, 48, and 72 hours, drawing upon research from Damopolii, et al, This research initially tested the ITS values of 60/70 penetration asphalt. ITS is a technique used to determine the tensile strength of asphalt and concrete mixtures. The traction style parameter serves as an indicator of the mixture's fatigue potential. This test, which simulates a tensile failure, is crucial for evaluating the likelihood of cracking in asphalt-concrete mixtures [9].

LITERATURE REVIEW

Asphalt Concrete Wearing Course (AC-WC)

The Asphalt Concrete Wearing Course (AC-WC) is a topmost coating layer integral to the pavement structure. It serves a dual purpose: protecting the underlying road structure from rainwater infiltration and shielding it against temperature fluctuations. Additionally, it functions as the primary asphalt layer. By implementing AC-WC coatings, the service life and durability of the roadway are significantly enhanced, improving its resistance to various stresses [1]. This layer directly interfaces with vehicle tires and is specifically engineered to endure weather variations, shear forces, tire pressures from vehicles, and to provide a waterproof barrier for the underlying layers [10].

Road Pavement Composition Materials

Aggregates are granular materials such as gravel, sand, or crushed stone. These are typically used in conjunction with a binding agent. Aggregates are categorized into two types: coarse aggregates and fine aggregates [11].

- Natural rubber asphalt modification

The modification of asphalt with natural rubber involves the incorporation of chemical additives for vulcanization and is performed at elevated temperatures. This process enhances the elasticity of the asphalt, enabling it to better withstand heavier vehicle loads. Additionally, the modified asphalt exhibits improved heat resistance and greater adhesion to aggregates, which increases the road surface's resistance to cracking and potholing However, this method does have a drawback in terms of cost, as it is more expensive compared to using standard 60/70 penetration asphalt [7] & [12].

- Filler

Filler is a material that serves to fill the asphalt mixture on the pavement layer. The filler material must be lump-free and dry. At least 75% of the filler must pass through a No. 200 sieve (0.075 mm). Acceptable types of filler include rock dust, cement, lime, or fly ash, all of which must receive approval from the project director [13].

Indirect Tensile Strength

Indirect Tensile Strength (ITS), also known as indirect pull strength, measures the tensile strength of an asphalt concrete mixture and serves as a basis for assessing its potential for cracking [14]. According to AASHTO T-283, the tensile strength ratio should not be less than 80%.

The results from ITS tests are critical for evaluating asphalt concrete mixtures to predict the likelihood of rupture in the field during service or over the period of curing. Furthermore, ITS values are utilized to assess potential damage to the stiffness of the pavement due to moisture. This assessment is conducted by comparing results from both conditioned (unimmersed) samples and unconditioned (immersed in water) samples [1].

The indirect tensile value can be calculated using equation 1 below:

$$ITS = \frac{2000 \times P}{\pi \; x \; d \; x \; h} \qquad (1)$$

Description:
ITS = Strong value of indirect pull (KPa)
p = Maximum load (N)
h = height or thickness of the test object (mm)
d = The diameter of the test object (mm)

The indirect tensile strength value of each specimen is used to calculate the tensile strength ratio, also known as the indirect pull strength ratio, with varying immersion durations. According to AASHTO T-283, the tensile strength ratio should be at least 80%, as determined using Equation 2 provided below.

$$TSR = \frac{S2}{S1} \, x \, 100 \quad (2)$$

TSR = Tensile Strength Ratio
S1 = Indirect tensile strength early (kg/cm2)
S2 = Indirect tensile strength with long immersion variation (kg/cm2)

METHODOLOGY

The research was conducted at the Civil Engineering Laboratories of Universitas Lancang Kuning and Sekolah Tinggi Teknologi Pekanbaru, focusing on asphalt concrete wearing course mixtures using asphalt modified with natural rubber. The standard for the workers followed the Bina Marga 2018 specification, second revision, as the testing criterion. The initial phase of this research involved conducting proper tests on the aggregates and asphalt used; the aggregates were sourced from PT. Haakaston Unit Stone Crusher Kampar, and the modified asphalt from PT. Emulsindo Polymer Asphalt in Demak. Prior to mixing, the materials were tested to determine their property values. The mixing process aimed to achieve the optimal asphalt content of 6.38%. Subsequently, test specimens were prepared for indirect tensile strength testing, with immersion durations of half an hour, 24 hours, 48 hours, and 72 hours. Following the immersion, the indirect tensile strength test was performed to determine the tensile strength ratio.

RESULT AND DISCUSSION

Aggregate Screening Result

Aggregates are a very important material for determining the strength of road clamping; when the used aggregates do not meet the specified specifications, it is not recommended to use them.

