Effect of Incorporating Super Bond Additives on Volumetric and Mechanical Characteristics of Cold Mix Asphalt Concrete using Asbuton

Rosman Hidayatulloh[1], I Dewa Made Alit Karyawan[1], Ervina Ahyudanari[2]
[1]Department of Civil Engineering, Faculty of Engineering, University of Mataram, Mataram, Indonesia
rosmanhidayatulloh@gmail.com
dewaalit@unram.ac.id
[2]Department of Civil Engineering, Faculty of Civil, Planning, and Geo-Engineering,
Sepuluh Nopember Institute of Technology, Surabaya, Indonesia
ervina@ce.its.ac.id

ABSTRACT

Asbuton is the natural asphalt of Buton Island, Southeast Sulawesi. Asbuton has substantial reserves with deposits estimated at between 150 to 300 million tons. Asphalt mixture using Asbuton can be done with a cold mix. This mixture requires a rejuvenating agent that serves to soften and rejuvenate the asphalt properties contained in Asbuton. The rejuvenation process that is less than optimal results in the low quality of the asphalt mixture. Therefore, it is necessary to conduct a study to imprfove the performance of cold mixtures using Asbuton. In this study, super bond additives were used. This study aims to determine the extent to which the performance of asphalt-concrete mixtures using Asbuton with the addition of super bond additives in the rejuvenating agent is increased. The addition of additives was varied with levels of 0.0%, 0.2%, 0.3%, and 0.4%, so that the impact could be known. The best asphalt concrete mix characteristics were obtained at the addition of 0.4% additives. Where, for volumetric characteristics the values obtained are: Void in the Mix (VIM) 5.08%, Void in Mineral Aggregate (VMA) 19.6% and Void Filled with Bitumen (VFB) 74.0%. While the mechanical characteristics are: Stability 609 kg, Flow 2.7 mm and Marshall Quotient 223 kg/mm. Only the Marshall Quotient value does not meet the minimum requirements, because it is < 250 kg/mm.

Keywords: Asbuton, cold mix, volumetric characteristics, mechanical characteristics, super bond additives

I. INTRODUCTION

One source of Indonesia's natural wealth that is quite potential is natural asphalt, which is found on the Indonesian island of Buton. So this asphalt rock is known as Asbuton (Buton asphalt). It is estimated that at least about 670 million tonnes are deposited in limestone formations and bitumen residues of ancient petroleum. The bitumen in the rock is between 15% and 35% of the total rock weight. If extracted, it is predicted that there will be around 160 million tons of pure bitumen. These reserves can guarantee the supply of bitumen for Indonesia for at least 100 years [1]. However, its existence has not been proportional to the percentage of its use, because the implementation of road pavement works in Indonesia is still dominated by petroleum asphalt which tends to be more expensive than Asbuton. The low stability value compared to mixtures that use petroleum asphalt is one of the reasons [2]. The weakness of Asbuton as natural asphalt is that the asphalt content is hard and not homogeneous. Asphalt that is not soft causes the bond is not optimal. Inhomogeneous asphalt content affects the homogeneity of the asphalt mixture. The bitumen present in the granular asbuton is very difficult to separate from the minerals, so it cannot wrap and bind between the aggregates [3]. Seeing these conditions, pure asphalt must be separated from Asbuton minerals so that asphalt can be used widely and economically and can replace the country's dependence on imports [1].

Research and implementation of mixed using Asbuton to get good quality has been done for a long time in Indonesia. Until the 1987's, Lasbutag and Latasbum were known for mixing asphalt with conventional grain asphalt. The properties of asphalt contained in Asbuton are softened and rejuvenated by using rejuvenating agents such as bunker oil or flux oil. However, this is very difficult to achieve, because the fluffier in the form of bunker oil cannot remove the bitumen and then keep it soft. It takes 254 days for the fuel oil type refining agent to reach the bitumen asbuton in the granules, and as a consequence, a good asphalt mixture is not achieved [3].

