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Volumetric of Eco-Friendly Asphalt Mixture Containing Local Limestone, Sea Sand, Portland Composite Cement and Buton Modified Asphalt

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ABSTRACT

This study used local limestone, sea sand, Portland Composite cement (PCC), and modified Buton asphalt (MBA) to create asphalt mixtures for asphalt concrete wearing course (AC-WC) layers. The combined aggregate was successfully designed within the required standard specification range (General Road Works Specifications by DGH in 2010). At an MBA content of 5.7 and 6.1%, the PCC and MBA showed a positive contribution to the binding of aggregates so that the mixture meet the satisfactory performance of asphalt mixtures in terms of volumetric properties, which include VIM, Voids in Mineral Aggregate (VMA) and VFB.

Keywords: local limestone, sea sand, PCC, MBA, volumetric

1. INTRODUCTION

A good transportation network is one of the most important factors to support the development of the regional economy [1]. Suitable materials are needed to build a road network, but there are many areas such as in West Papua Province which only have non-standard aggregates. To overcome this problem, a lot of proper aggregate material needs to be transported from other regions so that the price of road construction increases [2,3].

A number of areas in the Fak-Fak Regency, West Papua Province, Indonesia is covered by local rocks which chemically contain about 50-70% lime and other minerals of about 35%. These local rocks are categorized as non-standard rocks therefor they are not widely used as construction materials. This research is an attempt to use local rock as crushed aggregate in formulating asphalt mixtures.

In addition, Fakfak region is located on the coast, in order to overcome the deficiency of standard fine aggregates, this study chose sea sand as fine aggregate to create asphalt mixtures.

At present the use of domestic production materials is being promoted to support the national transportation network development. Hydrocarbon layers naturally coalesce with other minerals to form rock asphalt that cover a number of areas on Buton Island, Southeast Sulawesi Province [4-7]. Processed products from natural asphalt contained in Buton regency continue to be developed to be used as a binder or bituminous material in the manufacture of asphalt mixtures.

Buton modified asphalt (BMA) is a product made from bitumen extracted from Buton natural asphalt rock with petroleum bitumen. In this study BMA is used as a binding material to make asphalt mixture [8-10].

Nowadays national cement factories have included by-products such as fly ash as one of the ingredients together with the Portland cement clinker to produce blended cement. One type of blended cement is Portland composite cement (PCC) which is produced based on national standard (SNI). The purposes of the PCC development are to efficiently use fuel in the kiln, reduce mined raw materials and reduce fly ash dumping.

Volumetric properties which include VIM, Voids in Mineral Aggregate (VMA) and VFB are the determining parameters in a compacted asphalt mixture. This study examines VIM, VMA and VFB of asphalt mixtures containing local limestone, sea sand, PCC and BMA.

2. MATERIALS AND METHODS

A. Characteristics Material

Material testing carried out included testing the physical properties of coarse aggregate (local limestone from Fak-Fak regency), stone dust which is derived from the fine fractions of the local limestone, sea sand as fine aggregate, PCC as filler and MBA as binding material.

Table 1 to 3 show the characteristics of fine aggregate in the form stone dust and sea sand and coarse aggregate. Table 4 and 5 show the physical characteristics of Portland cement composite (PCC) and MBA.

Table 1. Physical properties of stone dust (fused local limestone)

No.	Parameter	Result
1	Water absorption (%)	1.89
2	Bulk specific gravity	2.50
	SSD specific gravity	2.55
	Apparent specific gravity	2.63
3	Sand equivalent (%)	87.88

Table 2. Physical properties of fine aggregate (sea sand)

No.	Parameter	Result
1	Water absorption (%)	1.89
2	Bulk specific gravity	2.50
	SSD specific gravity	2.55
	Apparent specific gravity	2.63
3	Sand equivalent (%)	87.88

Table 3. Physical properties of coarse aggregate (local limestone)

