Study on the Characteristics of Hot Mix Asphalt Compacted at Rain Water Simulation

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Abstract — **This paper reports the investigation results of hot mix asphalt compacted at rain water simulation (HMA-CARS). Objectives of the research are to analysis the characteristics of HMA-CARS and reclaimed HMA-CARS after certain treatments. Research method was developed through the two main programs. First, is to investigate the characteristics of hot mix asphalt compacted using roller slab with water spraying. Second, is to investigate the characteristics of reclaimed HMA-CARS with developing three alternatives treatments. The results can be described in two main points. First, due to water spraying during compaction process, the performance of HMA-CARS decrease and does not meet the general specification of Bina Marga 2010. Second, the performance of reclaimed HMA-CARS can be improved by the treatments; however it cannot help the reclaimed mixture to meet the specification requirements.**

Key words - Hot mix asphalt. Rain water simulation. Compaction. Density. Reclaimed materials.

I. Introduction

Construction process of asphalt road pavement can be started from mixing, spraying, leveling, and compacting prior open traffic. Based upon field observation, some of the contractors are still spreading and compacting asphalt mixture on the road pavement surface in spite of rain. Although it is prohibited in the general specification of Bina Marga 2010 [1], it is still often happen due to the weak of supervision or the materials have been already produced in large scale. Therefore, research into hot mix asphalt compacted with rain water simulation (HMA-CARS) is very demanding There are two fundamental questions. First, does the quality of hot mix asphalt compacted at rain water simulation (HMA-CARS) material still meet the specification? Second, if the HMA-CARS material is processed again in plant (called as reclaimed HMA-CARS), does this reclaimed material still able to be improved to meet the specification? This paper reports the results of research that addressed to answer those two questions.

The objectives of research are to analysis the characteristics of HMA-CARS material, and to analysis the characteristics of the reclaimed HMA-CARS material after certain treatments. Research into this material type is very demanding, because engineers need to understand the quality of HMA-CARS in order to make a good adjustment in field.

II. Compaction And Water/Temperature Effect

Compaction is a process in which the solid particles are denser by mechanistic force so that void in the mixture decrease and then the density of the mixture increase [2]. Crispino et al [3] added that one of the important aspect in compaction process is to distribute aggregate particles in the mixture, so that it results the optimum aggregates configuration in order to achieve the target of density. Gudimettla et al [4] agreed that the workability of asphalt materials in compaction process is affected by mixture properties, i.e. mixture temperature, bitumen and aggregate properties, and compactor type.

When a pavement is compacted at rainfall, the pavement temperature will decrease and it affect the workability of compaction. It can be understood that water is not only affect the temperature of mixture, but it can infiltrate to the bitumen-aggregate bonding. Water infiltration affect the adhesion between aggregate particles and bitumen, and cause the bitumen strip from the aggregate surfaces. Arifin et al. [5] found that temperature affect significantly the Marshall characteristics of asphalt mixture. Specimens compacted at low temperature (less then 110^{o}C) will have high air void (VIM) and low stability (Marshall Stability). In the investigation of water effect, Arifin et al. [6] found that the effect is not significant and the performances of asphalt mixture still meet the specification. It is found that water infiltration caused the VIM, VMA, and MS values decreased.

Sentosa et al [7] investigate the effect of compaction temperature on the asphalt mixture using Retona Blend 55. Based on SNI 6-2489-1991, bitumen viscosity for compaction should be on 280±20 Cst. For Retone Blend 55, it was found that at temperature of 156^{o}C, the viscosity will be 280 Cst. The temperature range of 146^{o}C to 186^{o}C was studied in order to investigate it effect to the mixture properties. It was found that with increasing temperature, the VIM values decrease, and the density and stability increase significantly. In this study, the temperature of 156^{o}C was selected as the compaction optimum temperature which produced the best mixture performance.

Widodo et al [8] stated that the effect of both short ageing (oven 135^{o}C for 4 hours) and long ageing (oven 85^{o}C for 2 days) on the asphalt concrete wearing course (ACWC) stability is very significant. Marshall Stability of ACWC

mixture without ageing was 1651 kg. This stability value reduced significantly to 1131 kg (short ageing) and to 569 kg (long ageing).

III. Research Method

Research method was developed through the two main steps of activities. First step is to investigate the characteristics of hot mix asphalt which was compacted using roller slab with water spraying. Second step is to investigate the characteristics of reclaimed HMA-CARS with developing three alternatives treatments.

