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THE EFFECT OF LIMESTONE AND REHEATING TEMPERATURE ON COLD PAVING HOT MIX ASPHALT

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ABSTRACT: The objective of the study is to evaluate the effect of the limestone proportion and reheating temperature to the Marshall characteristics of the cold paving hot mix asphalt (CPHMA) using a natural asphalt from Buton, Indonesia. The mix is prepared and mixed in hot temperature like hot mix asphalt, but laid and compacted at normal temperature. The normal application of this mix is for patchwork, due to its lower performance. In order to upgrade its performance, the research attempts to add limestone material and reheat the mix before laying and compacting. As many as 60 Marshall specimens were prepared with varied asphalt content, percentage of limestone, and reheating temperatures. The specimen were prepared in two stages: mixing process and compaction process. The mixing process was performed like regular hot mix asphalt. After the mixing, the specimens were placed in a batch for 24 hours. The mixes were then placed in the Marshall tube to prepare the Marshall specimens, compacted, and tested. The results showed that heating the mix to about 42ºC significantly improves the mix performance, particularly on its Marshall stability. The existence of limestone in the mix also improved its performance. Based on the results it can be concluded that given some treatments, the CPHMA can be used not only as patching material but also as structural layer material, particularly for low to medium traffic rural road.

Keywords: Buton Natural Asphalt, Cold Mix Asphalt, Cold Paving Hot Mix Asphalt, Marshall Characteristics

1. INTRODUCTION

Asphalt is the main ingredient used by Civil Engineer to build roads. The majority of roads built in recent years are flexible-type of pavement that requires asphalt as the main component particularly to prepare the surface layer. In Indonesia, more than 90% of roads are of flexible pavement type. Every year the Government of Indonesia requires about 1.2 million ton of asphalt either for new road construction or for the maintenance of the existing ones. About half of it (600,000 ton) is imported from overseas, while the rest is provided from domestic production, with natural asphalt (known in Indonesia as *Asbuton*) about 25,000 ton [1]. While in other countries the use of recycled has been common [2], this kind of materials have not been popular in Indonesia.

The very limited use of Asbuton for road construction in Indonesia has concerned some decision makers since the available deposits reach more than 660 million tons [1], which can suffice the asphalt need for at least 300 year to come. Most of the asphalt deposits lie in Buton Island, Indonesia as shown in Figure 1. Therefore, in the future the Government has set a plan to steadily increase the portion of Asbuton as the asphalt material for road construction in Indonesia. In 2016, the Government has set to double the use of Asbuton, totaling 50,000 ton. Table 1 presents the chemical content of Asbuton.

Recently, two forms of Asbuton products have been launched to the market: Hot Mix Lawele Granular Asphalt (LGA) and Ready Mix Asphalt-Lawele (RMA-Lawele), as shown in Figure 2. LGA is prepared like regular hot mix asphalt, while RMA-Lawele is a product mixed in high temperature and laid in normal/cold temperature, known as Cold Paving Hot Mix Asphalt (CPHMA).

Table 1 Chemical content of Asbuton

No	Type of Chemical Substance	Content
1	Nitrogen (N)	30%
2	Acidafins (A1), (A2)	6.6% , 8.43%
3	Malthenes	2.06%
4	Nitrogen/Parafins, N/P	3.28%
5	Asphalthenes	46.92%