Asbuton can also be treated with hot, warm or cold mixed systems. Energy consumption for mixing in a warm or cold way is smaller than the hot method which is usually done in asphalt concrete mixes (asphalt concrete). The use of cold mixed Asbuton can reduce production costs because aggregates and binders can be mixed, stored and compacted without energy consumption. Because it is made without heating, it is considered a green pavement, and is friendly to the environment [4]. Compared to Hot Mix Asphalt (HMA), especially at its low energy requirements, Cold Mix Asphalt (CMA) offers many environmental and economic advantages. However, generally less superior in performance [5].

The addition of 0.3% Wetfix-BE additive to improve the performance of the cold asphalt mixture with Asbuton was able to speed up the asphalt setting time. This can be seen from the time required for the asphalt softening process in Asbuton where as long as needed, 3x24 hours, but in this research, optimal results were obtained for materials with Marshall characteristics according to the 2010 Bina Marga Specification, without curing [6].

With a large number of reserves, Asbuton has the potential to be developed as an asphalt mixture for road pavements, especially in Indonesia. The use of Asbuton as an asphalt mixture needs to be increased to meet the needs of road construction programs in Indonesia. This utilization must be accompanied by efforts to improve performance through research. In this regard, a study was conducted on the use of Asbuton as a cold asphalt mixture by adding super bond additives. The research objective was to obtain volumetric and mechanical values of cold asphalt mixture using Asbuton with the addition of super bond additives. So that recommendations can be given whether the composition of the mixture and the addition of additives meet the requirements. Or provide recommendations both in terms of mixture composition or the percentage of addition of super bond additives, so that they meet the requirements as road pavement materials.

II. METHODS AND MATERIAL

Materials

The materials used to make asphalt concrete mix test specimens are: (1) Asbuton; (2) Aggregate; (3) Rejuvenating agents; and (4) super bond additives. Super bond works by increasing adhesion and bonding and reducing the negative effects of water and moisture resulting in a very sticky surface.

Properties of Asbuton

Asbuton contains asphalt (bitumen) and minerals. Based on the asphalt content, Asbuton can be divided into several types. In this study, Asbuton type B 5/20 was used. Asphalt content contained in Asbuton B 5/20, is known by testing the centrifugal method of extraction using premium as a decomposer. Asphalt content in Asbuton B 5/20 is 19.83% (see Table 1), the rest is fine minerals that will be mixed in the asphalt mixture. This shows that the asphalt content in Asbuton B 5/20 is close to 20% according to the label on the package.

TABLE 1

ASBUTON EXTRACTION TEST[6]

No	Weight		Value	Unit
a	The weight of the cup + asphalt mixture		879.3	gram
b	The weight of the cup + material elements after extraction		739.3	gram
c	Weight of the cup		173.2	gram
d	Weight before extraction	(a - c)	706.1	gram
e	Weight after extraction	(b - c)	566.1	gram
f	Filter paper weight + material element		16.7	gram
g	Filter paper weight		14.8	gram
h	Additional material on filter paper	(f – g)	1.9	gram
i	Cup weight + filler		144.2	gram
j	cup weight		140.0	gram
k	Weight of filler on the cup	(i - j)	4.2	gram
l	The total weight of the material elements	(e + h + k)	572.2	gram
m	Weight of asphalt in mix	(d - l)	140.0	gram
n	Percentage of asphalt in the mix	(m ÷ d × 100)	19.83	%

TABLE 2
AGGREGATE PROPERTY TEST RESULTS[6]

Test type		Testing standard	Test result	Specification
Los Angeles abrassion		SNI 2417:2008	19.10%	Maximum 40%
	CA 3/4”		0.20%	Maximum 1%
Clay lump	CA 3/8”	SNI 4141:2015	0.23%	Maximum 1%
	FA		0.23%	Maximum 1%
	CA 3/4”		3.86%	Maximum 10%
Soundness test	CA 3/8”	SNI 3407:2008	4.29%	Maximum 10%
	FA		4.22%	Maximum 10%
Aggregate adhesiveness to bitumen		SNI 2439:2008	98.75%	Minimum 95%
Aggregate flatness index		ASTM D 4791-10	2.80%	Maximum 5%

