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Effect of limestone and buton granular asphalt (BGA) on density of asphalt concrete wearing course (AC-WC) mixture

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Abstract. This research aims to examine feasibility of local material of limestone as asphalt pavement aggregate and also Buton Granular Asphalt (BGA) was used for petroleum bitumen partial replacement in the Asphalt Concrete Wearing Course (AC-WC) mixture. The research method used is a laboratory experimental. Density of asphalt mix determined by void in mix (VIM) referred to Bina Marga specification, i.e. minimum 2,5%. The results showed that all of the mixtures meet the standard density which compacted by 2×75 blows. The secondary density was evaluated by using the specimen compacted with 2×200 blows. The secondary density AC-WC mix used limestone and petroleum bitumen pen. 60/70 binder did not meet the Bina Marga requirements, while AC-WC mix used limestone, petroleum bitumen pen. 60/70 and 10,5% BGA satisfied the stipulade of Bina Marga requirements.

1. Introduction

In an effort to support national sustainable road development strategy, the use of local materials both as asphalt binders and as material is very important to be improved. The use of local limestone material as a paved mixed material is still rarely used even though the potential of limestone in Indonesia is very large. According to the Data Update and Mineral Resource Balance Report, Center for Geological Resources-Ministry of Energy and Mineral Resources-RI [1], Indonesia has the potential of limestone resources of around 639.36 billion tons. Some regions in Indonesia do not have frozen type rocks (andesite, basalt, and granite) as road pavement material, so that for the needs of road construction must bring material from outside the area.

Other local materials in Indonesia, which are very important to improve their use are the use of Asphalt Natural Buton. This is considering that the need for the use of oil asphalt for road construction in Indonesia is not comparable to the availability of Oil Asphalt produced by bitumen refinery plant. The shortage of oil asphalt needs for road construction in Indonesia should not be imported from abroad but covered by Buton asphalt production. According to [2], based on national petroleum bitumen refinery plant's data, the asphalt requirement in 2015 was 1,325,709 MT of which 67% came from imports, 18% were produced by national petroleum bitumen refinery plant, and the remaining 15% are imported from abroad. The amount of BRA is very abundant therefore the import demand of petroleum bitumen can be reduced through the effective use of BRA. Utilization of Buton asphalt is not optimal for road infrastructure development in Indonesia, making Buton asphalt deposits on Buton Island "stalled" by 677 million tons. During this time Buton asphalt was exported abroad, both to



China, Singapore and other neighboring countries to meet consumer demand in building road infrastructure.

In recent years, the mechanical process has employed on BRA to obtain Buton granular asphalt (BGA) in form on grains with water content, bitumen content and penetration value those are in accordance with stipulation [3]. Some studies on the use of Asbuton show that the benefits of using Buton granular asphalt (BGA) increase, where BGA addition physical properties of asphalt mixture [3, 4, 5, 6].

In this present paper, an Asphalt Concrete Wearing Course (AC-WC) was made with petroleum bitumen BGA as binder addition, limestone was used as aggregate in AC-WC mixture production. The objective of this paper is to study where the effect of limestone and BGA additive on the volumetric related to Void In Mix (VIM), Void Mineral Aggregate (VMA) and Void Filled Bitumen (VFB) of AC-WC mixture.

2. Materials and Methods

2.1. Limestone

The source of limestone aggregate is taken in Muna Regency, Southeast Sulawesi Province. The aggregate consisting coarse aggregate, fine aggregate, and filler meet Indonesia National Standard for Road Pavement Development. The physical characteristics of coarse aggregates have Los Angeles abrasion value of 27.5%, pH of 9.4, Bulk Specific Gravity of 2.53 gr/cc, and Water Absorption of 2.03%. The physical characteristics of fine aggregate have Bulk Specific Gravity of 2.5 gr/cc and Water Absorption of 3.94%. The aggregate gradation was designed for the Asphalt Concrete Wearing Course (AC-WC) according to SNI 06-2489-1991 [7]. The ideal gradation is shown in figure 1. Figure 2 shows dimension of limestone.

