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Analysis of the Use of Hemp Fiber in Stone Mastic Asphalt (SMA) Mixtures

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ABSTRACT

Road pavement is one of the important factors supporting the development of environmentally friendly, durable, and economical road transportation infrastructure. In this research, the Stone Mastic Asphalt (SMA) method is used, which is interspersed graded asphalt and has the advantage of high slip resistance and resistance to deformation, and also cracking. This study aims to determine the effect of the strength of interspersed graded asphalt with the use of jute fiber on Marshall characteristics and to determine the stability value of using jute fiber in asphalt with the Stone Mastic Asphalt (SMA) method compared to asphalt mixtures without the use of jute fiber. Asphalt concrete test specimens were made with planned asphalt content of 5%, 5.5%, 6%, 6.5% and 7% and variations in the use of jute fiber of 0%, 0.1%, 0.2% and 0.3%. The results showed that the stability value with the use of jute fiber in the Stone Mastic Asphalt (SMA) mixture was obtained at the optimum value at 0.2% jute fiber content, with an increase in stability of 1058.95 kg, this is because jute fiber can reduce the VIM and VMA values because jute fiber can fill the voids in the mixture which helps the bond between aggregates to be better and increase the stiffness of the mixture.

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1. INTRODUCTION

Pavement is one of the important factors supporting the development of environmentally friendly, durable, and economical road transportation infrastructure. The number of vehicles continues to increase which is slow in the development of pavement innovation, not every year resulting in road services must be improved. Indonesia includes countries such as developed countries out there such as countries in Continental Europe [1]. Asphalt is a binder used in flexible pavements. One way to prevent damage to the pavement due to the load from public vehicles is to improve the quality and stability of the work, SMA (Stone Mastic Asphalt) asphalt mixture is an alternative pavement that can be used.

used. Stone Mastic Asphalt was first developed in Germany in the 1960s to provide maximum protection against rutting caused by tire contact on the road surface. With the amazing performance of SMA, since 1984, SMA has spread all over the world. There are three kinds of Stone Mastic Asphalt mixes, namely, thin SMA, fine SMA, and coarse SMA [1]. The selection of jute fiber as an added material for the research is based on consideration of the abundant and underutilized potential of jute fiber in Indonesia. Jute fiber derived from natural fibers has the potential to be developed and meets the criteria for the use of natural materials. In addition, the selection of the use of cellulose fiber in the mixture of Stone Mastic Asphalt (SMA) method is because the method sometimes results in bleeding due to the large coarse aggregate content, with the use of cellulose fiber in this method can reduce draindown on asphalt and make asphalt much more durable and increase the stability value of the asphalt mixture. The relationship of jute fiber itself to the asphalt mixture is that this plant has a high water absorption that allows it to absorb asphalt, then jute fiber in this study has the effect of filling the cavity space between aggregates so as to increase the stability value of asphalt [2]. For other research, namely the use of asbestos fibers in making asphalt with the Split Mastic Asphalt method, in this study researchers wanted to know the performance testing on the Split Matrix Asphalt (SMA) mixture by varying the use of cellulose fibers with varying asphalt content using pen 60/70 asphalt and asbestos fibers. For durability testing by testing variations in soaking time at 25ºC and testing at a standard temperature of 60ºC. The results obtained from this study on the addition of asbestos fiber are that it meets the optimum level of 2.81% and can increase the value of the characteristics of asphalt concrete mixtures. The durability value obtained is above the average of 84% which is expressed by the residual strength index (IKS). The IKS value of the percentage of added material 2.81% is 86.9% [3]. The novelty of this research from previous research is in the mixture material and method, the focus of this research is to produce marshal test values in the manufacture of asphalt Stone Mastic Asphalt (SMA) method using a mixture of hemp fiber material [4]. Based on some of the above, the author wants to conduct research that aims to determine the effect of using hemp fiber on marshall parameters in the Stone Mastic Asphalt (SMA) method with hemp fiber variations of 0%, 0.1%, 0.2%, and 0.3% [5].

