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Effective Method of Mixing Porous Asphalt Using B-5/20 Grain Asbuton for Heavy Traffic on Asphalt Mixing Plant (AMP)

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Abstract Several factors that must be considered for the performance of porous asphalt mixtures using b-5/20 Asbuton are homogeneity of asphalt content in granular Asbuton, water content of Asbuton granular, mixture composition, combined aggregate gradation, temperature of aggregate in dryer system, method of mixing, mixing time, and compaction system. All the kind of that variable will affect mixture properties, so every single factor must be known by technician laboratory and quality engineer in the field. This research, will present an effective method that was applied to the mixing process in the Asphalt Mixing Pant (AMP), specifically the stages, temperature and mixing time based on laboratory test results which resulted in the highest performance of a porous asphalt mixture for heavy traffic, namely Marshall stability > 3600 kg, cavity volume > 8%, CL < 20% and AFD < 0.3%. This research uses dry method with varying the aggregate heating and mixing time in the mixer. The selection of the appropriate method is carried out based on the performance of the mixture as mention above. Based on the results of the analysis, the use dray method with aggregate temperature of 190 ℃, and time mixing 10 second for granular Asbuton in the mixing plant (pugmill) can be said. And the whole mixture of aggregate, granular Asbuton and asphalt is 45 seconds. So using the correct mixing method system will produce a porous asphalt mixture that is strong and durable to support heavy traffic loads.

Keywords Asbuton B-5/20, Dry Mixing Method, Mixture Properties

1. Introduction

Failures in using granulated Asbuton as an additive or as a substitute for hot asphalt mixtures still often occur; although hot asphalt mixtures with other added materials also fail, failures due to the use of Asbuton are still more dominant. The types of failure when using Asbuton are generally loose grains and early ageing, and crack, which happened for other asphalt mixture [1], [2], [3]. The use of granular Asbuton requires more detailed control efforts compared to the use of other modified asphalt because the source of Asbuton material in chunk form has bitumen content and water content that vary from one location to another even though they are close together. Detailed activities that must be carried out are checking the uniformity of bitumen content at each supply arrival.

The general specifications for Bina Marga 2018 rev-2 have determined the portion of granular Asbuton in hot asphalt mixtures of 2-3% for B-5/20 and 7-10% for granular Asbuton B-50/30, with several choices of mixing methods including the pre-mix method, dry method and wet method [4]. The biggest choice for using granular

Asbuton in hot asphalt mixtures is the pre-mix method, where this method requires quite a lot of energy and a relatively long time for the Asbuton and asphalt process, so the use of granular Asbuton is considered less effective and efficient. Apart from that, asphalt mixing plant (AMP) owners are hesitant about choosing the dry method or the wet method because they often experience failure in the field, both as an additive and as a substitute material. They can only justify that Asbuton products are not good for hot asphalt mixes, compared with other modified asphalt. This is a challenge for all parties, the government and service providers related to the use of Asbuton in hot asphalt mixtures, in a process which requires detailed attention, starting from selecting the material source, processing it into granules (uniforming bitumen content and water content) and in the mixture process (effective mixing method).

There is still no definite guarantee regarding the consistency of asphalt content and water content in granular Asbuton, so it is necessary to test the asphalt content and water content from each manufacturer (supplier), so that every time the material arrives, random sampling must be carried out in content tests including asphalt and water content [5]. Asphalt content is needed to determine the effective asphalt content based on the aggregate gradation composition, while water content is needed to determine the temperature of the aggregate heating/drying process in the dryer drum, as well as to determine the time limit for mixing the aggregate with granular Asbuton in the AMP mixer (pugmill). This varying consistency condition of granular Asbuton is often a source of problems in hot asphalt mixtures that use Asbuton as an additional or substitute material.