TABEL 3
PROPERTIES TEST RESULTS OF ASPHALT PENETRATION 60/70[6]

No	Type of Test	Results	Requirement	Unit
1	Penetration	62.4	60-70	mm
2	Softening Point	51.5	≥ 48	°c
3	Ductility	140	≥ 100	mm
4	Flash point	308	≥ 232	°c
5	Specific gravity	1.04	≥ 1.0	-
6	Losing weight	0.0484	≤ 0.8	% of weight
7	Penetration after losing weight	55.2	≥ 54	mm
8	Ductility after losing weight	130	≥ 100	mm

Aggregate Properties

The aggregates used are: coarse aggregate, medium aggregate and fine aggregate with a maximum grain size of 3/4 inch, 1/2 inch and No. 4. Aggregate in this mixture is the main component of cold asphalt mixture, which is 70-75% based on the percentage weight. Aggregate properties obtained through tests include: Los Angeles abrasion, clay lump, Soundness test, aggregate attachment to asphalt, index and aggregate flatness. The results of the aggregate test can be seen in Table 2. While the results of the combined gradation analysis are shown in Figure 1

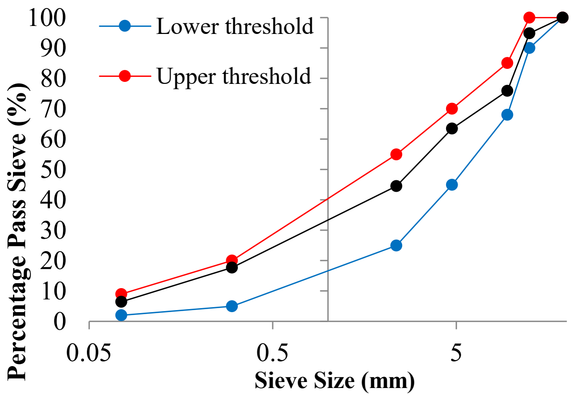

Figure 1: Combined gradation and specification limits

Figure 1 shows the gradation of the combined aggregate consisting of coarse aggregate, medium aggregate, and fine aggregate and the specification limits. These limits indicate the maximum and minimum sizes. No limits are exceeded so that the combined aggregate is eligible for use in asphalt mixtures.

Rejuvenating properties

The rejuvenating agent is a mixture of asphalt, kerosene, and bunker oil. Kerosene is a colorless and flammable hydrocarbon liquid resulting from the fractional distillation of petroleum at temperatures of 150°C and 275°C (carbon chain C12 to C15). The rejuvenating agent is made by heating (diluting) the 60/70 penetration bitumen first. After the asphalt melts, it is then mixed with kerosene and bunker oil. The composition of each ingredient for the rejuvenating agent is 63% asphalt 60/70 penetration, 22% kerosene, and 15% bunker oil. The asphalt used is 60/70 penetration oil asphalt. Table 3 is the result of testing asphalt properties including: penetration, penetration after weight loss, softening point, flash point, ductility specific gravity, and ductility after losing weight.

Research Design

Asphalt-concrete mixture used as a specimen with the following proportions: (1) coarse aggregate (CA) <3/4" = 22.5%; (2) coarse aggregate (CA) <3/8" = 9.0%; (3) fine aggregate (FA) <#4 = 43.5%; (4) Asbuton = 25.0%; (5) rejuvenating agen = 4.5%. Additives are added with variations of 0.0%, 0.2%, 0.3%, and 0.4% to the asphalt. For each variation, 3 specimens were made, so that the total number of specimens made was 4 x 3 = 12 specimens. Table 4 shows the code and number of specimens for each percentage addition of additives in the asphalt-concrete mixture.