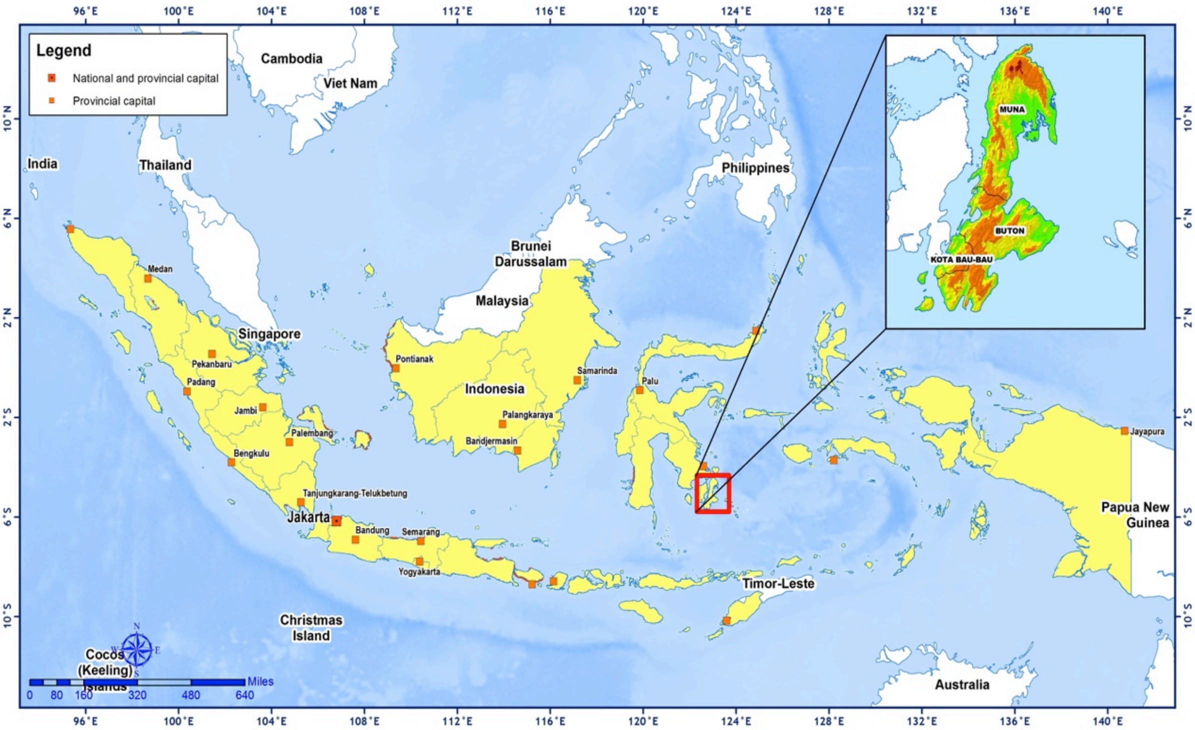

Fig. 1 Buton Island, Indonesia

Fig. 2 Ready Mix Lawele Granular Asphalt (Scale 1:3)

Previous research shows that Asbuton can substitute for about 70 – 80% in RMA [3]. Table 2 shows the specs requirements for RMA Lawele. As can be seen from the Table, stability requirement for RMA-Lawele is about 600 kg. This is due to the fact that this product is intended for road patching uses, not as structural layer.

Table 2 Indonesian Specifications for RMA

No	Description	RMA
1	VMA, %	≥ 15
2	VFB, %	≥ 65
3	VIM, %	3.5 – 6.5
4	Stability, kg	≥ 600
5	Flow, mm	≥ 3
6	Marshall Quotient, kg/mm	≥ 250
7	Retained Stability, %	≥ 75

With more than 13,000 islands spanning the Indonesian archipelago, the need for proper technology to improve the transportation and accessibility become essential. In some of the islands, it is just not feasible for a construction company to set up an asphalt mixing plant (AMP) due to the location and the minimum production that should be produced in order to be profitable. Therefore, in such areas, RMA-Lawele technology seems to be promising, since it can be processed in other areas and shipped to the construction area, laid and compacted in normal temperature.

Previous study, however, showed that cold asphalt mixes, as in the case of RMA, have been considered inferior to hot mix asphalt (HMA) over the last decades due to the high air-void content of the compacted mixtures, weak early life strength and long curing times required to achieve an optimal performance [4]. Although these shortcomings, the use of cold mix asphalt has steadily gained momentum, as shown in Turkey and France [5]. Unlike common cold mix asphalt in which a solvent is added during mixing and compaction process, the RMA does not need any solvent. It is just laid and compacted.

One of the challenges of the RMA is its lower performance compared to hot mix asphalt, as shown in Table 1. It is no wonder that current use of RMA is mostly for patching purposes, similar to the application of cold mix asphalt. In order to be considered for structural layer, its characteristics should be improved.

Studies to improve the performance of cold mix asphalt have been found in literature [6], although the ability to match the performance of its hot mixed counterpart (i.e., Hot mix Asphalt) has been elusive [7].