Even though the method for mixing granular Asbuton has been determined in the specifications, the results are still not optimal so AMP owners prefer other types of modified Asbuton, if there is no requirement in the use of granular Asbuton. There is still an opinion that using Asbuton is more expensive and difficult but the results are less than optimal. This research was carried out by developing a dry method, through more detailed stages, especially testing asphalt content and water content every day of production. Supply source of Asbuton must have a valid track record, as reference for receiving supplies of original Asbuton to be processed into granular Asbuton with consistent asphalt content and water content [6].

2. Research Purposes

The main objective of this study is to determine the appropriate porous asphalt mixing method in the Asphalt Mixing Plant (AMP), especially the aggregate drying temperature so that the water content in the aggregate and Asbuton granules is completely lost during mixing, and to soften the Asbuton granules so that the utilization of Asbuton bitumen can be maximized in supporting the strength of the porous asphalt mixture.

3. Literatures Review

Porous asphalt mixtures are generally only for road pavement surfaces with low to moderate traffic volumes, so the minimum Marshall stability value limit is only 500 kg [7]. This porous asphalt mixture is the target in this research, where the Marshall stability value is the main target because it supports heavy traffic, while seepage is the next target because surface water absorption is needed during rain to ensure surface roughness so that it is not slippery and hydroplaning does not occur. By seeping rainwater, there will be no contact barrier between the pavement surface and the tire surface so that the vehicle does not slip [8], [9], [10]. The seepage of porous asphalt mixtures for heavy traffic does not have to be as large as the seepage of porous asphalt mixtures for light traffic because the greater the cavity volume, the smaller the Marshall stability value that occurs. Several references state that with a void volume of more than 8.0%, a porous mixture has connected voids, prone to oxidation and water seeps into the mixture making it susceptible to premature damage [11]. This is different from the technical requirements for asphalt porous for light traffic, namely cavity volume value > 18% [12].

By using a modified open gradation and a maximum grain size of 1.5 inches, the surface texture will appear rough and form a series of gaps between interconnected coarse grain protrusions (water ropes), so that the surface is always rough when it rains, as in the illustration in Figure 1 [13]. Road pavement surface texture conditions like this are very beneficial because vehicle tires will tread optimally without being obstructed by surface water flow when it rains, so that hydroplaning mechanisms and water splashes do not occur. This does not happen because some of the water seeps into the porous asphalt mixture and some flows through the gaps between the surfaces of the crushed stone that protrude to the surface as in Figure 1. There will be no surface water puddles, with water seepage of more than 0.08 mm/second (according to the average rainfall in Indonesia is 4000 mm/year), so that the surface condition of the porous road pavement is always dry and free from slippery road conditions and hydroplaning incidents, and will be a safe road, good for road users, and for construction safety because it is free from trapped water.

Figure 1. Surface water flow through interconnected gaps and partly through vertically connected cavities

The structural strength of hot asphalt mix is greatly influenced by the gradation composition and type of modified asphalt or additional materials if necessary. A good aggregate gradation is a gradation that is formed from the interlocking of coarse aggregate grains, especially coarse granules, so that the bond that occurs between the coarse aggregate grains is a mechanical bond, while asphalt only strengthens the bond [14], [15], [16]. Especially in Indonesia, where heavy vehicle tire pressure can reach 160 psi, a Marshall stability value of 10 x tire pressure (in psi) = 1600 kg, is required [17]. If the asphalt mixture is expected to be able to produce this Marshall value, then the asphalt mixture must use a granular size, maximum 1.5 inches. With a gradation composition that refers to the interlock concept between coarse aggregates, a Marshall stability value of 3600 kg can be achieved with an asphalt penetration quality of 60-70, using a maximum grain size of 1.5 inches in one layer (AC-base). 15 cm thick was applied on the Road Province of Nganjuk-Bojonegoro at the end of 2020 [18].