2. METHODS

This research consists of several stages, namely the preparation of tools and materials, testing materials, namely aggregates and asphalt, making test pieces, marshall testing, analysis to determine the KAO value and marshall testing at KAO conditions. For the examination of aggregates and asphalt, several tests are needed, if from the results of the tests carried out if the results meet the provisions of the 2018 bina marga general specifications, it can proceed to the stage of making test objects. In the manufacture of test objects begins to prepare the tools and materials that will be used. Then proceed to the process of heating the aggregate mixture to a specified temperature and entering asphalt concrete and jute fiber with planned asphalt content of 5%, 5.5%, 6%, 6.5% and 7% and variations in the use of jute fiber of 0%, 0.1%, 0.2% and 0.3% which have been mashed first (passing sieve no.20). After it has been mixed well, prepare the printer and print the test object according to the predetermined temperature. Wait a few minutes for the test specimen to reach room temperature then remove the test specimen from the mold. Clean, measure, and weigh the test specimens and soak the test specimens ± 24 hours. The test object is ready for the marshall test and continued with data analysis to obtain the KAO value in accordance with the provisions of Bina Marga 2018. Re-conducting the manufacture of test objects and testing under KAO conditions to obtain final results.

3. RESULTS AND DISCUSSION

Tests carried out prior to marshall testing are testing the characteristics of natural aggregates and asphalt. This test is carried out to check the feasibility of the materials used before making test objects which will then be tested marshall. This test uses SNI testing standards and 2018 bina marga specifications. The following are the results obtained from testing the characteristics of these

materials.

3.1 Aggregate Characteristic Test Results

Table 1. Results of Aggregate Characteristics

No	Agg. Characteristics	Results	Spesifikasi Bina Marga 2018	
			Maks	Min
1	Abration %	19,24	40%	-
2	Specific Gravity Of Coarse Aggregate			
	Bulk	2,614	-	-
	SSD	2,68	-	2,5
	Apparent	2,799	-	-
3	Absorbtion	0,432	3%	-
4	Specific Gravity Of Fine Aggregate			
	Bulk	2,455	-	-
	SSD	2,505	-	2,5
	Apparent	2,585	-	-
5	Absorbtion	2,041	3%	-

For coarse aggregates, the average bulk specific gravity obtained was 2.641 while the water absorption was 0.432%. While the average specific gravity obtained for the fine aggregate was 2.455. The average water absorption was 2.041. The specific gravity value will affect the weight of the aggregate [6]–[8]. The greater the specific gravity of the aggregate, the greater the weight of the aggregate. However, the greater the specific gravity, the smaller the volume of the aggregate. Judging from the specific gravity formula, volume is inversely proportional to specific gravity. The specific gravity value is also used to determine the weight of each fraction to be used later. The wear test for the natural aggregate was found to be 19.24%. This wear value affects the strength of the aggregate to resist friction and impact. The greater the wear value, the weaker the aggregate is to resist friction and impact.

3.2 Hemp Fiber

(a) (b)

Gambar 1. (a) Serat Rami Awal, (b) Serat Rami lolos saringan no.200

Hemp (Boehmeria nivea) is a plant that has high potential. Hemp fiber can be processed into high-quality fashion fabrics, as it has similar characteristics to cotton fiber. In addition, hemp is a material for making high-quality cellulose [4], [9]–[11]. The relationship of hemp fiber itself to asphalt mixtures is that this plant has a high water absorption that makes it possible to absorb asphalt, then hemp fiber in this study has the

effect of filling the cavity space between aggregates so as to increase the stability value of asphalt [2]. The processing carried out on the hemp fiber itself is in the form of finer fibers with a fiber length of 3.6 mm where the hemp fiber used as an added material must pass the No.20 sieve (0.841mm) taken 85 ± 10% [5]. Jute fiber has physical, chemical and mechanical properties shown in Table 2 as follows:

Table 2. Physical, Chemical, and Mechanical Properties of Jute Fiber

No	Characteristics	Value
1	Diameter (μm)	40 - 60
2	Length (mm)	120 - 150
3	Modulus Of Elasticity (Gpa)	44-90
4	Density (g/cm^3)	1,5 - 1,6
5	Maximum Strain (%)	2
6	Specific Fiber Strength (kg/mm^2)	95
7	Cellulose (% berat)	68,6 - 76,2
8	Lignin (% berat)	0,6 - 0,7
9	Hemiselulosa (% berat)	13,1 - 16,7
10	Pektin (% berat)	1,9
11	Lilin (% berat)	0,3
12	Microfibril Angle (˚)	7,5
13	Moisture Content (% berat)	8
14	Density (mg/m^3)	1,5

The table explains that jute fiber has physical and chemical content that can improve the quality of the mixture on asphalt, especially the method used in this study, namely Stone Mastic Asphalt (SMA). In this method sometimes results in bleeding due to the large coarse aggregate content, the use of cellulose fibers, namely jute fiber in this method can reduce draindown in asphalt and make asphalt much more durable and increase the stability value of the asphalt mixture.