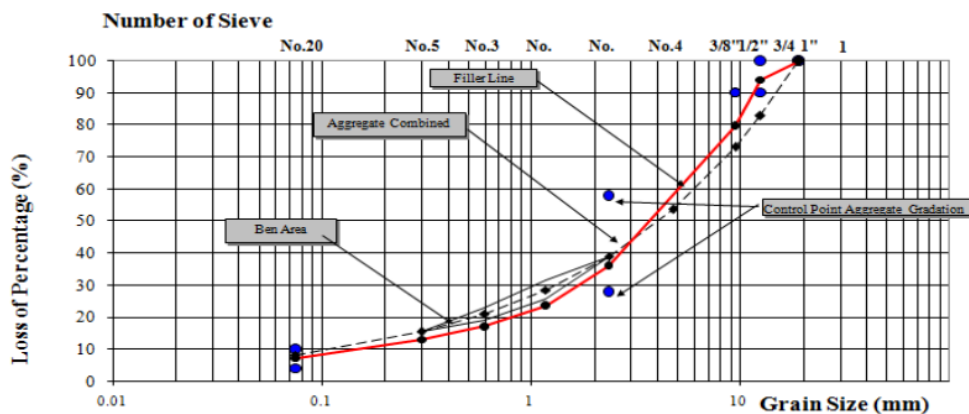


Figure 1. Combined Aggregates Gradation.

2.2. Petroleum Bitumen

This paper used petroleum bitumen produced by national petroleum oil. Asphalt concrete mixtures in Indonesia generally use petroleum bitumen grade 60/70 as shown in table 1.



Figure 2. Limestone (dimension in mm).

Table 1. Some properties of petroleum bitumen grade 60/70

Parameter	Value
Ductility (25°C)	110
Specific Gravity	1.01
Softening Point (°C)	52
Flash Point (°C)	310
Penetration (25°C)	65
Weight (With TFOT) (%)	0.2
Penetration After TFOT (25°C)	54

2.3. Buton Granular Asphalt (BGA)

In this study, BGA-50/30 used as a partial replacement of petroleum bitumen. In addition, the minerals contained in BGA are also used to replace limestone fillers or fine aggregates. Residual bitumen and mineral of BGA was tested according to SNI 03 – 3640 [8], which obtained Residual bitumen content of 32.10%, and Mineral content of 66.36%. Meanwhile water content of BGA was tested according to SNI 06-2489-1991 [7], which obtained water content of 1.54%. Grain and Mineral Size of BGA were tested according to The Directorate General of Highways Department of Public Works [9]. The testing results of grain and mineral size are shown in table 2. Figure 3 shows dimension of BGA.

Table 2. Grain and mineral Size of BGA-50/30.

Sieve Size	Grain of BGA Passing (%)	Mineral of BGA Passing (%)
No. 8	100	100.00
No. 16	59.86	98.13
No. 30	32.91	93.85
No. 50	12.66	87.73
No. 100	3.28	58.35
No. 200	0.82	39.42

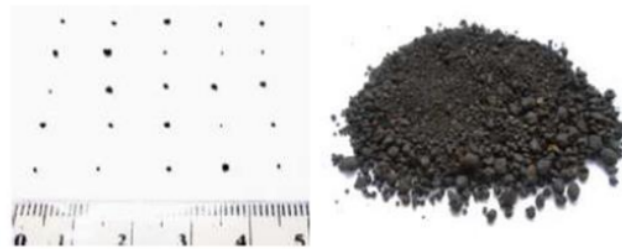


Figure 3. Buton Granular Asphalt (BGA) (dimension in mm).

2.4. Mixtures Design

The mixtures were all prepared in the laboratory. Based on preliminary study the petroleum bitumen optimum content was 6.25% of the total weight of the mixture. Table 3 shows the mixture by weight of AC-WC mixture without BGA and with 0, 5, 7.5, 9, 10.5, 12 and 13.5% BGA.