No.	Parameter	Result
1	Water absorption (%)	
	Local limestone 5 – 10 mm	1.04
	Local limestone 10 – 20 mm	1.87
2	Specific gravity	
	Local limestone 5 – 10 mm	
	Bulk specific gravity	2.59
	SSD specific gravity	2.51
	Apparent specific gravity	2.55
	Local limestone 10 – 20 mm	
	Bulk specific gravity	2.57
	SSD specific gravity	2.51
	Apparent specific gravity	2.58
3	Flakiness index (%)	
	Local limestone 5 – 10 mm	19.18

	Local limestone 10 – 20 mm	9.56
4	Abrasion (%)	
	Local limestone 5 – 10 mm	28.40
	Local limestone 10 – 20 mm	27.26

Based on the results of testing the characteristics of coarse aggregate, the fine aggregate, it shows that the aggregate used meets Bina Marga specifications for the required road material. However, for coarse aggregate, based on the results of the aggregate viscosity test for asphalt show results that are less than 95% so that it is classified as nonstandard aggregate (substandard). However, given the unfulfilled properties that are not natural properties of local limestone, efforts to improve these properties by engineering materials in the laboratory can be performed.

Based on the results of the filler characteristic testing, the displayed PCC cement shows that the aggregate used meets Bina Marga specifications for the required road material. The results of the inspection of the modified Asbuton characteristics shown in Table 5 show that the asphalt used in this study had fulfilled the specifications required by the 2010 General Specifications Revision 3, section 6 on asphalt pavement.

Table 4. Physical properties of filler (PCC)

Physical properties	**SNI 15-7064-2012** Standard	**Results**
Water content (%)	12 max	11.5
Fineness	280 min	382
Expansion, % (max)	0,80 max	-
Compressive strength		
a. 3 days (kg/cm^2)	125 min	185
b. 7 days (kg/cm^2)	200 min	263
c. 28 days (kg/cm^2)	250 min	410
Setting time (Vicat test)		
a. Initial setting, (minutes)	45 min	132.5
b. Final setting, (minutes)	375 min	198
Fake setting time	50 min	-
7 days hydration temperature, cal/gr		65
Normal consistency (%)		25.15
Specific gravity		3.03

Table 5. Physical properties of modified Buton asphalt

No.	**Properties**	**Testing result**
1	Penetration before weight loss (mm)	78.6
2	Softening point (°C)	52
3	Ductility in 25°C, 5cm/minute (cm)	114
4	Flash point (°C)	280
5	Specific gravity	1.12
6	Weight loss	0.5
7	Penetration after weight loss (mm)	86

B. Mixture Gradation

This study uses a combination of aggregate and filler gradation to make AC-WC (Asphalt Concrete Wearing Course) asphalt concrete mixture. Figure 1 shows the proportion of aggregates fulfilling the requirements based on the 2010 General Road Works Specifications by Bina Marga revision 3 section 6 regarding asphalt mixtures as AC Asphalt Concrete Wearing Course (Asphalt Concrete Wearing Course).

C. Preparing Test Specimens

MBA contents variation for the AC-WC mixture from 5.2% to 7.0%, with an increase interval of 0.5%. Table 6 shows the composition of the AC-WC mixture based on the estimated asphalt levels where the composition of the mixture was made based on the gradation of the aggregate in Hot Bin I (0 - 5 mm, fine aggregate consisting of sea sand and fine particles derived from local lime stone), Hot Bin II (5 - 10 mm), Hot Bin III (10-20 mm), Hot Bin IV (20-30 mm), filler (PCC) and MBA. Asphalt mixture that has been stirred evenly was put into a mould with a diameter of 100 mm. Marshall pounders are used as many as 75 blows each side to condense the asphalt mixture in the mould.