TABLE 4

SPECIMEN VARIATION

Additive Content (%)	Specimen Code	Number of Specimen
	0.0% - 1	1
0.0	0.0% - 2	1
	0.0% - 3	1
	0.2% - 1	1
0.2	0.2% - 2	1
	0.2% - 3	1
	0.3% - 1	1
0.3	0.3% - 2	1
	0.3% - 3	1
	0.4% - 1	1
0.4	0.4% - 2	1
	0.4% - 3	1
Total Specimen		**12**

Based on the percentage of asphalt in Asbuton and asphalt in the modifier, the asphalt content in the mixture is as shown in Table 5.

Specimen manufacture and testing

Making the specimen begins by weighing the asphalt-concrete mixture material according to the design composition. The mixing and compaction process was carried out without heating, at room temperature. Figure 2 is a specimen of the asphalt mixture that has been compacted and is ready to be tested.

Figure 2: Specimens of compaction of asphalt-concrete mixture

Testing using Marshall method [7] and [8] to obtain volumetric and mechanical characteristics. Volumetric characteristics include: Void in the Mix (VIM), Void in Mineral Aggregate (VMA), Void Filled with Bitumen (VFB), obtained by weighing the specimen, see Figure 3(a). While the mechanical characteristics, namely stability, flow and Marshall Quotient (MQ) were obtained by testing with Marshall test equipment, see Figure 3(b).

(a) (b)

Figure 3: Specimen testing: volumetric (a) and mechanical (b)

TABLE 5

ASPHALT PROCENTAGE CALCULATION

Mixed asphalt content without rejuvenating agen				
Proportion (%)		Asphalt Content (%)		Total in mixture (%)
Asbuton	Rejuvenating agen	Asbuton	Rejuvenating agen	
25.00	0	4.96	0	4.96
Mixed asphalt content with rejuvenating agen				
Proportion (%)		Asphalt Content (%)		Total in mixture (%)
Asbuton	Rejuvenating agen	Asbuton	Rejuvenating agen	
23.88	4.50	4.73	2.84	7.57

III. RESULTS AND DISCUSSION

Volumetric Characteristics

Volumetric is closely related to voids and density. Density-void analysis was used to determine unit weight, VIM, VMA and VFB [9]. Figure 4, shows the results of the density test (unit weight) of cold asphalt mixture specimens with Asbuton based on variations in the addition of additives. The density of the mixture increases with the addition of super bond additives. This means that the addition of a super bond can reduce the cavity so that the weight of the specimen increases.

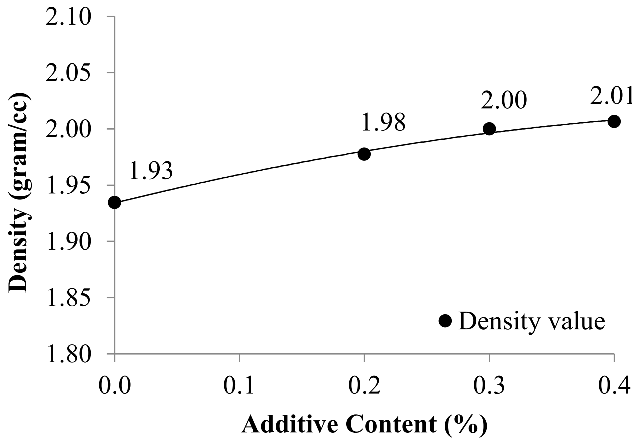

Figure 4: The relationship between additive addition and the density of the mixture

Figures 5 - 7 are the test results in the form of VIM, VMA and VFB. The volumetric characteristics of cold asphalt mixture specimens with Asbuton indicate that the addition of additives has a different effect on each volumetric characteristic.