To improve the performance of RMA, particularly its stability, the mix may need to be reheated for some degree, assuming that heating the RMA will increase the bonding capability of the Asbuton. Another potential to improve the performance is to add limestone to the mix. A study by Du [8] shows that hydration products can increase the stiffness and cohesion of the asphalt mastic of the recycled mixture. Wang et al [9] showed that the total hydration heat decreased with an increase in bitumen to cement ratio in the Cold Asphalt Mix.

In some areas in Indonesia, there are abundant availability of limestone aggregates. This material is usually avoided for use in the hot mix asphalt due its low abrasion problem. Investigating the possibility of use of limestone in the RMA-Lawele mix should be interesting. The objective of the study, therefore, is as follows:

1. To evaluate the effect of temperature increase to the Marshall characteristics of the RMA-Lawele
2. To evaluate the effect of adding limestone material in the aggregate to the Marshall characteristics of the RMA-Lawele.

2. MATERIALS AND METHODS

2.1. Materials

Materials used in this research came from several sources. Asbuton was provided by a company which runs the exploration of Asbuton in Buton Island. The aggregate came from two sources: one from quarry usually used as material source in Java and the other from Madura Island that produces limestone materials.

2.2. Material testing

Material testing was conducted to evaluate the basic characteristics of the material and compare them to the Indonesian specification. The tests included gradation, abrasion, impact test, specific gravity, and flakiness.

2.3. Design of Experiment

To achieve the objectives of the study, 60 Marshall specimens were prepared. Table 3 presents the design of experiment of the research. Variation was made in both compaction temperature and limestone content. The selection of temperature range (25^0 - 67.5^0C) was based on assumption that heating the RMA mix in the field would use simple equipment, as in the case in remote area.

Table 3 Design of Experiment

Temperature Variation (^{0}C)	Aggregate Mix Variation (Limestone/Standard) (%)				
	0/100	25/75	50/50	75/25	100/0
25	3	3	3	3	3
37,5	3	3	3	3	3
50	3	3	3	3	3
67,5	3	3	3	3	3
Total	60				

2.4. Specimens Preparation & Testing

3 specimens for 20 different mixes (groups) were prepared. Aggregates were prepared based on the proportion shown in Table 3. Aggregate gradation for each group of specimen was set using the Indonesian Directorate General of Highways (IDGH) Specification, shown in Table 4.

Procedure for specimen's preparation and testing is presented in Figure 3. There were two stages in preparing the specimens. Stage 1 was to prepare the RMA materials produced from LGA mix, as shown in Figure 3.

Table 4 Aggregate Gradation for each mix

				Aggregate Weight	1000 gr
				Modifier	30 gr
Sieve Size	Upper Bound %	Lower Bound %	Gradation Design %	Weight (gr)	Remarks
3/4" (19 mm)	100	100	100	0	Aggregate
1/2" (12,5 mm)	100	90	93.0	70	Aggregate
3/8" (9,5 mm)	-	-	-	0	-
No.4 (4,76 mm)	70	45	51.8	411.5	Aggregate
No.8 (2,36 mm)	55	25	25.1	267.8	Aggregate
No.50 (0,3 mm)	20	5	17.2	79.0	LGA
No.200 (0,075 mm)	9	2	6.8	104.2	LGA
Pan	0	0	0	67.5	LGA
Total				1000	

