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Evaluation of resilience modulus of polymer-modified asphalt mixture using gypsum filler

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ABSTRACT

Road infrastructure plays an important role as one of the driving wheels of economic growth and development so that during its service life, it can provide good comfort and safety with quality that must be met. The selection and change of materials used are measures to preserve the pavement construction quality. The utilization and renewal of waste in the road construction sector have become important. One of the waste materials in road construction developed is gypsum powder because the lime (CaO) content is quite high. Resilience modulus is one of the fundamental parameters used in determining the quality of the material used and measuring the stiffness of the asphalt concrete mixture. This study aims to determine the mechanical properties or the resilience modulus of the HRS-WC lataston asphalt mixture using polymer modified asphalt with gypsum powder as a filler. Based on the results obtained, it is known that the addition of gypsum filler into the lataston asphalt mixture can reduce the value of the resilience modulus so that the stiffness in the mixture is reduced and can make the mixture more resistant to repeated loads.

ABSTRAK

Infrastruktur jalan memegang peranan penting sebagai salah satu roda penggerak pertumbuhan ekonomi dan pembangunan sehingga selama umur layan dapat memberikan kenyamanan dan keamanan yang baik dengan kualitas yang harus dapat terpenuhi Salah satu upaya untuk menjaga kualitas struktur perkerasan adalah dengan pemilihan dan modifikasi material yang digunakan. Pemanfaatan dan pembaharuan limbah dalam sektor konstruksi jalan menjadi isu yang penting salah satu material limbah dalam konstruksi jalan yang telah dikembangkan adalah bubuk gypsum, karena kandungan kapur (CaO) yang cukup tinggi. Modulus resilien merupakan salah satu parameter fundamental yang digunakan dalam menentukkan kualitas material yang digunakan juga ukuran kekakuan campuran beton aspal. Penelitian ini bertujuan untuk mengetahui karakteristik sifat mekanis atau atau modulus resilien pada campuran aspal lataston HRS-WC yang menggunakan aspal modifikasi polimer dengan bubuk gypsum sebagai filler. Berdasarkan hasil yang diperoleh diketahui bahwa dengan adanya penambahan filler gypsum ke dalam campuran beraspal lataston dapat menurunkan nilai modulus resiliennya sehingga kekakuan dalam campuran berkurang dan dapat membuat campuran tersebut lebih tahan terhadap beban berulang.

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1. Introduction

Such as road infrastructure. Road infrastructure development aimed to increase connectivity and accessibility in support of increasing regional competitiveness and growth. The parameters that must be achieved are good comfort and safety provided during the service life of the pavement structure so that no damage occurs beyond the minimum service standard [1-2]. Furthermore, the quality must be met to pass the vehicle without prolonged repairs. The decrease in performance occurred in the pavement layer is due to the passing traffic load exceeding the design load [3], where we can estimate the performance of the asphalt mixture at the planning stage to minimize the damage that occurs to the pavement structure. One of the efforts is by selecting and modifying the materials used.

In recent years, the use and renewal of waste in the road construction sector, especially replacing aggregate composition. It is possible to build environmentally friendly, sustainable, and environmentally friendly asphalt pavements to preserve nature by reducing the need for natural resources [4].

One of the waste materials developed for the use of fillers in road construction is gypsum powder. If the waste of gypsum powder has a sufficiently high lime content (CaO) and can be used as a filler substitute for the asphalt mixture, gypsum powder can improve the quality of the asphalt mixture [5].

Road pavements in Indonesia generally use a mixture of asphalt concrete as a surface layer, one of which is HRS-WC. The HRS-WC is highly flexible and resistant to plastic fatigue, making it suitable for use in tropical regions such as Indonesia. According to the Ministry of Public Works [6], a thin layer of asphalt concrete (lataston) is a surface layer that is a mixture of gap-corrected aggregate, filler, and hard asphalt in a fixed ratio, hot-mixed, and compressed. Since it is a mixture with voids in a mixture large enough to use asphalt and many fine aggregates, the strength of this layer is the suspension of mortar formed from fine aggregates, fillers, and asphalt determined by the liquid [7]. The purpose of making a mixture of Lataston Hot Rolled Sheet (HRS) is to create a surface layer or an intermediate layer on the highway pavement that can contribute to the carrying capacity and functions as a waterproof layer that can add load-bearing capacity and protect the underlying structure. A smooth pavement surface has good resistance to corrosion and damage caused by repeated loads.

Polymer-modified asphalt has been widely developed in various countries, including in Indonesia. Modification of asphalt polymer obtained from the interaction between asphalt components and polymer additives can improve the properties of the asphalt by adding polymer as a modifier to conventional asphalt by about 2% to 6% [8]. Several polymers can be used depending on what road users want in their final products. Suppose road users want asphalt with high adhesiveness. In that case, the asphalt will be added with polymers that have high adhesiveness, such as elastomeric polymer types, or if road users want asphalt that can withstand varying temperatures, the asphalt will be added with elastomer type polymers that can withstand quite varied temperatures [9]. The study will evaluate the effect on the performance of the asphalt mixture used for the surface layer, namely a thin layer of asphalt concrete (lataston) using modified asphalt, namely elastomeric polymer asphalt.