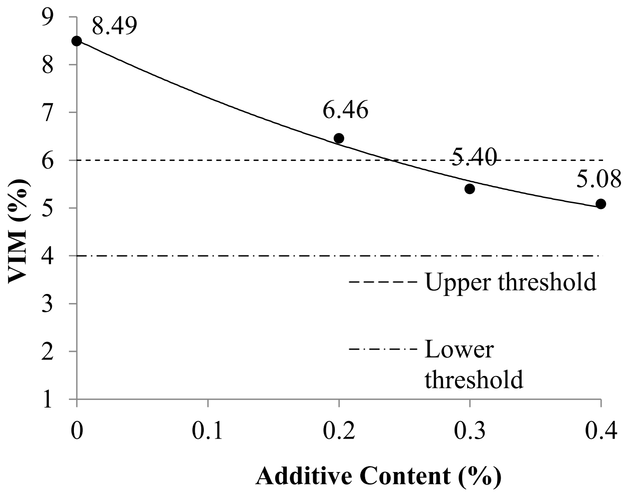

Figure 5: Relationship of additive addition with VIM

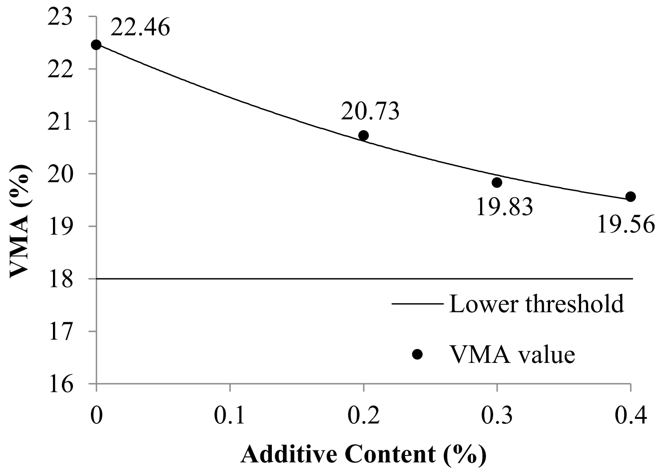

Figure 6: Relationship between additives and VMA

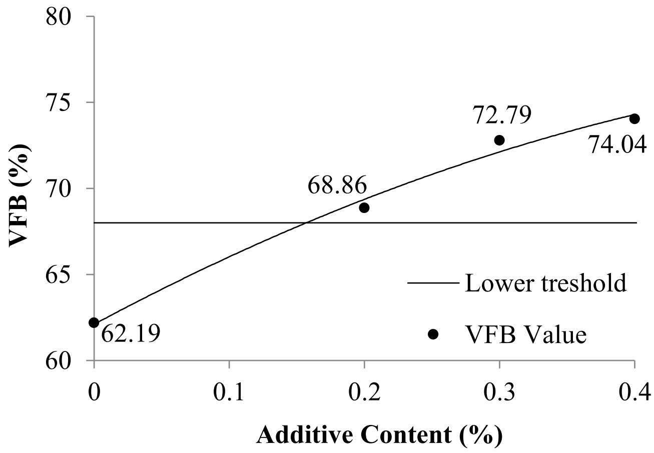

Figure 7: Relationship between additives and VFB

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The addition of additives showed an effect on the size of the void mixture. The higher the percentage of additive addition, the smaller the value of VMA and VIM (Figure 5-6). The decrease in the VIM value was caused by an additive reaction that was able to soften the asphalt in Asbuton so that it filled the voids between aggregates (VMA) and enveloped the aggregates. This also causes the VFB value to increase with the addition of additives (Figure 7). Based on the applicable standards in Indonesia [10], the addition of 0.3-0.4% additives meets the volumetric requirements of the mixture. As for the addition of < 0.3% additive, the requirements for VIM and VFB are not met.

Mechanical Characteristics

The Marshall mechanical characteristics measured were the stability and flow of the specimen. Stability is the value of the load at which the specimen fails or has undergone deformation. Flow is the amount of deformation to maximum stability when the sample reaches the limit of collapse [11]. Meanwhile, to determine the stiffness of the asphalt mixture can be known from the value of Marshall Quotient (MQ), namely the ratio of stability to flow. If the specimen loading results have low stability and high flow values, the mixture will tend to deform. On the other hand, if the specimen has high stability and low flow values, the mixture will tend to become brittle and crack when loaded. Figure 8-10 shows the results of stability, flow and MQ testing.