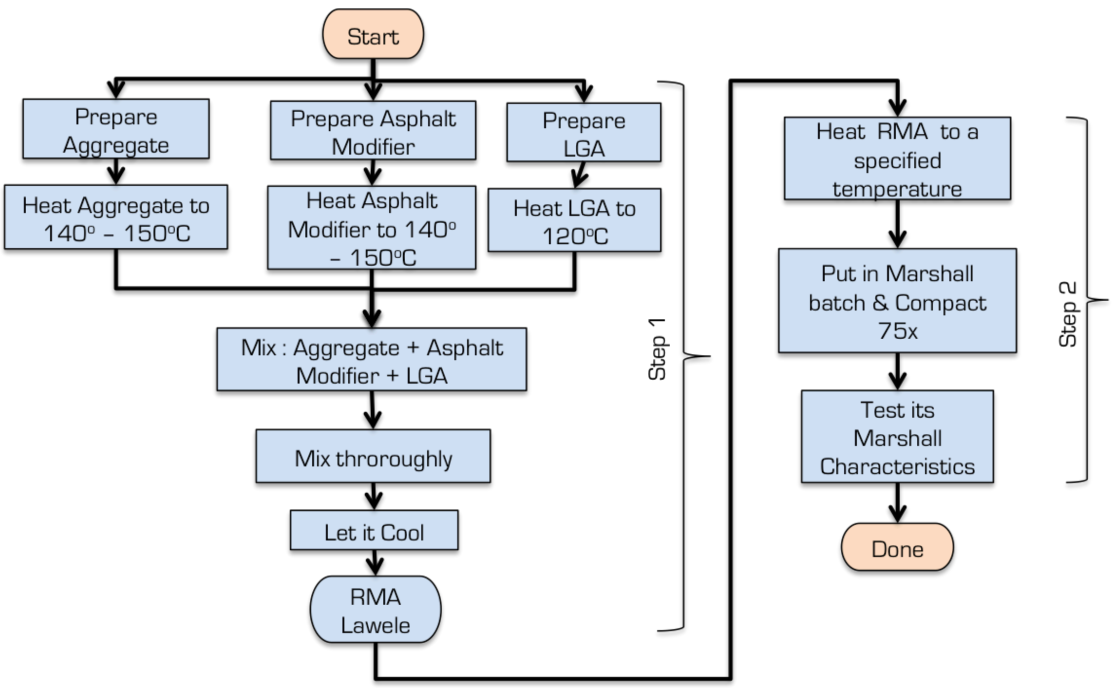

Fig.3. Procedure for specimen preparation & testing

The Aggregate was heated to 140ºC, while the LGA was heated to 120ºC. After reaching the specified temperature, aggregate and LGA were then mixed together with additive and cooled off and stored. This is to simulate the real condition of RMA production in the Asphalt Mixing Plant (AMP). The next stage is to stimulate the RMA placement and compaction in the field. As stated in the objective of the study, the research is to evaluate how reheating the RMA before placement and compaction can improve its Marshall Characteristics. Therefore, the RMA produced from the previous stage was reheated to a temperature as specified in Table 3, and subsequently put in the Marshall tube and compacted 75 times. The specimens were then tested using Marshall equipment and procedure [10].

3. RESULTS AND DISCUSSIONS

Table 5 presents the test results of the material characteristics. As can be seen from the Tables, limestone and local aggregates meet the specification. Table 6 presents the test results of the RMA-Lawele materials.

Table 5 Test results of the aggregate characteristics

No.	Test Methods	Unit	Test Results		IDGH Specs	
			Limestone	Local	Min.	Max.
1	Absorption	%	2,57	0,54	-	3
2	Bulk Specific Gravity	-	2,52	2,71	2,5	-
3	SSD Specific Gravity	-	2,56	2,72	-	-
4	Apparent Specific Gravity	-	2,69	2,75	-	-
5	Abrasion	%	28,78	12,96	-	40
6	Elongation Index	%	11,50	12,96	-	25
7	Flakiness	%	8,66	2,74	-	25
8	Impact Test	%	16,29	15,06	-	30

Table 6 Test results of the RMA materials

No.	Test Method	Unit	Test Results	IDGH Specs
1	Penetration (25^{0}C, 100gr, 5 sec)	0,1 mm	55	50 - 70
2	Flash Point (Cleveland Open Cup)	^{0}C	-	> 200
3	Ductility (25^{0}C, 5 cm/min)	cm	>140	>100
4	Specific Gravity (25^{0}C)	-	1,019	Min 1.0
5	Bitumen Content	%	22-25	25 - 35

Figures 5 through 9 present the Marshall characteristics of the RMA specimens. As can be seen from Figure 4, reheating compaction temperature increases stability, with specimens having higher percentage of limestone aggregate seems to provide better performance for almost all temperature ranges. Figure 4 also shows that increasing compaction temperature to about 50ºC has resulted an increase of stability to about 750 kg. This is a remarkable increase of the stability when compared to the RMA, which requires minimum stability of 600 kg. A mixture with 750 kg stability can withstand traffic load at least for local or residential roads. It also means that RMA may have some potential to be used not only for patching, but also as structural layer for road surfacing.