3.3 Asphalt Characteristics Test Results

Asphalt is defined as a black or dark brown colored adhesive material, with bitumen as the main constituent. Asphalt can be obtained in nature or is a residue from petroleum refining. Asphalt is a material that at room temperature is solid to slightly solid, and is thermoplastic. So asphalt will melt if heated to a certain temperature, and re-freeze if the temprature drops. The amount of asphalt in a pavement mixture ranges from 4-10% by weight of the mixture, or 10-15% by volume of the mixture [12]. In this research, the asphalt used is pen 60/70 binder asphalt.

Table 3. Asphalt Characteristics Test Results

No.	Asphalt Characteristics	Results	Spesifikasi Umum Bina Marga 2018		Spesification
			Minimal	Maksimal	
Aspal Penetrasi 60/70					
1	Specific Gravity	1,052	1	-	SNI 2441:2011
2	Soft Point 25°C (cm)	50 ˚C	48˚C	-	SNI 2432:2011
3	Penetration, 25 °C; 100 gr	64,6	60	70	SNI 2456-2011
4	Weight Loss (%)	0.295 %	-	0,80%	SNI 06-2441-1991
5	Viscosity 135°C (cSt)	445˚C	≥300˚C	-	SNI 06-2433-1991
6	Flash and Burn Point	326˚C	232˚C	-	SNI-2433-2011

332˚C

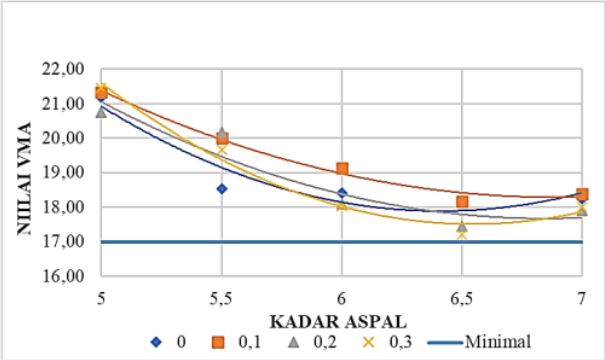
The asphalt test results are stated to meet the specifications set out in the 2018 General Specifications of Division 6 of the Department of Public Works. From the results of the research, the specific gravity of asphalt is obtained 1.052 with a minimum limit of ≥ 1, it can be concluded that the asphalt to be used is still good because it meets the 2018 bina marga specifications. For the results of the research on the loss of asphalt specific gravity obtained 0.295 from the minimum limit ≤ 0.8, it can be concluded that the asphalt to be used has good quality because it can maintain its original properties due to the influence of weather or temperature changes during the road service period. In the mushy point test, a temperature of 50 ° C is obtained from the minimum limit ≥ 48 ° C, the mushy point test is carried out to obtain information at what temperature the asphalt changes phase from solid to liquid form and this temperature is needed when carrying out work in the field. For the flash point test, the value is obtained at a temperature of 326 ° C from the minimum limit of ≥ 232 ° C, this is done to obtain information about the temperature at which the asphalt starts to ignite and burn. This is very necessary during implementation in the field for safety at work [13]. In the penetration test, the penetration value is 64.6 with a limit of 60-70, it can be concluded that the test results show the level of asphalt hardness in accordance with the asphalt to be used, namely asphalt pentrasi 60/70.

3.4 SMA Paved Mixture Testing

This test is carried out with a Marshall tool in accordance with SNI 06-2489-1991 or AASHTO T245-90, namely by placing the test specimen into the lower segment of the Marshall Tool, the time required since lifting from the maximum water bath should not exceed 30 seconds. Then the test specimen is loaded at a speed of about 50 mm per minute until the maximum loading is reached and then record the stability and flow load. Results and Discussion The following are the results obtained from the Marshall test.

3.4.1 Characteristics Of Asphalt Mix SMA

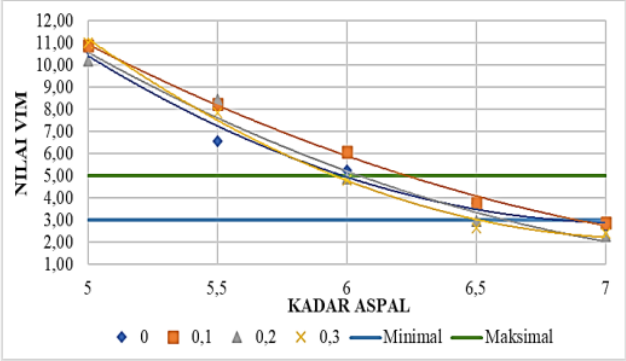
- VMA *(void in mineral agregats)*



Gambar 2. Grafik Hubungan Nilai VMA dan Kadar Aspal

In the figure above, the effect of using jute fiber itself on the VMA value results in a decrease in the VMA value because jute fiber itself has the property of filling the air space between aggregates, therefore the addition of asphalt content to the mixture tends to reduce the VMA value but the decrease in VMA value is still within the required limit of at least 17% [14].