Asphalt mixture used in this research was asphalt concrete for wearing course (AC-WC) with binder type of 60/70 pen. Asphalt mixtures at optimum bitumen content were compacted for 45 passing. It was generated four variation types of samples, i.e. (1) sample with no rain simulation, (2) sample with rain water simulation during compaction 15 passing, (3) idem 2 during compaction 30 passing, end (4) idem 2 during compaction 45 passing. The rain simulation was conducted by spraying water on the surface of pavement sample during compaction process. Water pipe was installed on the both side of wheel roller, i.e. output pipe 1 and 2 (Figure 1).

Sample size of slab was 30x30 cm2 with thickness of about 4-7 cm. Each sample was then drilled to generate four cylindrical specimens with diameter of 100 mm. All those specimens with four variations were then evaluated using Marshall test prior analyzing the characteristics of HMA-CARS.

The specimens that have been tested were then heated, destroyed, and developed as materials that ready to be processed again. In this research, this materials were then be named reclaimed HMA-CARS materials. This reclaimed HMA-CARS mixtures were then processed with three different methods, i.e. (1) without treatment, (2) air dried at ambient temperature for 48 hours, and (3) oven dried at temperature of 35^0C for 6 hours. Following those three treatments, the materials were then processed using hot-mix system, and compacted to generate the cylindrical specimen with diameter of 100 mm. All those specimens with three treatments were then evaluated using Marshall test prior analyzing the characteristics of reclaimed HMA-CARS.

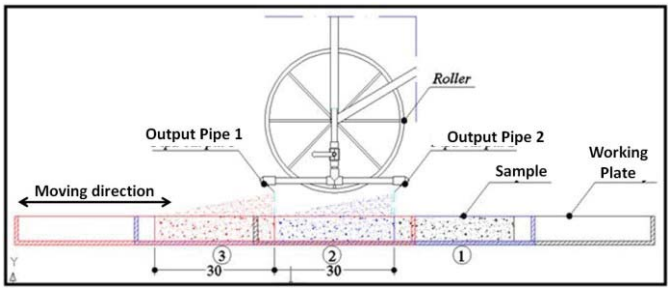


Figure 1. Rain Simulation during Compaction Process using Roller Slab Compactor

IV. Discussion

A. *Characteristics of HMA-CARS*

As described previously that rain simulation was conducted during compaction process, it can be calculated that discharge of water is about 1.4406ml per passing. Thus the amount of water sprayed on the pavement can be approached about 21.6ml (15 passing), 43.2ml (30 passing), and 64.8ml (45 passing). This water discharge data is needed in order to understand the quantity of water in the pavement. It is understood that the increase in moisture content will reduce the performance of the mixture.

Water has two effects. First, water affects the function of bitumen as a mixture binder, and it can separate the bonding between aggregate and bitumen. Second, water affects the decreasing of mixture temperature. Unfortunately in this research the amount of water infiltrate into the pavement is still unknown accurately. The assumption that 100% of the sprayed water will infiltrate into the pavement is not fully correct. It is caused by the three possibilities, i.e. (1) water attached on the roller surface, or (2) water evaporate due to the increasing of temperature, and (3) the water infiltration is depend upon the mixture density. The possibility that no water infiltrate into pavement is only logic if the water simulation is applied during the end of 15 passing. However, if the water simulation is applied 45 passing during compaction process, the prediction of water infiltration into the pavement will be more valid.

If water infiltrates 100%, the amount of water in the pavement will be about 21,609 ml (water spraying during 15 passing), or about 0.16%. In Arifin et al [6], the effect of rain water on the Marshall specimens of asphalt mixture was investigated using penetrating 1-5 ml of water. Estimation of specimen weight is 1132 gr, so that the water content estimation is about 0,088% - 0,44%. It is note that in this research the water content is between 0,16% - 0,47% with assumption 100% of water infiltrate into pavement.

The surface temperature of pavement sample was measured using laser at before and after spraying water. The water spraying affects significantly the decreasing temperature of pavement surface. Water spraying time is then the key factor in decreasing temperature. Based upon specification of Bina Marga 2010 [1] for compaction of hot mix asphalt layer, the minimum temperature should be at 95^oC (or maximum viscosity is about 20 Pa.s.) at the final compaction phase using steel roller. In this research, the pavement temperature after water spraying for 15 and 45 passing was found less than 95^oC.