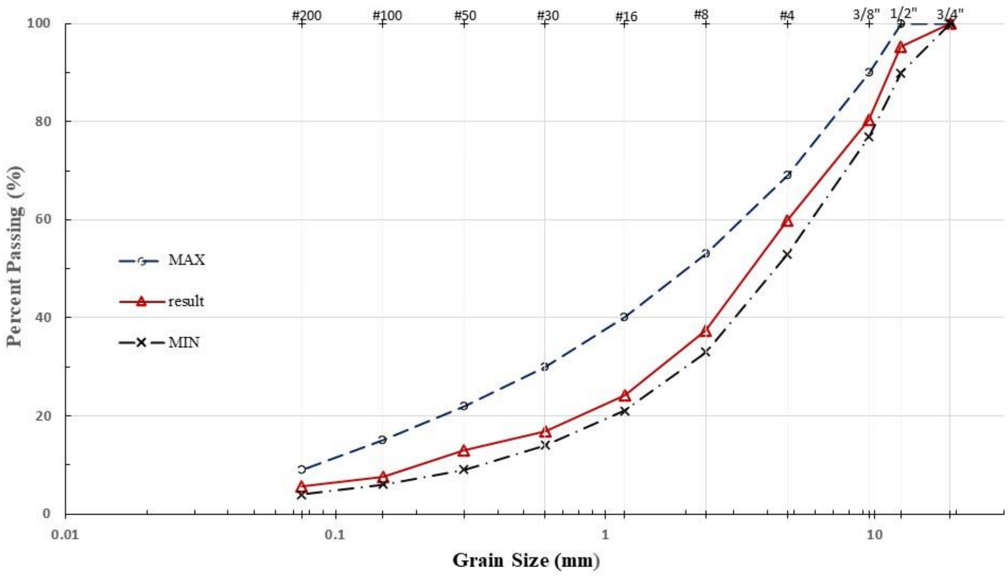

Figure 1. Aggregate gradation

Table 6. Material composition by weight for 1200 grams of the test specimen

<table>
<tr><th>Material</th><th>Material size</th><th colspan="10">Weight (gram)</th></tr>
<tr><td>Hot Bin I</td><td>0 – 5 mm</td><td colspan="2">625.70</td><td colspan="2">622.40</td><td colspan="2">619.70</td><td colspan="2">617.10</td><td colspan="2">613.80</td></tr>
<tr><td>Hot Bin II</td><td>5 – 10 mm</td><td colspan="2">318.50</td><td colspan="2">316.80</td><td colspan="2">315.50</td><td colspan="2">314.20</td><td colspan="2">312.50</td></tr>
<tr><td>Hot Bin III</td><td>10 – 20 mm</td><td colspan="2">170.60</td><td colspan="2">169.70</td><td colspan="2">169.00</td><td colspan="2">168.30</td><td colspan="2">167.40</td></tr>
<tr><td>Filler</td><td>Stone dust</td><td colspan="2">22.80</td><td colspan="2">22.60</td><td colspan="2">22.50</td><td colspan="2">22.40</td><td colspan="2">22.30</td></tr>
<tr><td>Asphalt (%)</td><td>MBA</td><td>5.2</td><td>62.4</td><td>5.7</td><td>68.4</td><td>6.1</td><td>73.2</td><td>6.5</td><td>78.0</td><td>7.0</td><td>84.0</td></tr>
<tr><td colspan="2">Total</td><td colspan="2">1200</td><td colspan="2">1200</td><td colspan="2">1200</td><td colspan="2">1200</td><td colspan="2">1200</td></tr>
</table>

3. RESULT AND DISCUSSION

A. Relationship of Modified Buton Asphalt with VIM (Void in Mix)

Based on volumetric test results, it can be seen in Fig. 2 the relationship between modified Buton asphalt content and VIM. Figure 2 shows that at an MBA content of 5.2%, 5.7%, 6.1%, 6.5% and 7.0%, the VIM (Void in Mix) value was 5.59%, respectively 4.64%, 3.59%, 2.84% and 1.99%. It can be seen that with increasing contents of the MBA, even though collisions are received equal (75 blows each face) the MBA and filler (PCC) that form the mastic bitumen fill more cavities so that the VIM decreases. The VIM value required by the 2010 General Specifications, revision 3 is from 3% to 5%. VIM values that meet the 2010 Indonesia requirement, is the MBA content of 5.7% and 6.1% while the modified Asbuton content of 5.2%, 6.5% and 7.0% does not meet the 2010 Indonesia requirement.