For porous asphalt mixtures, several references use open gradations, with polymer or plastomer modified asphalt, natural rubber, crumb rubber, cellulosic fiber, glass fiber and other additives which function to strengthen the properties of the asphalt. The need for adding material and modifying asphalt is to prevent creeping and softening of the asphalt if the temperature in the field exceeds the softening point of the asphalt [19]. Most porous asphalt mixtures are blocked by asphalt melting and compression due to grooves because asphalt softens when the surface temperature of the pavement exceeds the softening point [7].

The specifications [4] stated that B-5/20 granular Asbuton is used as an additional ingredient in hot asphalt mixtures with a portion of 2% to 3%, as a substitute for asphalt. The method used is the wet mix, for B-5/20 Asbuton, namely using a filler chamber as a mediator for the mobilization of B-5/20 Asbuton. In the wet method, 60-70 penetration asphalt, heated at a temperature of 150 C, is mixed with hot aggregate at a temperature of 165-170 ℃, then 2-3% granular Asbuton is added after the asphalt is mixed with the hot aggregate in the pugmill. The pre-mix process requires longer time and high operational costs, but the mixture results are better compared to the wet mixture process.

4. Method of Research

Method of research consisting of stages sequences that must be conducted start from data collecting, data validation, gradation composition, calculation of bitumen content, and method of mixing, determines Asbuton granular, and temperature mixing of granular Asbuton. All the above activities are useful for supporting production of asphalt mixture, the highest value of Marshall stability as a main indicator of porous asphalt mixture in the next future. The stages that mention above was illustrated in Figure 2.

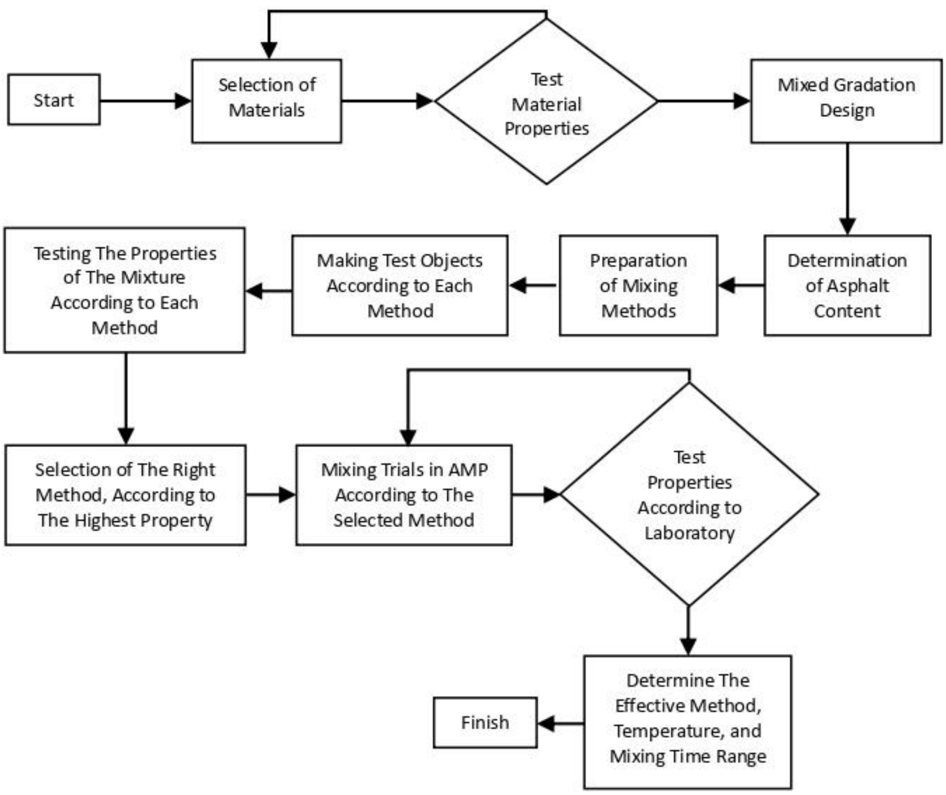

Figure 2. Research stages for determining an effective mixing method

The main material properties data as attached are presented in Table 1 and Table 2. This data is verified and validated based on the value of each characteristic. For example, data validation between test results is that the abrasion value is positively proportional to the water absorption value, meaning that the smaller the abrasion value, the smaller the absorption value. If conflicting results are found, they need to be verified with other supporting data, for example the flatness value. Flat materials tend to break easily when tested for abrasion, resulting in a large abrasion value, even though the absorption value is small.