Arifin et al [5] used compaction temperature of 50^oC to 110^oC in order to investigate the effect of temperature on the pavement performance. While Akem (2012) used compaction temperature of 125^oC to 145^oC to study the effect of compaction temperature on performance HRS-WC using buton bitumen Retona blend 55. The result found that the temperature between 133^oC to 140^oC gave good performance.

Table 7 presents the results of Marshall test on the AC-WC cylindrical specimens with diameter of 100 mm. These specimens are generated from core drill of pavement slab

sample with size of 30 cm x 30 cm x 6.8 cm compacted using roller slab. Each slab was cored to generate 4 specimens. Before Marshall test, the specimens were soaked in the water bath with temperature of 60°C for 30 minutes. In the Table 7 the values are the average of 4 specimens.

Based upon Table 7, the specimens without water spraying have good performance which meets all requirements of Bina Marga 2010 specification. While the specimens with water spraying, the values of stability, flow, and VMA can meet the specification, but the values of MQ, VIM, and VFWB are out of the specification. In general, the effect of water spraying decreases mixture performance significantly, so that the performance is out of the specification. Water infiltration and temperature decreasing work together in decreasing the mixture performance. As seen in Figure 2, it looks that those two aspects caused the mixture density decrease significantly. It is found that each increasing water infiltration of 7 ml and temperature decreasing of 3°C cause the density decreasing of 0.01 g/cm^3.

The performance of specimens with water spraying was lower than specimens without water spraying. The decreasing of mixture performance occurs for all properties. Similar case when the water spraying time increases, the mixture performance tend to decrease. For example, the specimens with water spraying time 45 passing have VIM value of 10.46 %, while with spraying time 15 passing the VIM value is only 7.84%. The effect of water spraying on the all Marshall properties can be confirmed in the Figure 3 dan 4.

As seen in Figure 3, the Marshall stability reduction is in line with the density decreasing. Marshall stability value indicates the ability of a mixture in supporting a load. The higher the stability the higher the strength. The stability value also control load spreading on the under layer. It means, more water spraying on the pavement will decrease the strength of the mixture and reduce the ability of load spreading. As seen in Table I, the density decreasing is also followed by increasing the flow values. This value can be represented as the permanent deformation (rutting) resistance of the mixture. The higher flow values due to more water spraying mean the rutting resistance of this HMA-CARS becomes lower. Besides, as the results, the decreasing of stability values that followed by increasing flow values affect the MQ values decrease. MQ value indicates the flexibility of mixture. Lower MQ means the mixture is more flexible, however if MQ value is too small (less than the specification limit) the mixture will tend to rutting and bleeding.

As seen in the Figure 4, the density decreasing is in line with the increasing of VIM and VMA values, and the decreasing of VFWB. High value of VMA means the mixture will have problem with stability, while low value relate with durability problem. In this research, in spite of the VMA values still meet the specification (should be more than 15%), but the value tends to increase with water spraying time, so that it will cause the stability of mixture decrease. The increasing of VIM values with water spraying time will cause the mixture more porous, and cause air and water easier to introduce in the pavement. This two components cause mixture oxidation, and it cause raveling and stripping. The decreasing of VFWB values indicates that this HMA-CARS material is less durable due to not impermeable mixture.

TABLE I
CHARACTERISTICS OF HMA-CARS

No	Water Spraying Time (Passing)	*Marshall* Properties						
		Stability (kg)	Flow (mm)	MQ (kg/mm)	Density (gr/cm^3)	VMA (%)	VIM (%)	VFWA (%)
1	0	1212	4.73	260	2.27	18.9	4.9	71
2	15	1112	6.41	173	2.20	21.5	7.8	61
3	30	1089	6.94	170	2.17	22.5	9.1	57
4	45	966	6.52	150	2.14	23.3	10.5	54
Specification of BM 2010 for AC-WC		Min 800	Min 3	Min 250	-	Min 15	3-5	Min 65