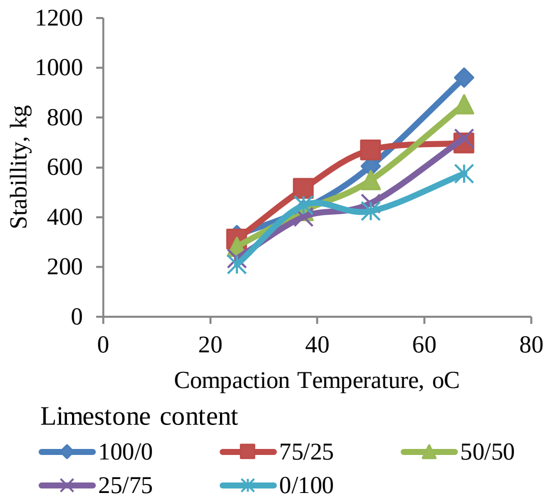

Fig. 4 Compaction temperature versus stability

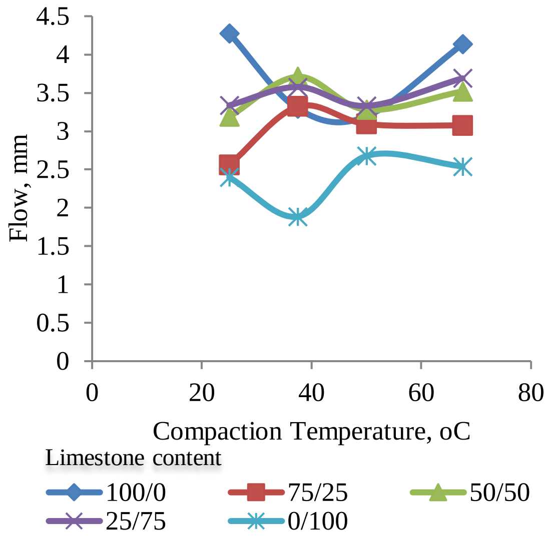

Fig.5 Compaction temperature versus flow

Figure 5 shows the flow of the specimens at different temperature and coarse aggregate proportion. The spec requires that the flow be at least 3 mm. As can be seen from Figure 5, all specimens, except those with 100% local materials meet the specification. In other word, higher limestone aggregate improves the mix performance. The Figure also shows that increasing compaction temperature does not significantly affect the flow.

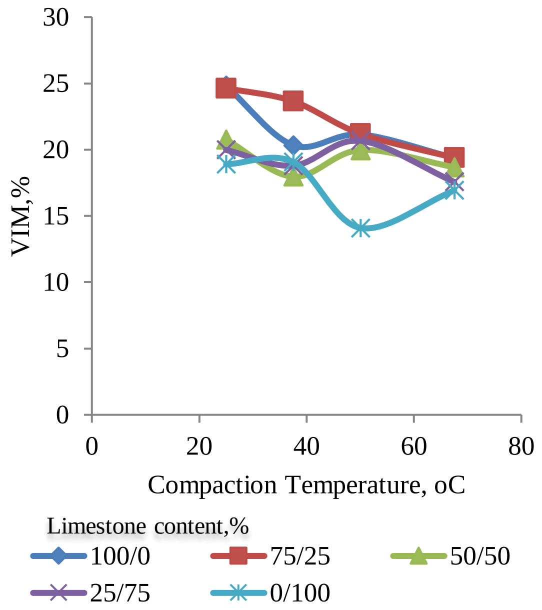

Fig.6 Compaction temperature versus VIM

Figure 6 shows the VIM of the specimens as compaction temperature increased. The specs require that VIM be between 3.5% – 5.5%. The result shows that none of the mix meets the specs. However, the Figure also shows that increasing temperature reduces the VIM.