Table 1. Analysis of Aggregate Sieve and Asbuton B-5/20

	% Gradation					
Sieve	Crushed Stone				Asbuton B-5/20	
	0–5	5–10	10–15	10–27	Before Ext.	After Ext.
1 1/2	100	100	100	100	100	100
1	100	100	100	100	100	100
3/4	100	100	100	73.74	100	100
1/2	100	100	58.81	23.40	100	100
3/8	100	98.45	10.82	0.46	100	100
#4	99.71	37.95	2.53	0.36	100	99.67
#8	83.26	4.69	1.67	0.29	99.14	94.21
#16	52.95	3.54	0.50	0	56.81	72.22
#30	39.42	2.61	0.40	0	34.64	55.21
#50	29.65	1.49	0	0	22.28	43.52
#100	19.09	0.81	0	0	6.44	19.05
#200	9.36	0.73	0	0	1.5	6.02

Table 2. Volumetric and Fine Aggregate Field Data

Variable	Unit	Coarse Aggregate	Fine Aggregate
G_{sb}	Kg /cm^3	2.626	2.61
Absorption	%	2.06	2.249
Comb G_{sb}	Kg /cm^3	2.618	

Sieves analysis is needed to determine the combined gradation composition and effective asphalt content. By determining the asphalt layer thickness of 9-10 microns [20], the effective asphalt volume will be obtained. If the effective asphalt volume is divided by the specific gravity of the asphalt, the effective asphalt content will be obtained. The asphalt content in the mixture is obtained from the effective asphalt content plus ½ of the aggregate's water absorption capacity. An example of calculating asphalt content can be seen in Table 3.

Table 3. Example of Calculating Asphalt Content in a Mixture

	23,31	46,42	13,28	13,00	4,00	100,00
Sieve	CR-10-27	CR-10-15	CR-5-10	CR-0-5	Asb-B5/20	Combined
1 1/2	100	100	100	100	100	100
1	95,2	100	100	100	100	98,88
3/4	80,7	96,86	100	100	100	94,04
1/2	2,22	41,39	98,23	100	100	49,77
3/8	1,55	12,87	92,7	100	100	35,64
#4	1,39	4,1	22,78	99,57	99,67	22,18
#8	0	2,64	2,64	72,47	94,21	14,77
#16	0	0	1,57	47,46	72,22	9,27
#30	0	0	1,38	32,93	55,21	6,67
#50	0	0	1,24	22,66	43,52	4,85
#100	0	0	1,06	14,89	19,05	2,84
#200	0	0	0,85	9,02	6,02	1,53

From Table 3, it is obtained that the surface area of 1 kg of combined aggregate is = 2.105 m^2 from the cumulative results of multiplying each sieve size through the multiplier factor as stated in Table 4.

Table 4. Volumetric and Fine Aggregate Field Data

Sieve size (mm)	Area Factor (m^2/kg)
+4.75 mm	(0.41x1.00)
4.75 mm	0.41
2.36 mm	0.82
1.18 mm	1.64
600 μm	2.87
300 μm	6.14
150 μm	12.29
75 μm	32.77

(Sources: [20])

Volume of Asphalt in 1 kg of Aggregate:
= Area x Thickness of film
= 2.10^5 m^2 x 10 μ
= 2.10^5 x 10^{-5}m^3
= 2.10^5 x 10^{-5} x 103 dm^3
= 2.10^5 x 10^{-2} dm^3
= 0.02105 dm^3