The modulus of elasticity is used to determine the coefficient of highway pavement in the design of pavement thickness. The modulus of elasticity is a very important factor that will affect the performance of asphalt pavements [10]. Resilience modulus is a modulus of elasticity based on reverse deformation, asphalt factor, gradation, temperature, and time of loading that affect the resilience modulus. The higher the temperature, the smaller the value of the resilience modulus. This condition occurred because the asphalt is visco-elastic [11]. Resilience modulus is one of the fundamental parameters used in determining the quality of the material used and a measure of the stiffness of the asphalt concrete mixture [12]. The value of the resilience modulus can be determined by testing methods in the laboratory using the UMMATA tool. Stiffness modulus is a fundamental mechanical parameter expressing synthetically the structural properties of asphalt mixtures determined by non-destructive tests and is very useful for statistical evaluation of the effect of one or more components in the mechanical response of the mixture [13-14].

Asphalt pavement with a surface directly in contact with hot weather causes a tensile force on the layer and an indirect tensile force on the horizontal axis. It was also influenced by the repetition of vertical loads [15]. Based on this, further study is needed to see how the resilience modulus's performance in the lataston asphalt mixture with the use of polymer modified asphalt using gypsum powder filler. The resilience modulus as a measure of the stiffness of the asphalt concrete mixture is one of the fundamental parameters used in evaluating material quality and as an input for asphalt pavement planning.

2. Research Methodology

The base material of the asphalt mixture consists of the binder used in this study was polymer modified asphalt, and gypsum powder was used as the aggregate and filler. The asphalt used in this study was elastomeric polymer type E55 and was expected to improve crack resistance at temperature if the asphalt was derived from PT. Table 1 shows that the tests were performed on the physical properties of asphalt. According to the hard asphalt type II modified asphalt regulations in the 2018 road and highway bridge general specifications, the penetration value was 56.3 mm, which corresponds to the performance class (PG) 76 and the lost weight value and mass weight according to requirements.

Aggregate is the main component material with a percentage of 90 – 95% divided into a coarse aggregate (split 1-2), coarse aggregate (screening), and fine aggregate (stone ash). The test results can be seen in Table 2. The aggregate used comes from Bojonegara, Banten Province, with a specific gravity greater than 2.5 gr/cm3 for specific gravity and at least 3% for absorption. The wear test of 18.32 showed that the aggregate used was resistant to abrasion with a maximum condition of 40%. From these results, it can be concluded that the aggregate can be used in asphalt mixtures because it complies with the general specifications for roads and bridges of highways 2018.

Table 1. Physical properties of polymer asphalt E-55.

No	Type of Test	Result	Specification of test		Standard
			Min	Max	
1	Penetration, 25^{O}C; 100 gr 5 second; 0.1 mm	56.3	40	-	SNI-2456-2011
2	Lost weight value (%)	0.06	-	0.8	SNI-2440-1991
3	Density (gr/ml)	1.042	1	-	SNI-2441-2011

Table 2. Properties of coarse and fine aggregates

No	Type of test	Result	Specification of test	
			Min	Max
I	Coarse aggregates			
	1 BJ bulk	2.78	-	-
	2 BJ apparent	2.85	-	-
	3 BJ SSD	2.8	2.5	-
	4 Absorption (%)	0.94	-	3
	5 Abrasion test (%)	18.32	-	40
II	Screening aggregates			
	1 BJ bulk	2.78	-	-

No	Type of test	Result	Specification of test	
			Min	Max
	2 BJ apparent	2.85	-	-
	3 BJ SSD	2.8	2.5	-
	4 Absorption (%)	0.94	-	3
III	Fine aggregates			
	1 BJ bulk	2.61	-	-
	2 BJ apparent	2.76	-	-
	3 BJ SSD	2.67	2.5	-
	4 Absorption (%)	2.04	-	3

Filler is a fine-grained material that passes filter no. 200 (0.075 mm) and functions as filler granules in the asphalt mixture. The gypsum filler used in this study was calcium sulfate hydrate ($CaSO_4.2H_2O$), having better properties than organic adhesives. The determination of the gradation used in this study was at the middle value of the fuller curve in the General Specifications for Roads and Bridges of Highways in 2018, where the calculation stages used the trial and error method and then the percentage of the mixture of each aggregate in the HRS-WC mixture was ideal for used in the mixing process. The results of the gradation design can be seen in Figure 1. The methodology in this study consisted of several stages, namely preparation, testing, data analysis, and the results of the conclusions. The initial stage carried out was preparing the material using coarse, fine aggregate, filler, gypsum, and polymer modified asphalt. The test was done after determining the mix design for making the test object. Then, testing the test object was done using Marshall to get the optimum asphalt content used as a reference for further testing the mixed resilience modulus. In the last step, present data processing and analysis were shown to conclude the relationship between stability and mixed resilience modulus.