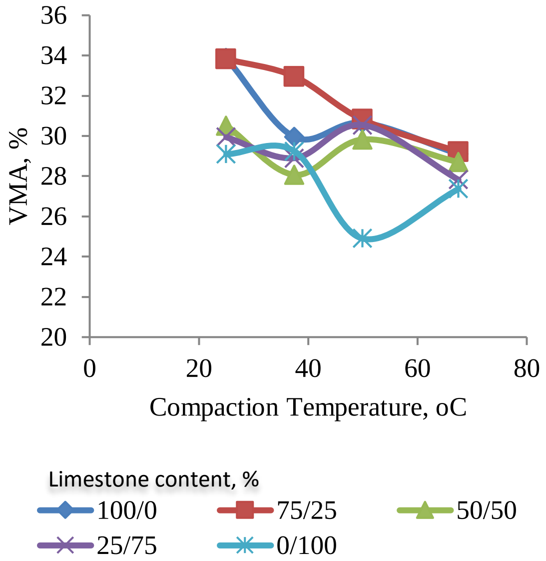

Fig.7 Compaction temperature versus VMA

The same trend also happens to the VMA. As shown in Figure 7, increasing compaction temperature reduced the VMA. The spec requires that VMA be at least 15%. In this case, all specimens meet the specs at all compaction temperature ranges. The Figure also shows that it seems that no much differences on the effect of aggregate proportion to the VMA.

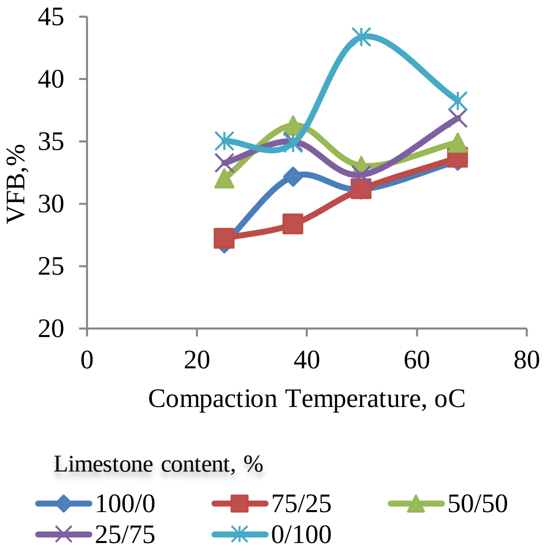

Fig.8 Compaction temperature versus VFB

The VFB, as shown in Figure 8, shows that all mixes, except of the 100% local material have similar behavior. The spec requires that VFB be at least 65%. Therefore, none of the specimens meets the specs.

The test results discussed in the previous paragraph give some hints about the RMA mixes. The mixes met the specs on VMA, Flow, and stability parameters, but not in VIM and VFB. That indicates that the selection of gradation in this study has been proper, as indicated in value of VMA that meets the specs since VMA is "actually a property of the aggregates in the mixture [11]. The test results also indicate that the RMA mixes need some additional asphalt content, as shown from VFB. Increasing asphalt content will increase VFB [11]. The VFB also indicates that the mix is susceptible to rutting and deformation.

3.1 **Optimum Compaction temperature and aggregate proportion.**

To determine the optimum compaction temperature and optimum aggregate proportion, the Newton generalized iteration method was applied. First, a quadratic regression model from each test result, which has 4 data each, was developed. Then, each model was derived twice, as part of the Newton iteration procedure, to obtain the optimum value as follows:

$$x^{(n+1)} = x^n - w\frac{f_1(x^n, y^n)}{\partial f_1(x^n, y^n)/\partial x}$$

$$y^{(n+1)} = y^n - w\frac{f_2(x^n, y^n)}{\partial f_2(x^n, y^n)/\partial y}$$

where:

x = compaction temperature
y = aggregate proportion
w = iteration coefficient
f_1 = first derivation of the regression to x
f_2 = first derivation of the regression to y

Detailed procedure can be found elsewhere [12]. The final result showed that the optimum temperature was 42^0C and optimum percentage aggregate proportion was 85% limestone and 15% local material.

4. CONCLUSION

Based on the above discussions, the following conclusions can be drawn:

1. Reheating RMA to about 42^oC before placement and compaction significantly improves the mix performance.
2. Limestone contributes significantly in improving the Marshall characteristics of the RMA-Lawele.
3. Given some reheating before placement can make RMA-Lawele suitable not only for use for patching but also for use as structural particularly for road with low to medium traffic.
4. One of the drawbacks of the RMA is that is has larger VFA. Adding some asphalt content, therefore, may improve the performance.
5. RMA has the potential to be used as surface material in flexible pavement in remote area where Asphalt Mix Plant is hard to build due to economic consideration.

5. ACKNOWLEDGEMENTS

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