Weight of Asphalt in 1 kg Aggregate:
= Volume of Asphalt x Specific Gravity of Asphalt
= 0.02105 dm^3 x 1.036 kg/ dm^3
= 0.022 kg

Effective Asphalt Content:
= 0.022 / (1+0.022) x 100 %
= 2.15 %

From the combined gradation showing 22% portion of fine aggregate and 78% portion of coarse aggregate,

Then Total Aggregate Absorption of Water:

= (0.22 x 2.249 + 0.78 x 2.06)

= 2.10 %

Asphalt Absorption Value:

= ½ x 2.10 %

= 1.05 %

Design Asphalt Content:

= Effective Asphalt Content + Asphalt Absorption

= 2.15 + 1.05

= 3.20 %

5. Mixture Properties Test

The main mixture properties of porous asphalt are the strength, permeability (connected void), and finally durable. Strength was indicated by a high value of Marshall stability and rutting condition, while durable was indicated by asphalt flow down (AFD/ Creep) and cantabro loss (CL) is Marshall stability, creep, reveling, so this research will present all the materials.

5.1. Prepare Marshall Test Specimens

Marshall test specimens (4 inches) in diameter were made based on the design results of the gradation composition and asphalt content according to the calculation results above, where the heating and mixing process was carried out based on the dry method with the heating temperature referring to the Director General's specifications. In laboratory research, heating/ drying of the aggregate was carried out referring to other modified asphalt, namely around 180-190 ℃. Making 3 test specimens for each method according to Table 5, where the proportion of aggregate is the same for all types of methods, the effective asphalt content is also calculated based on the thickness of the asphalt covering the aggregate of 10 microns.

Table 5. Mixing method with Asbuton Item B-5/20

Properties	Specification 2018		Dry Method Modification
	Wet Method	Pra-mix Method	
Marshall Stability(kg)	1100	1460	1450
Flow (mm)	5-8	4-6	4-7
Voids (%)	12	9.5	10
Density (g/cm^3)	2.19	2.11	2.13
AFD (%)	0.15	0.0	0.0
CL (%)	0.13	6.5	7.83

For comparison, PG-76 shell asphalt is heated to a temperature of 190 ℃ for mixing, according to the 2020 shell asphalt factory brochure. In this method, the chance of water being trapped in the asphalt mixture is quite high, so there is a chance of disrupting the bond between the asphalt and the aggregate, as well as the potential for a faster temperature drop. As a result of this condition, compaction does not occur optimally and is prone to loss grains. As an illustration of the Marshall stability test results and other mixture properties can be seen in Table 5, a summary of test results for asphalt mixtures with granulated Asbuton for various mixing methods is provided.

5.2. Properties Testing of Porous Asphalt Mixture

Marshall stability and flow tests were carried out on test objects printed the day before with reference to test standards. Before testing, Marshall test objects were subjected to volumetric and seepage testing to obtain density, cavity volume (VIM), and seepage velocity. If the properties and seepage do not meet the targeted requirements, changes are made to the composition of the fine aggregate fraction and asphalt content. Asphalt content is maintained with a layer thickness of 9-10 microns, so that changes in fine aggregate will be followed by changes in asphalt content. The composition of the coarse aggregate fraction still refers to the lowest VCA $_{DRC}$ value from the previous volume weight test results. As the main reference, the Marshall stability value is > 1400 kg and flow > 4 mm, cavity volume > 8%, and seepage > 0.02 cm/sec. If these three factors are met then proceed with asphalt flow down (AFD) and Cantabro Loss (CL) testing, where the AFD value is > 0.3% and CL non-immersion < 20%.

