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MECHANICAL CHARACTERISTICS OF HOTMIX COLD LAID CONTAINING BUTON GRANULAR ASPHAT (BGA) AND FLUX OIL AS WEARING COURSE

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ABSTRACT

Buton granular asphalt (BGA) is produced from natural rock asphalt that deposited in South Buton Island, Southeast Sulawesi in Indonesia. The national and regional road infrastructure development sustainability can be empowering by utilization of BGA as pavement material. Ordinary asphalt mixture (hotmix asphalt and hot rolled asphalt) need to be heated to construct. Technical obstacles exist, as asphalt mixing plant is required for the hotmix production and hot rolled asphalt (HRA) construction at the distance and remote areas. The employment of hotmix cold laid mixture containing Buton granular asphalt is one solution to substitute hot rolled asphalt application in the remote and distance areas. The experimental results show that the bitumen within BGA and flux oil governs the Marshall Parameters and compaction ability of mixture. At 7.8% bitumen content within BGA (30, 62% by weight of BGA content in the mixture equivalent), no significant differences on VIM, VMA stability, flow, VFB and indirect tensile strength were observed when the storing and compaction time were extended from 3 to 7 days.

Keywords: hotmix cold laid buton granular asphalt (BGA), Marshall parameters, indirect tensile strength.

1. INTRODUCTION

There is a large resource of natural rock asphalt (sedimentary rock containing of high hydrocarbon substances) in South Buton Island, Southeast Sulawesi in Indonesia. The deposit of Buton rock asphalt resource are approximately 60.991.554.38 tons (24.352.883.07 barrel oil equivalent) (Suryana.A. 2003). By optimizing the utilization of Buton asphalt product can reduce the petroleum bitumen consumption, thus can sustain the national and regional road infrastructure development. Buton granular asphalt (BGA) is produced by crushing the rock asphalt and has size between 1.18mm to 9.5mm. There were many researches and developments have been carried out to optimize the utilization of Buton asphalt and its product variation in the wearing course of pavement (Firdaus *et al*., 2014), (Furqon *et al*., 2009), (Gaus *et al*., 2014), (Nur Ali *et al*., 2011), and (Tjaronge *et al*., 2013).

Asphalt mixing plant (AMP) is required to produce hot mix asphalt (HMA), but there are many distant and remote areas without AMP. The required of hot temperature and AMP introduce an obstacle in rolling and compaction of asphalt mixture that has prevented its utilization in paving construction at the remote area. HRA (hot rolled asphalt) is rolled and compacted at temperatures between 120°C-160°C. The high temperature maintains the bitumen viscosity and ensures the workability of asphalt mixture. The decreasing temperature of mixture creates the bitumen within the asphalt mixture harder, reduce the workability of asphalt mixture and resulting in asphalt mixture more poorly compacted. The inadequate compaction of asphalt mixture reduces the quality of pavement construction work.

This paper is part of an ongoing study to investigate the suitability of bitumen within BGA to produce hotmix and compact it in cold temperature between 27ºC to 50ºC. Application of hot mix cold laid containing BGA as surface in the pavement structure presents available alternative to pavement constructed using HRA. Mixture containing BGA, filler and aggregates was modified by flux oil in order to maintain its workability.

Marshall Parameters were analyzed in order to determine the BGA content in the mixture. When a layer of wearing course is loaded tensile stresses and strains are induced at the immediate bottom zone. Indirect tensile strength (ITS) tests were conducted to get the tensile strength of the storing and compaction of hotmix cold laid containing BGA.

2. MATERIALS AND EXPERIMENTAL METHODS

2.1. Some properties of buton granular asphalt

BGA is from Lawele area and produced by the national asphalt Buton plant, it is available in the market. Table-1 shows some properties of BGA. Contain of bitumen is 25.47%, which means it contains of 75% minerals. BGA has grains smaller than 9.5mm and with a water content of 0.81%.

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Table-1. Some properties of buton granular asphalt.

Properties	Value
Bitumen content; %	25,47
Passing sieves 3/8″ (9.5mm); %	100
Water content , %	0,81
Asphalt mineral level,%	74,53
Penetration of bitumen, (dmm)	36
Melting point of bitumen, ^{O}C	59
Flash point before extract, ^{O}C	198

2.2 Physical properties of aggregates

Crushed river stone and river sand used as coarse aggregate and respectively. In this study, aggregates testing were carried out prior the mix design and analysis. Standard laboratory tests were carried out to determine the physical properties of aggregates. Table-2 and Table-3 show some physical properties of coarse aggregate and fine aggregate, respectively.