TABLE 1. Rough aggregate inspection results

No.	Test Type	Requirements (Bina Marga 2018)	Test Result
1	Wear and tear with los angeles machines (%)	Max. 40%	26,71%
2	aggregate specific gravity	Min. 2,5	2,636
3	Absorption	Max. 3	2,266

Source: Laboratory test results 2023

Based on the test results, the properties of coarse aggregate must meet specific specifications. As detailed in Table 1, the coarse aggregate used in this study is crushed stone. The density of the coarse aggregate is 26.71%, the bulk specific gravity is 2.363, and the water absorption rate is 2.266%. These values comply with the requirements of the Bina Marga 2018, second revision specification. The outcomes of the coarse aggregate analysis are presented in Table 2.

TABLE 2. Fine aggregate check results

No.	Test Type	Requirements (Bina Marga 2018)	Test Result
1	aggregate specific gravity	Min. 2.5	2.667
2	Sand equivalent	Min. 50	94.19 %
3	Absorption	Max. 3	1.626

Source: Laboratory test results 2023

Based on the results of the coarse aggregate properties test presented in Table 2, the specific gravity is recorded at 2.667, the sand equivalent at 94.19%, and the absorption rate at 1.626%. These values comply with the specifications outlined in the Bina Marga 2018, second revision.

Results of the Inspection of Asphalt Modified Natural Rubber

Natural rubber asphalt modification involves combining asphalt with natural rubber and chemical additives for vulcanization. These components are mixed together in a heated state. The properties of the modified natural rubber asphalt are detailed in the following test results:

TABLE 3. Results of the inspection of asphalt modified natural rubber

No.	Test Type	Requirements (Interim Special Specifications SKH-2.M.04)	Test Result
1	asphalt specific gravity	Min. 1,0	1,05
2	Penetration	Reported	26,9 (0,1 mm)
3	Softening point	Reported	65°C

Source: Laboratory test results 2023

Based on the data presented in Table 3, the specific gravity of the asphalt is 1.05, the penetration value is 26.9 (0.1 mm), and the softening point is 65°C. These values comply with the requirements outlined in the interim special specification SKH-2.M.04.

Indirect Tensile Strength Test Result

Based on the tests conducted at the Highway Laboratory of the Civil Engineering Program at the Pekanbaru School of Technology, the indirect tensile strength (ITS) value was determined using the formula outlined in Equation 1. Presented below is the calculation used to obtain the ITS value for the first sample subjected to a ½ hour immersion:
ITS value of the first sample after ½ hour immersion:

$$\text{ITS} = \frac{2000 \times \rho\, maks}{\pi \times d \times h}$$

$$\text{ITS} = \frac{2000 \times 5{,}049}{3{,}14 \times 0{,}101 \times 0{,}067}$$

ITS = 477.334 Kpa

The next ITS values can be seen in the following table:

TABLE 4. Indirect Tensile Strength Test Result

Immersion duration (hours)	Sample thickness (m)	Sample diameter (m)	Maximum load (ρ) (KN)	ITS (KPa)	Average ITS (KPa)
	0,067	0,101	5,049	477.042	
1/2	0,065	0,101	4,613	447.610	459.752
	0,066	0,101	4,757	454.604	
	0,065	0,101	4,613	445.326	
24	0,065	0,101	4,469	435.858	427.571
	0,066	0,101	4,181	401.528	
	0,068	0,101	4,181	389.661	
48	0,065	0,101	4,036	389.661	379.771
	0,066	0,101	3,748	359.991	
	0,067	0,101	3,604	340.953	
72	0,066	0,101	3,892	371.949	347.287
	0,066	0,101	3,460	328.960	

The relationship between variations in immersion time and indirect tensile strength values can be seen in Figure 1 below:

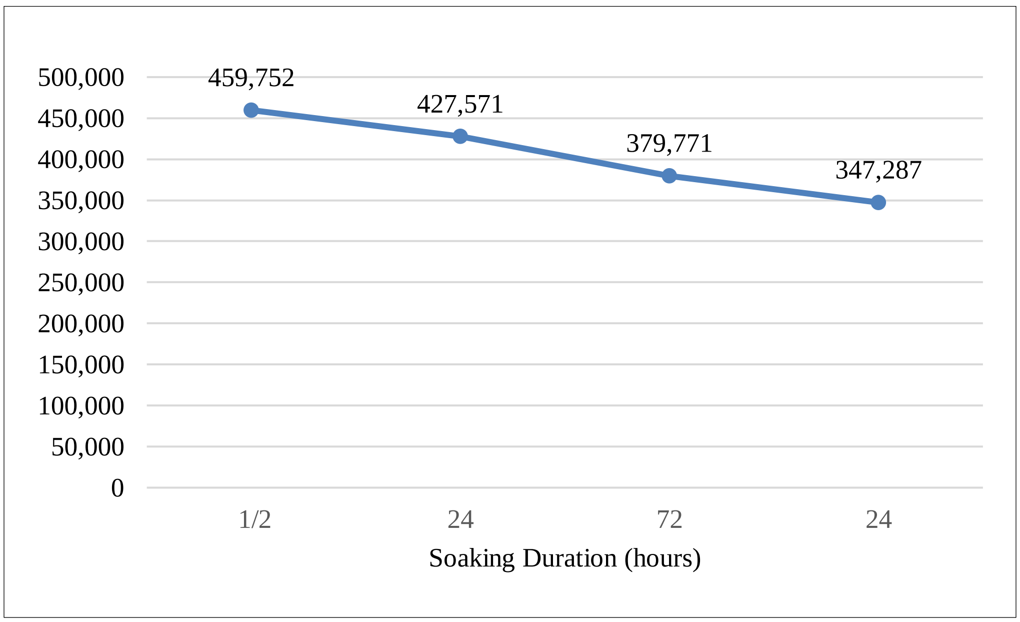

FIGURE 1. The relationship between immersion and ITS value

Figure 1 shows that there is a decrease in the ITS value obtained due to immersion, where the duration of immersion causes the low ITS value to be obtained.