5.3. Mixture Testing at Asphalt Mixing Plant (AMP)

The results of experiments in the laboratory will be applied to AMP, where the temperature obtained is to produce the targeted property values. Trials were carried out for a mixing weight of 1 ton of mixed production. The steps/stages carried out in AMP are as follows:

1. The aggregate is heated at a temperature of 180-190 °C;
2. Asphalt penetration 60-70 is heated at a temperature of 150-160 °C;
3. Aggregate composition according to laboratory results is with the highest stability values and other properties that meet the requirements;
4. Aggregate with a temperature of around 190 °C enters the pugmill immediately followed by B-5/20 granular ashbuton according to the specified dosage and is stirred for around 10-12 seconds, until white smoke appears as a sign of the release of water vapor, and an odor similar to what happens in the laboratory can be smelled;
5. Mixing is continued until the total cumulative mixing time is approximately 45-52 seconds;

6. If it is visually even and shiny, then the mixture is poured to be taken. Part of it is cast into a test object with a mold size of 6 inches, 4 pieces, of which 2 are for the Marshall stability test, and for the Cantabro loss test, AFD is taken from other bulk test objects that have been prepared;
7. If the results are the same as the results in the laboratory, the test results are reported as successful research results.

6. Discussion and Analysis

Aggregate properties testing uses results from PT Bumindo (secondary data), while the proportions of each aggregate are designed based on the relationship $VCA_{DRC} > VCA_{MIX}$. This is necessary to increase the role of stone on stone contact between coarse aggregate grains. The porous asphalt mixture uses a modified open gradation, where the strength of the mixture is obtained from the mechanical bond between the coarse aggregate grains (interlock/stone on stone contact), while the permanent voids are designed based on the fine and medium aggregate portions which fill part of the volume of the voids formed between the coarse aggregate grains. interlock (interlock) [21], [22], [23]. From the Marshall stability test results, a small value will be obtained (1100 kg to 1200 kg), if the cavity volume is more than 10%. On the other hand, if the cavity volume is less than 10%, then the Marshall stability value is more than 1400 kg, with a melting value (flow) of 4-6 mm. This is the subject of discussion in research related to the method of mixing granular Asbuton in asphalt mixtures, both solid gradations and modified open gradations as carried out in this research.

6.1. Material Properties for Porous Asphalt Mixture

The Rev-2 2018 specification states that B-50/30 granular Asbuton is mixed dry, while B-5/20 Asbuton is mixed wet method, with temperatures as in Table 6 for dry and wet methods. This research was carried out in a different way, taking into account several things, including:

1. There are differences in water content in granular Asbuton, so different heating or drying times and temperatures are required in the heating drum (dryer);
2. It is necessary to look for certain indicators regarding the dry condition of the Asbuton granules so that they are free from water content, as well as the melting of the asphalt so that it can be used as the right temperature for drying the aggregate in the drying drum, as well as the length of time for mixing the Asbuton granules with the hot aggregate;
3. Indicators as in point 2 can be the smell of smoke during mixing and the surface of the coarse aggregate which is partially covered by melted bituminous Asbuton and is free of water;
4. In the asphalt mixing process using granular Asbuton, there is a possibility of temperature differences, because the water content and bitumen content in granular Asbuton tend to be different, so more intensive mixture control is needed to ensure production consistency, especially the water content in granular Asbuton, so that aggregate heating is required at a certain temperature in the mixture as well as a heating period in the heating drum (dryer);
5. Based on the results of trials in the laboratory and at AMP, a support system is needed at AMP if you have to use granular Asbuton as an additional ingredient or substitute for oil asphalt in hot asphalt mixtures.