Table-2. Some mechanical properties of coarse aggregates.

Properties	Value	Range
Soundness of aggregate by use of sodium sulfate or magnesium sulfate (%)	2,62 %	Max. 12 %
Abrasion (%)	24,09 %	Max. 40 %
Adhesion (%)	> 95%	Min. 95 %
Angularity (%)	97/95	95/90
Flat and elongated particles (%)	6,00 %	Max. 10 %
Passing Sieve No.200 (%)	0,37 %	Max. 1 %

Table-3. Some mechanical properties of fine aggregate.

Testing	Result
Fine aggregates (%)	85,74 %
Angularity	52

2.3 Combined aggregate gradation in hot mix design

Table-4 shows the combined aggregate gradation that used in this study was gradation of Hot mix Cold Laid Asbuton with according to Section 6.3 of Special specification Interim Asbuton Hot mix Cold Laid Asbuton SKH-1.6.3.3 Directorate General of Highways Ministry of Public Works in 2013. When BGA is added into the mixture, the mineral within it become filler. This mineral should be taken into account when analysis the mixture composition.

Table-4. Result testing of combined gradation aggregates (crushed stone, sand and filler).

Sieve size	Result testing	Specification
1” (25 mm); % passing	-	-
3/4 ” (19 mm); % passing	100	100
1/2” (12,5 mm); % passing	93	90 – 100
3/8 ” (9,5 mm); % passing	-	-
No.4 (4,76 mm); % passing	55	45 – 70
No.8 (2,36 mm); % passing	32	25 – 55
No.50 (0,300 mm); % passing	14	5 – 20
No.200 (0,075 mm); % passing	5	2 – 9

2.4 Mixture of asphalt concrete wearing course made of BGA and Flux Oil

The stages of mix the aggregates, filler (dust stone), flux oil and BGA are as follow:

a) Before adding aggregates to the mixture, it was heated to 170^{o}C for a period of approximately 30 minutes. The weight of aggregate for each sample was 1200 gr.
b) The flux oil used was 3.5% by weight of aggregates content; it was heated to 90^{o}C for about 1 minute prior to mixing with aggregate and filler (dust stone).

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c) The mixing of aggregate, filler and flux oil was blended at a temperature 130±5ºC for around 1 min minutes prior to blending with BGA.
d) BGA was added into the mixture and blended with other material for about 2 minutes.

The percentage of the added BGA was varied in the mixture in order to investigate the effect of the bitumen within BGA on the properties of mixture, as show in Table-5. Bitumen within BGA it calculated as bitumen content of the mixture. Table-5 shows the percentage of added BGA and bitumen within it. Table-6 shows the composition of aggregates, filler and mineral of BGA. The experimental work followed the test matrix show in Table-5 and Table-6.

Table-5. Bitumen within BGA.

Bitumen within BGA (%)	**6**	**7**	**8**	**9**	**10**
(%) BGA by weight by mixture	23, 5	27, 5	31, 4	35, 3	39, 3

Table-6. Composition of aggregates, filler and mineral of BGA.

Bitumen within BGA (% by weight)	**crush stone Ø 1-2cm** (%)	**crush stone Ø 0, 5- 1cm** (%)	**Filler** (%)	**Mineral of BGA** (%)
6	30	35	17.45	17.55
7	30	35	14.52	20.48
8	30	35	11.59	23.41
9	30	35	8.66	26.34
10	30	35	5.74	29.26

2.5 Marshall parameter analysis and indirect tensile strength

Marshall Parameters are voids in mixture (VIM), voids mixture asphalt (VMA), stability, flow, and voids filled bitumen (VFB). Testing procedure consist of two parts. The first part focused to determine VIM, VMA, and VFB of the specimen whilst measured the stability and flow of specimen. Samples were prepared in triplicate for each asphalt binder formulation. The Marshall compactor was used for the compaction stage of the process with 75 blows applied to the top and bottom side of specimens at temperature of 50ºC. Stability was tested in dry condition without immersed the specimens in the water.

The second part was conducted after obtained the optimum BGA content. The influence of curing time on stability and tensile strength were evaluated by utilized the specimen with optimum BGA content. After storing the mixture up to 3 and 7 days, it was compacted into the mould by using the Marshall compactor with 75 blows applied to the top and bottom side of mixture at room temperature of 27ºC. The specimen with diameter of 100mm and height of approximately 60 mm were used to investigate the stability of mixture. Tensile strength value were determined in cylindrical test specimen (Ø100 x 60±5mm) molded and tested according to the procedure listed in ASTM D6931 - 12. All specimens were tested in dry condition.