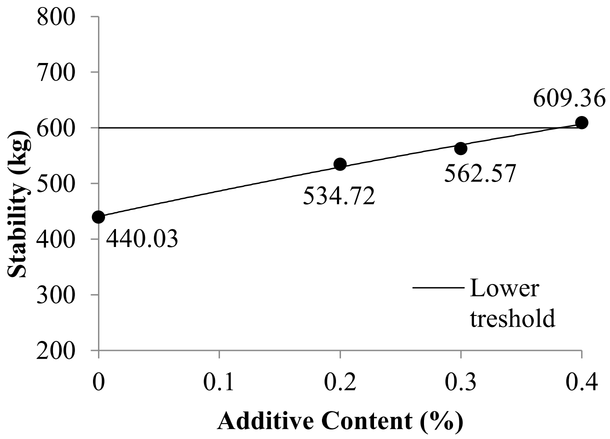

Figure 8: Relationship between additives and stability

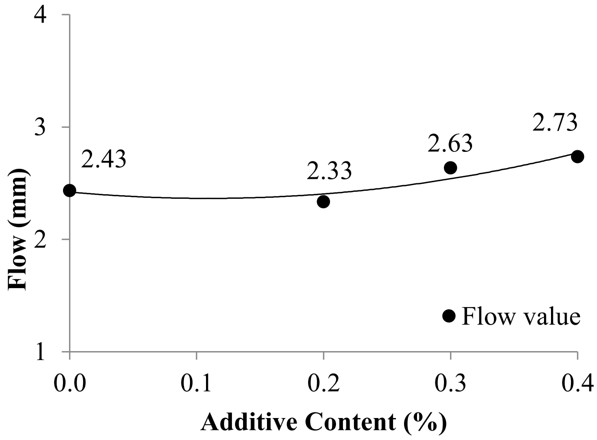

Figure 9: Relationship between additive addition and flow

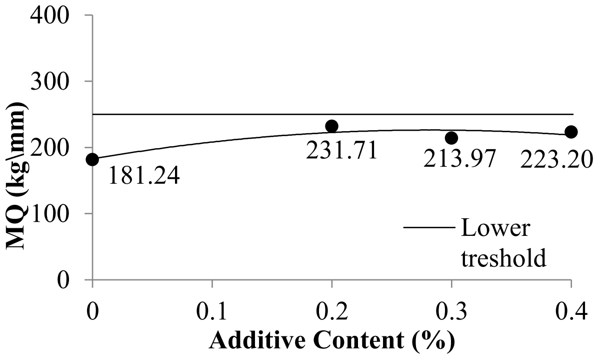

Figure 10: Relationship between additive addition and MQ

The stability test results show that the increase in the amount of additive addition results in an increase in the stability value. However, the addition of additives <0.4 has not reached the minimum requirements. The addition of additives has an effect on increasing flow, but overall it does not meet the requirements. When viewed from the test results curve, the higher the percentage of additive addition, the performance of the asphalt mixture will increase. So that further research can be done by optimizing the addition of super bond additives to meet all requirements, including MQ which is still < 250 kg/mm.

IV. CONCLUSION

The addition of super bond additives affects the volumetric and mechanical characteristics of the asphalt concrete mixture using Asbuton. Addition of additives with the highest percentage (0.4%) showed the best results. However, not all of the parameters meet the requirements. The value of Void in the Mix (VIM) 5.08%, Void in Mineral Aggregate (VMA) 19.6% and Void Filled with Bitumen (VFB) 74.0%, as volumetric characteristics. While the Stability is 609 kg, Flow 2.7 mm and Marshall Quotient 223 kg/mm, for its mechanical characteristics.

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