Table 6. Mixing Temperature of Dry and Wet Method

	Temperature Estimation of Asphalt (℃)		
Procedure for Implementing	Asphalt Pen. 60-70 with Asbuton B 50/30	Asbuton Pre-mix	Asphalt Pen. 60-70 with Asbuton B 5/20
Marshall Test Object Mixing	160 ±1	165 ±1	
Marshall Test Specimen Compaction	150 ±1	155 ±1	
Mixing in the Asphalt Mixing Unit			
- Aggregate Heating in Dryer	170-180	160-170	
- Asphalt Heating in Tanks	160-170	165-175	
Pouring the Asphalt Mixture from the Mixer into the Truck	140-155	145-160	
Supply to Spreader	135-155	145-160	
Initial Compaction (Steel Wheels)	130-150	135-155	
Intermediate Compaction (Rubber Wheel)	105-130	110-135	
Final Compaction (Steel Wheel)	> 100	> 105	

(Sources: [1])

6.2. Wet Mixing Method

Several things need to be considered when mixing wet, especially if using Asbuton B-5/20, namely:

1. The water content in the granular Asbuton must be completely liberated, so before the B-5/20 granular Asbuton must be dried first. If the water content in the Asbuton is trapped in the asphalt that holds the aggregate together, then it is very likely that the bond between the aggregate grains encased in the asphalt and the water in the Asbuton will be released;
2. Many granular Asbuton mixtures are found that experience a faster decrease in temperature, which is most likely caused by the trapping of water content in granular Asbuton which is covered directly by oil asphalt;
3. With a hot asphalt temperature of 150 °C and aggregate in a heating drum (dryer) up to a temperature of 170-180 °C, these two types of temperature do not capable for releasing the water content in the granular Asbuton;
4. Test results in the laboratory on the process of making test objects by frying the aggregate at a temperature of 180-190 °C, then mixing it with B-5/20 granular Asbuton, stirring in a frying pan until white smoke comes out, indicate of water coming out. Followed by the distinctive smell of melted Asbuton and some of it sticks to the coarse aggregate in the form of spots;
5. If the asphalt has disappeared but the characteristic smell of Asbuton has not yet appeared, then the frying pan needs to be placed on the fire and stirred thoroughly until the characteristic smell of Asbuton appears and the temperature recorded at this condition;
6. The temperature as referred to in point 5 is used as a reference for the aggregate drying process at AMP;
7. The average temperature for aggregate heating in this study was 180-190 °C. This is equivalent to heating a PG 76 modified asphalt shell;
8. If the stirrer on the pugmill is still intact, the mixing time for granular Asbuton with hot aggregate at this temperature is 10-12 seconds, this is indicated by an indicator that shows the appearance of the typical Asbuton odor;
9. As the main indicator of the function of Asbuton mixed with asphalt, the Marshall stability value can reach more than 1400 kg in both solid graded mixtures and modified open graded mixtures in porous asphalt mixtures, as was done in this research.

6.3. Evaluation of the Efficiency and Effectiveness of the Application of Asbuton B-5/20 as an Additive and Substitute Material

Evaluation of the performance of asphalt mixtures was only carried out using the modified dry method, because the mixture property values were not much different from the pre-mix mixing method, where the pre-mix method was considered an expensive and cheaper method, effective and efficient, while the results of the mixture properties carried out using the modified dry method were relatively equivalent. The less effective and efficient pre-mixing method is that you need a special kettle to directly mix granular Asbuton with 60-70 penetration asphalt. Apart from that, the time required to mix is no less than 4 hours, so it takes quite a long time and high operational costs, especially fuel consumption. In addition, the cost of maintaining the stirrer and kettle which often wear out must be replaced within a certain period of time. These are the things that prevent AMP owners from producing asphalt mixtures using B-5/20 granular Asbuton.