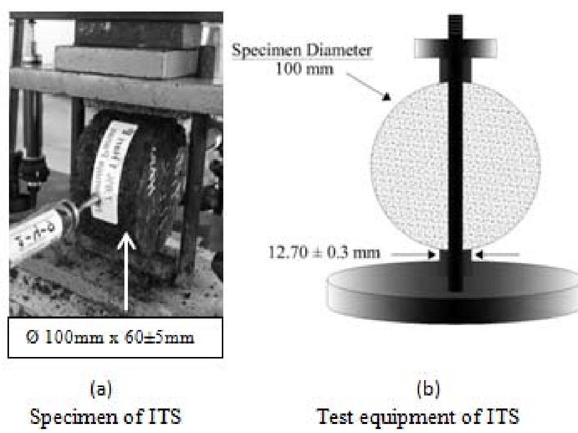

Figure-1. Equipment of indirect tensile strength (ITS) test (ASTM D6931- 12).

RESULT AND DISCUSSIONS

3.1 Determination of optimum BGA content for mixture by Marshall parameters analysis

The influence of BGA content on VIM, VMA, stability, flow and VFB are shown in Figure-2 to Figure-7. As mention in Table-5 and Table-6, the increase in BGA content led to increase the bitumen within the mixture.

Figure-2 shows increasing the BGA content in the mixture caused the VIM value to decrease, but all VIM value can provide a sufficient asphalt binder to coat the aggregate particle. Figure-3 displays all VMA values increased by increasing the BGA content and led to an increase in the film thickness on aggregate particle.

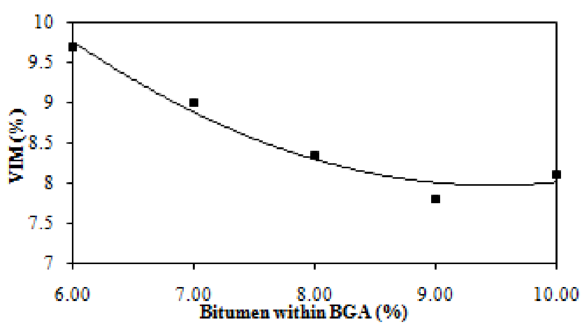

Figure-2. Relationship between bitumen within BGA and VIM.

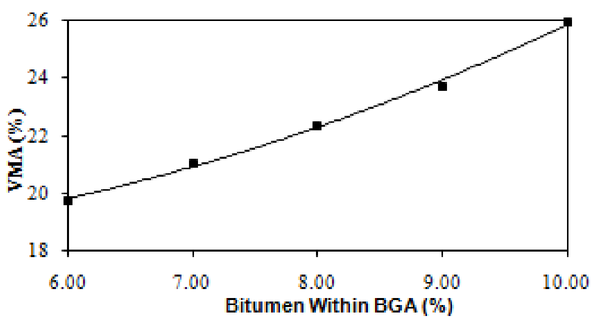

Figure-3. Relationship between bitumen within BGA and VMA.

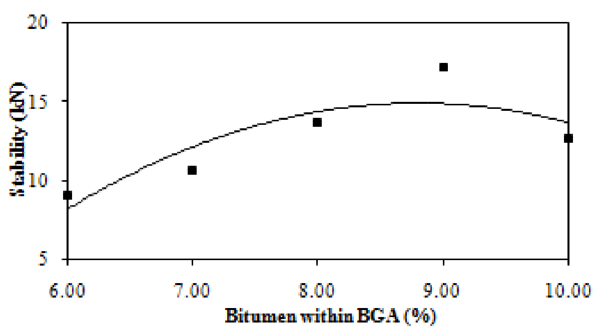

Figure-4. Relationship between bitumen within BGA and stability.

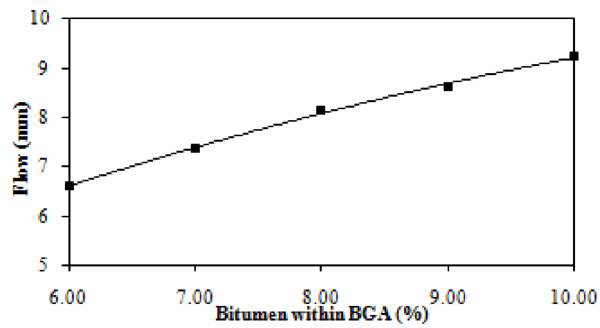

Figure-5. Relationship between bitumen within BGA and flow.