Note: The values of Marshall properties are the average value of 4 specimens

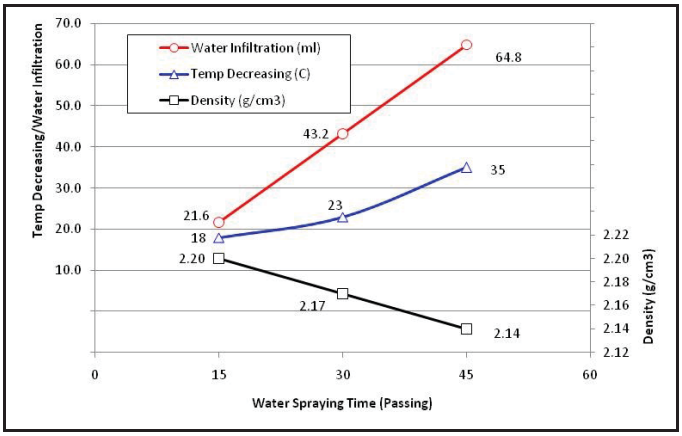


Figure 2. Effect of Water Spraying Time on the Water Infiltration, Temperature Decreasing, and Density

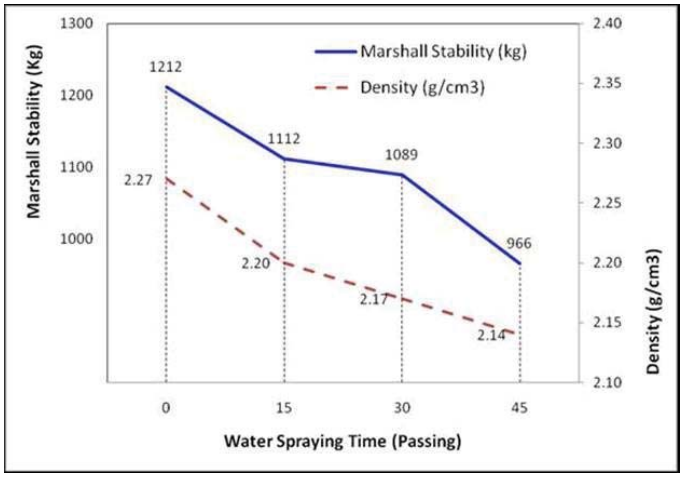


Figure 3. Effect of Water Spraying Time on the Density and Marshall Stability

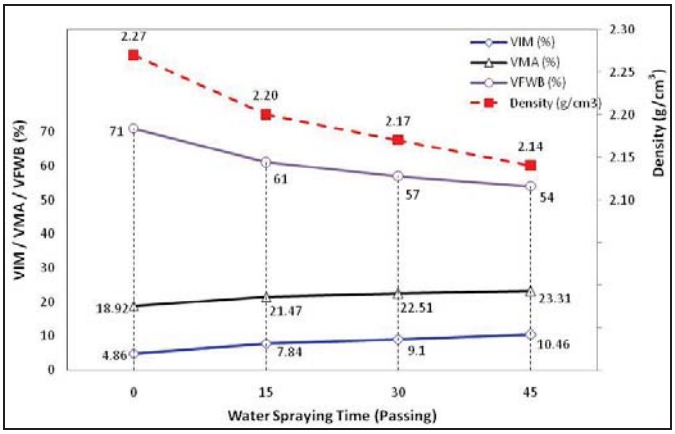


Figure 4. Effect of Water Spraying Time on the Density and Mixture Volumetric

B. *Characteristics of Reclaimed HMA-CARS*

As discuss previously the reclaimed HMA-CARS used in this research are HMA-CARS materials with variation of water spraying time. However the reclaimed HMA-CARS is not differed based on type of water spraying time variation.

In the initial step, all the reclaimed HMA-CARS were mixed as homogeneous as possible. This reclaimed material was then separated into 3 parts with different treatment as following, i.e. (1) no treatment, (2) air dried for 48 hours, and (3) oven dried at temperature of 35^0C for 6 hours. After treatment, the reclaimed mixture was compacted and Marshall tested. Table II shows the results of Marshall test on the reclaimed HMA-CARS specimens. These results were then compared to the reference specimen which was generated as a common hot mix asphalt.

As seen in Table II, the reference specimen performace fulfil all criteria of Bina Marga 2010 specification. On the contrary, all reclaimed HMA-CARS do not meet the criteria of flow and VIM. The reclaimed HMA-CARS with no treatment is even out of VFWA criterion. Properties of reclaimed HMA-CARS look opposite the properties of HMA-CARS (Table I). The stability and MQ values of reclaimed HMA-CARS are much higher, while the flow values are lower than the HMA-CARS. The values of VMA and VIM of reclaimed mixture are lower than HMA-CARS.