The B-5/20 granular Asbuton bitumen content is around 17-20%, but when it is mixed into a hot asphalt mixture, the effective Asbuton bitumen only appears to be no more than 60%. This is proven in an open gradation asphalt mixture equivalent to AC-Base with a planned asphalt content of 4.5%, the addition of B-5/20 Asbuton of 5.0% of the total mixture, the following calculation:

1. Contribution from Asbuton assuming a bitumen content of 20%, then there is additional asphalt of 0.2 x 5.0 = 1.00%;
2. The oil asphalt content used is 4.50 – 1.00 = 3.50%, so that it corresponds to the design asphalt content of 4.50%;
3. After carrying out the extraction test, it turned out that the total asphalt content was found to be 4.10%, meaning that there was only an additional 0.60% asphalt content from Asbuton;
4. The explanation for point 3 shows that only 60% of the Asbuton is mobilized in the mixture, but it provides additional Marshall stability strength that is high enough to be equivalent to polymer modified asphalt or others;
5. Referring to the pre-mix method, the Asbuton bitumen is directly mixed with 60-70 penetration asphalt, which also functions as a modifier so that the Asbuton bitumen functions optimally in the mixture also the water content in the Asbuton has most likely evaporated because the mixing process takes more than 4 hours at a temperature of 180 °C, the pre-mix method is more optimal than other methods;
6. The dry-modification method is the same as the dry mixing method for Asbuton B-5/20, other things that need special attention include:
   a. Check the bitumen content every day of production, to design the actual portion of Asbuton in the mixture;
   b. Check the water content, to predict the drying and heating temperature of the aggregate, especially to ensure the exhaustion of the water content in the Asbuton. When granular Asbuton is poured, thick white smoke will occur as a form of water vapor released from the Asbuton;
   c. Check the melting of the Asbuton, this is indicated by the characteristic smell of Asbuton if the

Asbuton granules are mixed with a certain hot aggregate and in a certain cycle for a certain time;

d. Check the evenness of the distribution of Asbuton in the mixture, as an indicator, the mixture appears shiny evenly over the entire surface;
e. The length of impact time affects the evenness of the asphalt covering over the entire surface of the aggregate, not a single grain of coarse aggregate that is not covered by asphalt. From the monitoring results at AMP, since the aggregate enters the mixer (pugmill), immediately the B-5/20 granular Asbuton enters, and stirred with the mixer for 10-12 seconds, then the asphalt is mixed into the mixture of aggregate and granular Asbuton, which has been mixed, stirred with the mixer rotation and certain speed for approximately 35-40 seconds;
f. Compare the results of the 1st round of mixture with the results of the mixture in making the test object, if visually it looks the same, perhaps even more evenly distributed in the mixer, then the mixture is considered suitable, and mixing activities at the AMP and spreading in the field can be continued.

7. As stated in the 2018-Rev-2 specification, the emphasis on mixing granular Asbuton B-5/20 is more important on the even distribution of Asbuton in the mixture, the release of water content in granular Asbuton, and the melting of Asbuton when interacting with hot aggregate, so that the bitumen Asbuton will easily mix with asphalt oil to become a better binding agent;
8. By applying the similarity method as described above, the intermixing, especially the bond between aggregate and asphalt, can be maximized, because the Asbuton functions completely without obstruction to the water content, which has not been optimally controlled so far.

7. Conclusions

1. The dry type mixing method is more appropriate to apply for mixing granular Asbuton for porous asphalt, because the water content in the granular Asbuton comes out completely, the bitumen of Asbuton melt, the all of Asbuton part works maximally so that it can bind the aggregate optimally;
2. The mixing temperature for heating the aggregate is 180-190 °C;
3. The appropriate time for mixing of granular Asbuton with the hot aggregate at mixer is 10-12 seconds, then immediately followed by hot asphalt, stirred for about 35-40 seconds, so totally 45-52 seconds for all mixing;
4. As an indicator of mixture performance, the average Marshall stability value was obtained above 1400 kg with a flow of 4-5 mm, AFD 0.0% CL = 7.83% and voids in the mixture 9-10%.

8. Recommendation

1. Further research is needed to increase the volume of the cavity above 16% so that it is not easily clogged by dust or mud, which has been quite common in Indonesia.
2. There are other additives besides Asbuton to improve the mixture even with quite large cavities.

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