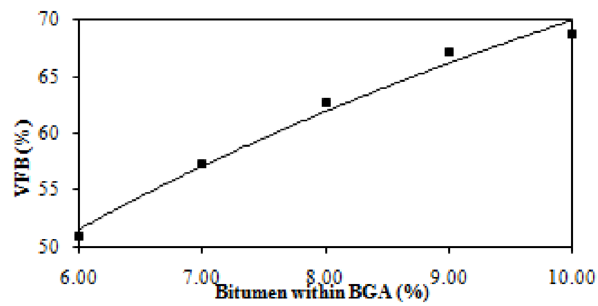

Figure-6. Relationship between bitumen within BGA and VFB.

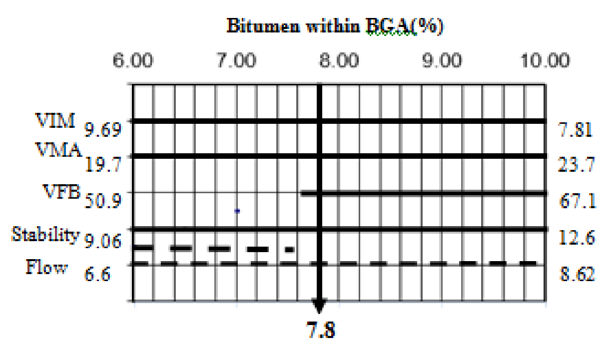

Figure-7. Optimum bitumen content.

Figure-4 shows Marshall Stability depend on BGA content. After adding BGA, the stability value increased until it reached the maximum value which was approximately 9% of the used BGA content and correspond to the stability value 17.2kN, and then stability value changed to decrease. Figure-5 displays a high percentage of BGA content increased the flow value; this result can contribute to the formation of a flexible mixture. Fig.6 shows the effect of the BGA addition on VFB at different BGA content. In general, VFB value increased with the increase of BGA content.

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Figure-7 shows the optimum bitumen content. All flow values exceeded 5mm and the VFB value of 60% was reached by 7.6% bitumen within BGA, therefore the optimum content was determined as 7, 8% bitumen within BGA with equal to 30.62% (by weight) BGA content in the mixture.

3.2 Influence of storing and compaction time on Marshall Parameters and Indirect Tensile Strength

Table-7 shows the influence of storing and compaction time on Marshal Parameters. When the storing and compaction time were extended to 3 and 7 days the mixture still can maintain its compaction ability, led to an adequate compaction of mixture. No significant differences on VIM, VMA stability, flow, and (VFB) were observed.

Figure-8 shows the relationship between storing and compaction day with ITS. The IT'S at 3 and 7 days were 0.3 and 0.29 MPa, respectively. This fact was attributed to an adequate compaction results, led to maintain the capability of mixture to bear the load that induces the indirect tensile strength value at 3 and 7 days.

Table-7. Influence of storing and compaction time on Marshal Parameters.

Storing and compaction	Compaction	Marshall parameter				
Time	Temperature	VIM	VMA	VFB	Stability	Flow
(days)	(ºC)	(%)	(%)	(%)	(kN)	(mm)
3	27	9.27	22.76	59.28	22.06	5.03
7	27	9.25	22.75	59.35	23.56	5.23

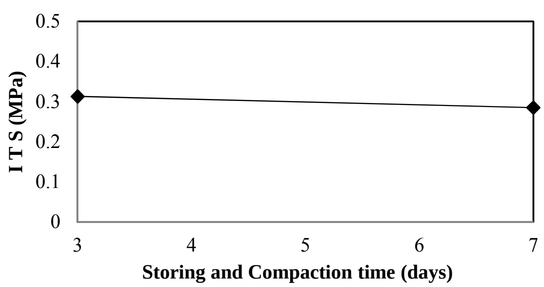

Figure-8. Relationship between storing and compaction days with ITS.

CONCLUSIONS

This research conducted an experimental laboratory to investigate the performance of hotmix cold laid containing BGA and flux oil. Based on the results obtained from this research, the following conclusion can be drawn:

a) An adequate compaction of mixture can be attained at temperature of 27ºC to 50ºC.
b) At 7.8% bitumen content within BGA, no significant differences on VIM, VMA, stability, flow, VFB and indirect tensile strength were observed when the storing and compaction time were extended from 3 to 7 days.

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