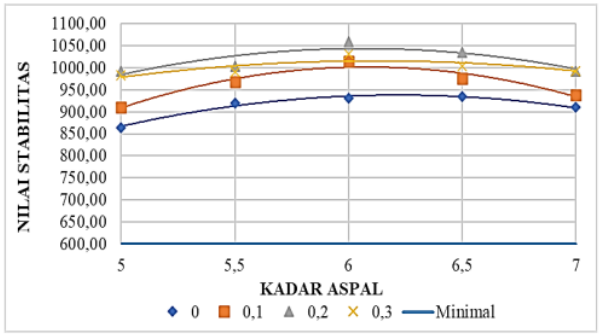
- VIM *(void in mixture)*



Gambar 3. Grafik Hubungan Nilai VIM dan Kadar Aspal

The figure above shows that the effect of adding jute fiber content as the asphalt content increases shows a decrease in VIM value. The addition of jute fiber tends to have a smaller VIM value than without using jute fiber, this is due to the function of jute fiber which can fill the air space between aggregates [12].

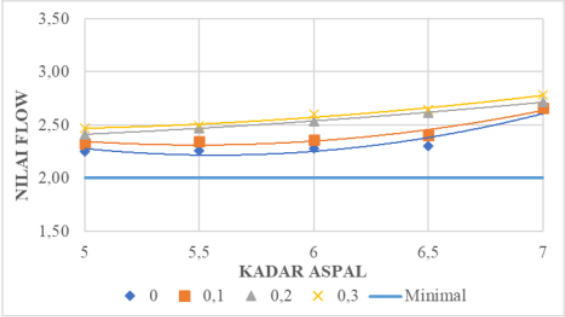
- Stability



Gambar 4. Grafik Hubungan Nilai Stabilitas dan Kadar Aspal

Figure 4 shows that the highest stability value is at 0.2% jute fiber content, which is 1059.95kg, where at 0% jute fiber content to 0.2% jute fiber content the stability value increases. This is due to the addition of asphalt content which causes the asphalt to cover the aggregate very well. The stability value decreases at 0.2% jute fiber content to 0.3% asphalt content, this is because the asphalt content is too high so that the asphalt is no longer effective in covering the aggregate. The thicker the asphalt blanket, the interlocking properties between the aggregates are reduced.

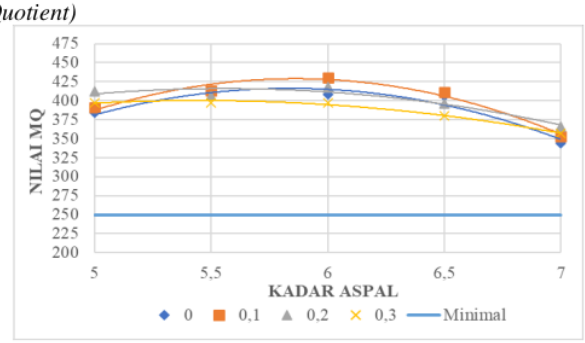
- Flow



Gambar 5. Grafik Hubungan Nilai Flow dan Kadar Aspal

The use of jute fiber in this mixture tends to increase because jute fiber is less perfect in absorbing asphalt so that the mixture has a thick asphalt blanket. It can be seen that in the variation of hemp fiber content of 0%, 0.1%, 0.2% and 0.3%, all of them have met the requirements of the 2018 Revision 2 bina marga general specifications, namely the flow value must be in the range of 2 - 4.5mm.

- MQ (*Marshall Quotient)*



Gambar 6. Grafik Hubungan MQ dan Kadar Aspal

The use of jute fiber results in an increase in the hardening process which makes the mixture stiffer. It can be seen that in the variation of hemp fiber content of 0%, 0.1%, 0.2% and 0.3%, all of them have met the requirements of the General Specifications of Bina Marga 2018 Revision 2, namely the MQ value of at least 250 kg/mm. The MQ value is interconnected with the stability value When the stability rises the MQ value also rises and when the stability value drops it will also go down [15].

3.4.2 Marshall Testing of Mixture Gradation SMA at KAO Condition

The next test was the marshall test using the optimum asphalt content of each jute fiber content used. The optimum asphalt content obtained was 6.5% for mixtures without jute fiber and 0.1% jute fiber addition, and 6% for mixtures with 0.2% and 0.3% jute fiber addition. The KAO value is obtained from the results of the previous marshall characteristic test. The following are the marshall test results for the KAO values obtained [16]–[18].