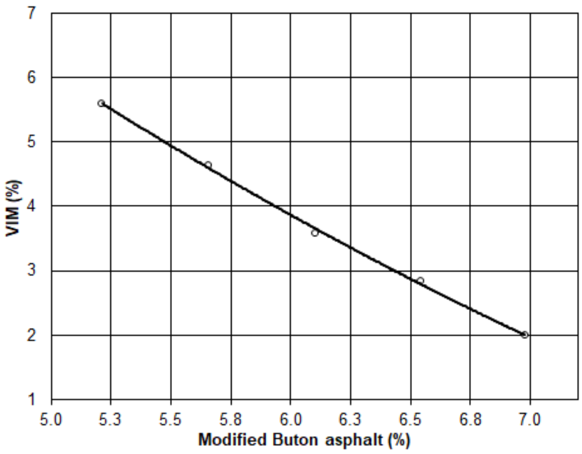

Figure 2. Relationship of Buton modified asphalt with VIM

B. Relationship of Modified Buton Asphalt with VMA (Void in Mineral Aggregate)

Indonesia requirement stipulate that the VMA value in the asphalt mixture is at least 15%. VMA indicates the presence of cavities that occur between binding aggregates. Figure 3 shows the relationship between the modified Asbuton content level and VMA value, where the minimum VMA value required by the specification is 14%. It is clearly seen that the MBA content from 5.2% to 7% results in VMA values that met specific minimum requirements of 14% where it shows that air void spaces can be formed properly between local limestone aggregates and sea sand particles, including spaces filled with BMA and PCC as a filler in the compacted asphalt mixture. The minimum VMA value can be adapted by using aggregates from local limestone, sea sand, BMA and PCC so that the thickness of the durable asphalt film can be achieved.

Therefore, it can be stated that all the modified Asbuton levels used in this study meet the specifications stipulated by Indonesia requirement.

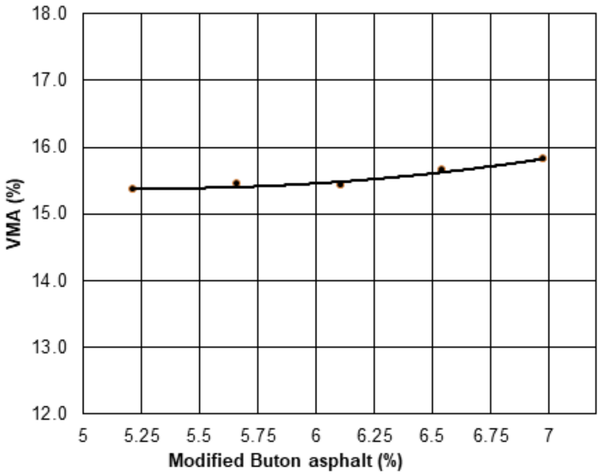

Figure 3. Relationship between Buton modified asphalt with VMA

C. Relationship of Modified Buton Asphalt with VFB (Void Filled Bitumen)

Figure 4 shows the relationship between modified Asbuton content with the VFB value (asphalt filled bitumen). Based on Indonesia requirement, the VFB requirement in asphalt mixes is at least 65%. Asphalt mixed volumetric test results using modified Asbuton as a binder in the form of parameters VFB (asphalt filled cavity) showed values of 63.66%, 70.00%, 76.75%, 81.87% and 87.42% for each Modified Asbuton content of 5.2%, 5.7%, 6.1%, 6.5% and 7.0%. Therefore, all modified Asbuton levels used meet the 2010, Revised 3 general Specifications except for the modified Asbuton content of 5.2%.