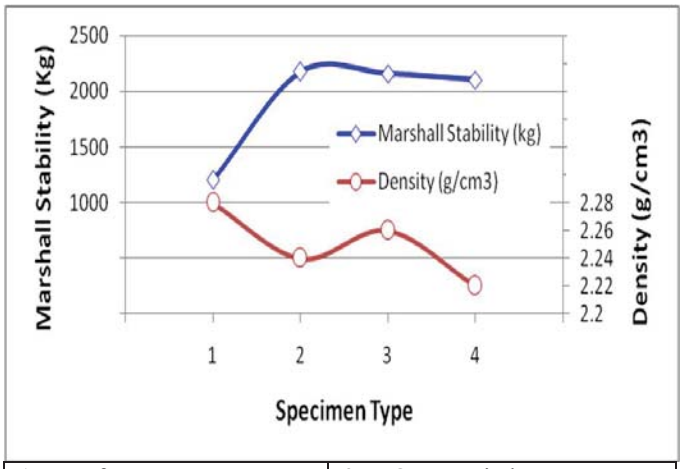
Based upon the stability, flow, and MQ values, the reclaimed mixture represent too rigid. This behaviour may be affected by bitumen ageing. This properties cause the mixture will be easier to crack when support the vehicle load. Although the mixture is too stiff, but the mixture VIM is high that means the reclaimed mixture is sensitive to oxidation process, and then potent to ravelling and stripping.

As seen in Figure 5, the air and oven dried treatment can improve the mixture density relatively. However the high values of stability is not caused by the density, it because the bitumen ageing. The improvement of the mixture density cannot help the VIM values which are still higher than the specification limit. Thus, it can be deduced that the treatment have improved the reclaimed HMA-CARS performance, but it is not significant, and it cannot help the reclaimed mixture to meet the specification.

TABLE II
CHARACTERISTICS OF RECLAIMED HMA-CARS

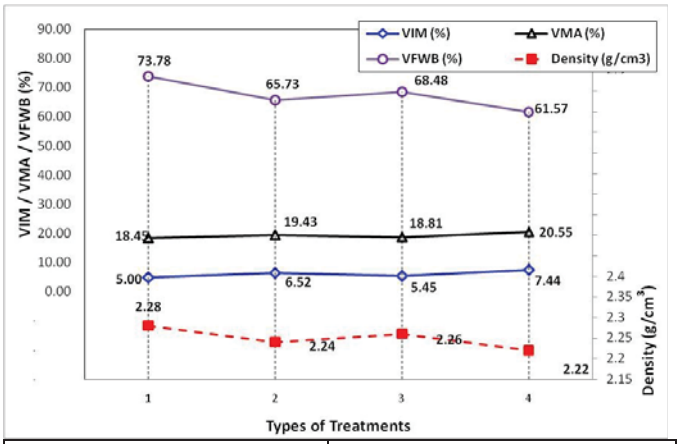
No	Specimen Types	Marshall Properties						
		Stability (kg)	Flow (mm)	MQ (kg/mm)	Density (g/Cm³)	VMA (%)	VIM (%)	VFWB (%)
1	Reference	1202	4.73	254	2.28	18.5	5.00	74
2	No Treatment	2104	2.44	862	2.22	20.5	7.44	62
3	Air Dried	2159	1.99	1085	2.26	18.8	5.45	68
4	Oven Dried	2177	1.69	1288	2.24	19.4	6.52	66
Specification of BM 2010 for AC-WC		min 800	min 3	Min 250		min 15	3 - 5	min 65

Note: The values of Marshall properties are the average value of 4 specimens



1. Reference	2. Oven Dried
3. Air Dried	4. No treatment

Figure 5. Mixture Density and Marshall Stability of the Reclaimed of HMA-CARS



1. Reference	2. Oven Dried
3. Air Dried	4. No treatment

Figure 6. Mixture Density and Volumetric of the Reclaimed of HMA-CARS

V. Conclusions

The research results can be concluded as the following two main points:

1. Due to water spraying during compaction process, the performance of HMA-CARS decrease and does not meet the specification of Bina Marga 2010.
2. The performance of reclaimed HMA-CARS can be improved by the treatments; however it cannot help the reclaimed mixture to meet the specification requirements.

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