Table 3. Asphalt mixtures with 0 - 10.5% BGA

No	Description	Unit	BGA 50/30 Buton asphalt content (%)						
A	Asphalt composition		0	5	7.5	9	10.5	12	13.5
	Buton asphalt	gr	0	60	90	108	126	144	162
	Buton asphalt residue	gr	0	18	27	32	38	43	49
	Mineral Asbuton (filler)	gr	0	42	63	76	88	101	113
	Petroleum bitumen pen. 60/70 (6.25%)	gr	75	57	48	43	37	32	26
B	Aggregate weight retained by filter								
	3/4"	gr	-	-	-	-	-	-	-
	1/2"	gr	103	103	103	103	103	103	103
	3/8"	gr	112	112	112	112	112	112	112
	No. 4	gr	280	280	280	280	280	280	280
	No. 8	gr	193	193	193	193	193	193	193
	No. 16	gr	159	159	159	159	159	159	159
	No. 30	gr	89	89	89	89	89	89	89
	No. 50	gr	55	55	55	55	55	55	55
	No. 100	gr	41	41	41	41	41	34	21
	No. 200	gr	26	26	26	18	6	-	-
	PAN (Filler)	gr	68	26	5	-	-	-	-
	Aggregate weight	gr	1,125.0	1,083.0	1,062.0	1,049.0	1,036.0	1,024.2	1,011.6
	Mineral Asbuton weight	gr	-	42	63	76	88	101	113
	Aggregate weight dan Mineral Asbuton	gr	1,125	1,125	1,125	1,125	1,125	1,125	1,125
C	Weight of test object design	gr	1,200	1,200	1,200	1,200	1,200	1,200	1,200

5. Sample Preparations

In order to fabricate the samples, the stages to be followed are as follows:

- Before adding limestone aggregates (stone dust and filler) to the mixture, it was heated to 145°C for a period of approximately 20 minutes.
- The optimum petroleum bitumen contents used in the mixture was 6.25%.

- The BGA varied between 0% and 13.5% (0%, 5%, 7.5%, 9%, 10.5%, 12% and 13.5%) by the weight of petroleum bitumen. The selected bitumen was heated to 185°C for about 1 h prior to blending with the aggregate.
- The combination of limestone aggregate, petroleum bitumen and BGA was mixed at a temperature of 160 ± 5°C for around 5 min.
- The Marshall compactor was used for the compaction stage of the process with 75 blows applied to the top and bottom side of the mixture at 145°C.

2.6. Density of Asphalt Mixtures

Some related volumetric literature of asphalt mixtures consisting of void in mixtures (VIM), void in mineral aggregates (VMA) and void filled bitumen (VFB/VFA) can be obtained through experimental testing in the laboratory included in the empirical testing group with the Marshall test [10]. The Marshall volumetric test was conducted on AC-WC mixture specimens according to SNI 06-2489-1991 [7].

3. Results and Discussion

3.1. Void in Mix (VIM)

Figure 4 shows the Void in Mix (VIM) value versus BGA 50/30 content. VIM value represents the air void content within the compacted asphalt mixture where the air void is one of the prominent factors used to obtain optimum bituminous binder content in asphalt mixture design. Scientific literature states that excessive air void will cause concrete asphalt mixture to crack easily while inadequate amount of air void will cause bleeding and plastic flow to occur easily [10].

The test results show that the AC-WC mixture made with limestone and BGA content of 5% to 10% met the VIM requirements of 3 - 5%. Thus the AC-WC mixture containing BGA 5 - 10% by weight of petroleum bitumen content within the AC-WC mixture as partial substitution for petroleum bitumen provided an adequate amount to cover limestone aggregate and was able to prevent bleeding and plastic flow.

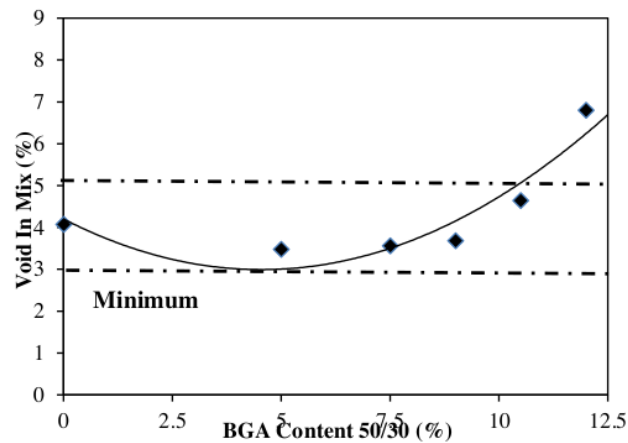


Figure 4. Void in Mix value versus BGA 50/30 content.