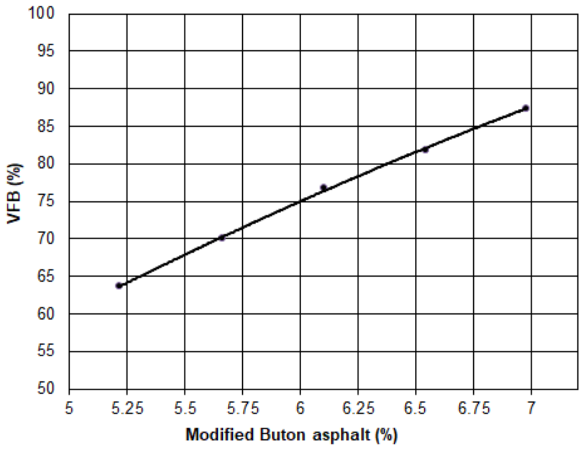

Figure 4. Relationship between Buton modified asphalt with VFB

4. CONCLUSIONS

No detrimental effects were seen in the AC-WC mixture containing local limestone, sea sand, MBA and PCC. Sufficient combination of local limestone, sea sand, and PCC produced aggregate gradation density to a point above the minimum VMA value obtained leading to sufficient asphalt films and high durability. At MBA content of 5.7 and 6.1%, PCC and MBA contribute positively to aggregate binding so that satisfactory performance of asphalt mixtures in terms of volumetric properties including VIM, Voids in Mineral Aggregate (VMA) and VFB can be achieved.

REFERENCES

[1] Furqon A., Properties of bituminous mixes using Indonesian natural rock asphalt, Proceedings of 13th conference of the road engineering association of Asia and Australia (REAAA), 2005, 9–15.

[2] Tumpu M., & Irianto. 2022. Marshall Characteristics of Asphalt Concrete Binder Course (AC-BC) Mixture Containing Modificated Asbuton (Retona Blend 55) Type. AIP Conference Proceedings 2391, 070012 (2022); https://doi.org/10.1063/5.0073735

[3] One, L., Tjaronge, M. W., Irmawaty, R., & Hustim, M. (2020). Effect of buton granular asphalt gradation and cement as filler on performance of cold mix asphalt using limestone aggregate. *Journal of Engineering Science and Technology*, *15*(1), 493–507.

[4] Tumpu, M., Tjaronge, M. W., Djamaluddin, A. R., Amiruddin, A. A., & One, L. (2020). Effect of limestone and buton granular asphalt (BGA) on density of asphalt concrete wearing course (AC-WC) mixture. In *IOP Conference Series: Earth and Environmental Science* (Vol. 419).

[5] Suaryana, N. (2016). Performance evaluation of stone matrix asphalt using indonesian natural rock asphalt as stabilizer. *International Journal of Pavement Research and Technology*, 9(5), 387-392.

[6] Tumpu M., Tjaronge M. W., & Djamaluddin A. R. 2020. Prediction of long-term volumetric parameters of asphalt concrete binder course mixture using artificial ageing test. IOP Conf. Series: Earth and Environmental Science 419 (2020) 012058.

[7] Tjaronge, M. W., & Irmawaty, R. (2013). Influence of water immersion on physical properties of porous asphalt containing liquid asbuton as bituminous asphalt binder. In *Sustainable Construction Materials and Technologies* (Vol. 2013-August). International Committee of the SCMT conferences.

[8] Ali, N., Samang, L., Tjaronge, M. W., & Djamaluddin, A. R. (2011). Influence of sea water on the mechanical properties of porous asphalt containing liquid asbuton. In *Asian and Pacific Coasts, 2011 - Proceedings of the 6th International Conference* (pp. 2115–2122).

[9] Mabui, D. S., Tjaronge, M. W., Adisasmita, S. A., & Pasra, M. (2020). Resistance to

cohesion loss in cantabro test on specimens of porous asphalt containing modificated asbuton. In *IOP Conference Series: Earth and Environmental Science* (Vol. 419).

[10] Mabui, D. S., Tjaronge, M. W., Adisasmita, S. A., and Pasra, M. (2020). Performance of porous asphalt containing modificated buton asphalt and plastic waste. *International Journal of GEOMATE*, *18*(65), 118–123.