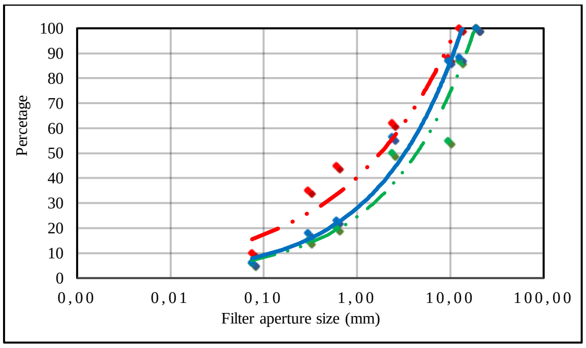

Figure 1. Gradient design.

3. Result and Discussion

The marshall test of the HRS-WC asphalt mixture was carried out using a Marshall tool. The test results include stability, flow, marshall quotient, volumetric values, and the optimum asphalt content value (KAO) in the mixture with the percentage of gypsum filler combination. In the HRS-WC mixture, the KAO value ranged from 6% to 8%, as shown in Figure 2. The test results showed that the addition of gypsum filler gave a smaller KAO value than the mixture without using gypsum filler.

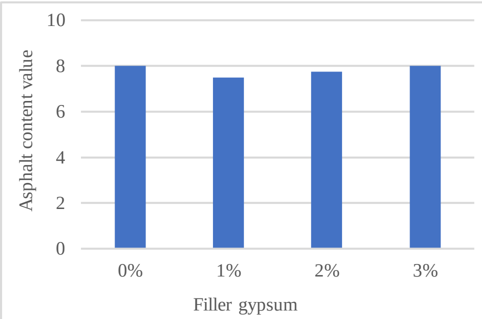

Figure 2. The level of HRS-WC optimum asphalt content.

At the optimum asphalt condition with the addition of gypsum filler, it affected the characteristics of the mixture as described in Table 3, where the VIM and VMA values relatively increased, indicating that the gypsum powder filler made the asphalt mixture's ability to fill the aggregate voids decrease, so it also affected the VFA value. This decrease occurred because the voids that could be filled by asphalt were getting smaller, so the asphalt blanket covering the aggregate was getting thinner. In line with the smaller stability value with the addition of gypsum, this reduced the ability of asphalt to bind aggregates, while the Marshall Quotient value tended to increase so that the mixture became stiffer and was resistant to load deformation.

Table 3. HRS-WC mixture characteristics.

Mixture Characteristics	**Unit**	**Filler gypsum**				**Spesification**
		0%	**1%**	**2%**	**3%**	
Void in mixture (VIM)	%	5.04	4.58	4.20	5.88	Min 4, max 6
Void in aggregate Minerals (VMA)	%	21.83	20.37	21.14	22.53	Min 18
Bitumen filled void (VFA)	%	76.91	77.52	80.13	73.90	Min 68
Stability	Kg	4196.25	3974.10	2703.75	2175.60	Min 800
Melting	mm	8.90	4.10	3.50	3.60	Min 3.0
Marshall quotient	kg/mm	471.49	558.02	659.45	604.33	Min 250

The resilience modulus test of the HRS-WC asphalt mixture is described in table 4. This test used the UMATTA tool referring to the ASTM D4123-82 standard test method for indirect tension test for resilient modulus of bituminous mixtures. The loading conditions were 250 ms pulse width and pulse repetition period 3000 ms with conditioning pulse count 5 with a temperature of 20°C, and 45°C based on the average annual pavement temperature. Based on the analysis carried out from the Marshall test, the next test was carried out on the variation of the mixture with 0% and 1% gypsum filler because, in these conditions, it gave a greater stability value.

Table 4. HRS-WC mixture characteristics.

Testing temperature (^{0}C)	HRS-WC resilient modulus value	
	0% filler gypsum	1% filler gypsum
25	4265	2853
45	1559	1528

Based on the results of the resilience modulus test with the assumption that each test object was in the same asphalt condition and properties indicating that the addition of gypsum filler to the Lataston HRS-WC mixture can reduce the value of the mixed resilience modulus, where the test was carried out at a temperature of 250C for gypsum filler 0 % is 4265 Mpa and 1% gypsum filler is 2853 Mpa. A decrease in the resilience modulus of the mixture caused reduced stiffness, but it can make the mixture more resistant to repeated loads.

4. Conclusion

Based on the analysis and discussion that has been carried out, it was found that the asphalt and aggregate materials used in the HRS-WC asphalt mixture meet the requirements of the General Specifications for Roads and Bridges of Highways 2018. The use of gypsum filler in the HRS-WC asphalt mixture caused a lower optimum asphalt content values and caused an increase in the value of voids in the aggregate and cavity in the mixture, but on the other hand, there was a decrease in the cavity in asphalt and stability values. While the stiffness of the mixture decreases with the addition of gypsum filler in the HRS-WC asphalt mixture, this causes the mixture to have resistance to repeated loads.

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