3.2. Void in Mineral Aggregate (VMA)

Figure 5 illustrates Void Mineral Aggregate (VMA) value versus BGA 50/30 content. The film thickness on the aggregate particles governs the durability of mixture, where space for film binders on

aggregate particles is provided by VMA. VMA must be available with a minimum amount ¹ in order to provide the required durability [12].

As shown in Figure 5, all VMA values related to the BGA content meet the requirements for the amount of VIM (above 15%). Regarding the VMA value, the use of BGA from 2.5 to 15% is predicted to provide good durability in AC-WC mixtures containing limestone. However, as an important note, based on the VMA test, the maximum use of BGA was 10%.

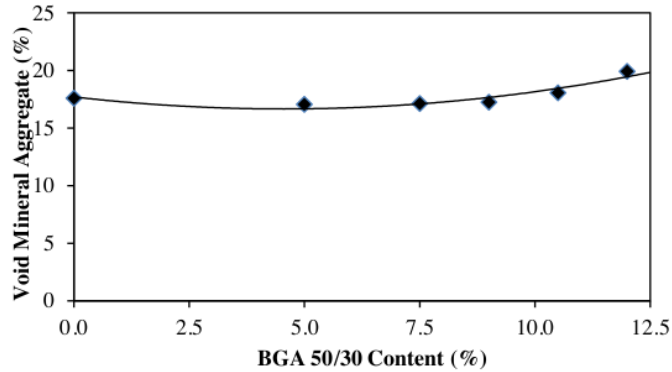


Figure 5. Void Mineral Aggregate value versus BGA 50/30 content.

3.3. *Void Filled Bitumen (VFB)*

The relationship between BGA content and VFB is shown in figure 6. A low VFB value will reduce the ability of asphalt binders to penetrate into voids on aggregate particles that will unstable form adhesive interfaces based on adhesive interlock theory [13, 14], resulting in interfacial failure between asphalt films and aggregate surfaces [15]. Based on Figure 6, the AC-WC mixture made of limestone without BGA and containing BGA 2.5 to 15% of the total weight of the binder meets the minimum VFB requirement of 65%. Binder without BGA and with BGA can penetrate sufficiently into voids of limestone aggregate particles to create a stable interface adhesion between aggregate surface and bitumen film.

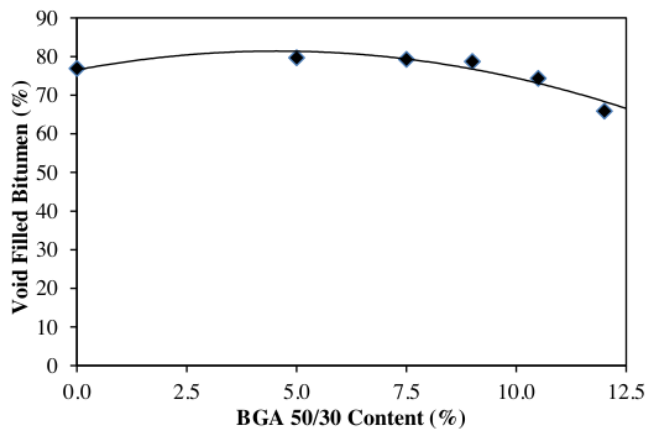


Figure 6. Void Filled Bitumen value versus BGA 50/30 content.

4. Concluding Remarks

Based on analysis of volumetric values related to VMA and VFB, addition of BGA as petroleum bitumen replacement in AC-WC mixture prepared with limestone aggregates create a stable interface adhesion between aggregates. However, the maximum use of BGA was 10% by weight of bituminous binder according to VIM evaluation result.

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