Tabel 4. Recapitulation of Marshall Test Results with Optimum Asphalt Content

Marshall Characteristics	Hemp Fiber	Asphalt	Results	Specification
VIM	0	6,5	4,92	3 % - 5 %
	0,1	6,5	4,46	
	0,2	6	3,91	
	0,3	6	3,75	
VMA	0	6,5	19,13	Min 17 %
	0,1	6,5	18,74	
	0,2	6	17,26	
	0,3	6	17,12	
Stability	0	6,5	988,47	Min 800 kg
	0,1	6,5	1073,89	
	0,2	6	1126,19	
	0,3	6	1058,2	
Flow	0	6,5	2,62	2 mm - 4 mm
	0,1	6,5	2,65	
	0,2	6	2,76	
	0,3	6	2,64	
MQ	0	6,5	377,91	Min 250 kg/mm
	0,1	6,5	405,15	
	0,2	6	408,77	
	0,3	6	400,39	
Residual Marshall Stability (kg)	0	6	948,93	Min 90 %
	0,1	6	1020,2	
	0,2	6,5	1064,25	
	0,3	6,5	1010,58	

Based on the recapitulation of marshall test results in table 4 above. The highest VMA value is 19.13% at 0% jute fiber content with an optimum asphalt content of 6.5%, this is because the asphalt content is too much so that it can fill the air voids between aggregates while the VMA value tends to decrease from each addition of jute fiber content, namely at 0.2% and 0.3% jute fiber content with an optimum asphalt content of 6%, this occurs because the use of jute fiber itself has the property of filling the air space between aggregates. The highest VIM value is at 0% jute fiber content with an optimum asphalt content of 6.5%, this is because a lot of asphalt fills the voids between aggregates, while at 0.2% and 0.3% jute fiber content at the optimum asphalt content of 6%, it shows that the addition of jute fiber content tends to reduce the VIM value, this occurs because the jute fiber content fills the space between aggregates, therefore it becomes a factor in decreasing the VIM value in the study of jute fiber as a filler additive. The optimum stability value is 1126.19kg at 0.2% jute fiber, this is because the addition of jute fiber can result in increased durability in asphalt. However, if jute fiber is used at high levels, it will reduce the stability value. Flow values in mixtures that use hemp fiber have a smaller value than those that do not use hemp fiber, it can be seen that the value at 0% hemp fiber content is 2.62mm and for the value with 0.3% hemp fiber content is 2.64 mm. that is because the use of hemp fiber can reduce the flow value which will make the mixture tend to be stiffer. The MQ value obtained increases to its optimum value, after which the Marshall Quotient (MQ) value will decrease, the addition of jute fiber can increase the flexibility of the mixture if it is at the right level, if excessive will produce a mixture that is more rigid and easy to crack, so that the mixture is easier to crack [19].

stiff and easy to crack, so the mixture is easily oxidized which results in peeling of the pavement. But all of them meet the general specifications of Bina Marga 2018 Revision 2.

And for the remaining marshall, it increases when adding jute fiber content with each optimum asphalt content. This is due to the use of jute fiber which can help the interlocking properties between aggregates to be good so as to increase the stability value of the remaining marshall also in the use of jute fiber can reduce the cavity in the mixture to be impermeable. Based on the results of the recapitulation of the residual marshall stability can be seen in table 5, the residual marshal stability at hemp fiber levels of 0%, 0.1%, 0.2% and 0.3% meets the general specifications of division 6 bina marga 2018. So it can be concluded that the asphalt mixture can withstand the effects of weather, water, temperature or wear due to vehicle friction.

4. CONCLUSION

Based on the results of research conducted on the use of jute fiber in Stone Mastic Asphalt (SMA) mixtures, it can be concluded that the use of jute fiber in asphalt testing with the Stone Mastic Asphalt (SMA) method will be able to increase the stability value up to 0.2% jute fiber content and a decrease at 0.3% jute fiber content, then the marshall results at KAO do not increase the value of asphalt content in this mixture, this is due to a decrease in the value of asphalt content by 0.5% against the asphalt content without fiber and the addition of 0.1% fiber. In addition to the results of the optimum content value obtained, with the use of jute fiber, it decreases at the optimum asphalt content with a jute fiber content value of 0.3% because jute fiber can help the bond between aggregates become better and increase the stiffness of the mixture. The MQ results also explain that the higher the asphalt content and the more jute fiber used, the smaller the optimum level.

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