From the results of the indirect tensile strength calculations obtained, calculate the value of the tensile strength ratio using the formula in equation 2. The following is the calculation to obtain the TSR value at ½ hour variation.

TSR ½ hour = $\frac{S2}{S1}\ x\ 100\%$

TSR ½ hour = $\frac{427.571\ KPa}{459.849\ KPa}\ x\ 100\%$

TSR ½ hour = 92,98 %

The next TSR value can be seen in the following table:

TABLE 5. Tensile Strength Ratio Test Ratio

Immersion Duration (hours)	Average ITS (KPa)	Tensile Strength Ratio Value (%)
½	459.849	100
24	427.571	92,98
48	379.771	82,59
72	347.287	75,52

Based on the data presented in Table 5, the tensile strength ratio (TSR) for immersion durations of ½, 24, and 48 hours meets the criteria established by AASHTO T-283, which requires a TSR of at least 80%. However, the TSR for 72 hours of immersion falls below this threshold. The test results indicate a progressive decrease in TSR values at 24, 48, and 72 hours of immersion. The relationship between TSR and immersion duration is depicted in Figure 2.

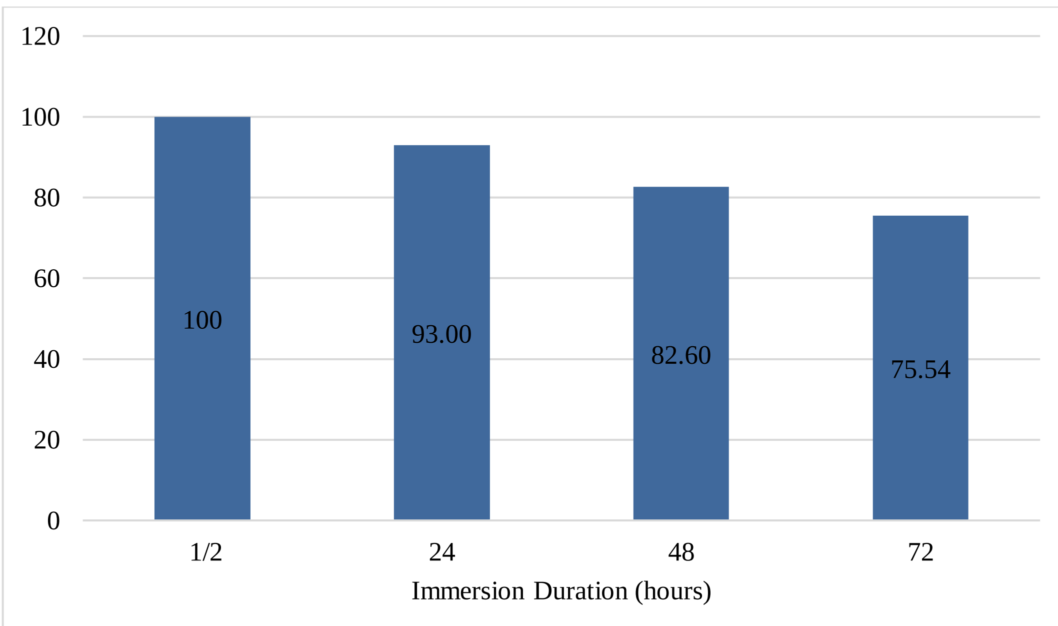

FIGURE 2. The relationship between immersion and TSR value

The test results displayed in Figure 2 indicate the highest TSR value of 100% occurred during the 12-hour immersion variation. Additionally, Figure 2 reveals that the TSR values for immersion durations of ½ hour, 24 hours, and 48 hours meet the AASHTO T-283 requirement of 80%, with recorded values of 100%, 92.98%, and 82.60%, respectively. In contrast, the 72-hour immersion variation fails to meet this requirement, as it only achieved a TSR of 75.52%, which is below the required 80%.

CONCLUSION

The conclusion from the research conducted on indirect tensile strength (ITS) values is that the ITS values at immersion for ½ hours, 24 hours, 48 hours, and 72 hours, respectively, are 100%, 92.98%, 82.59%, and 75.54%. The value of the tensile strength ratio (TSR) at ½ hours, 24 hours, and 48 hours immersion variations has met the specifications of AASTHO T-283, namely ≥ 80%.

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