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To cite this article: Henry Prastanto *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **509** 012049

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Study of physical characteristic of rubberized hot mix asphalt based on various dosage of natural rubber latex and solid rubber

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Abstract. Currently, the implementation of rubberized asphalt technology become the main concern of Government in natural rubber producing countries, especially Thailand, Indonesia, and Malaysia. The policy is intended to increase natural rubber domestic consumption and support national infrastructure project. Rubberized asphalt is made from the mixture of hot asphalt with polymer such as natural rubber either in the form of latex or compound. For field implementation, rubberized asphalt should be mixed with aggregate to form rubberized hot mix asphalt. The research was conducted to study the rubberized hot mix asphalt characteristic at laboratory scale. Types of natural rubber were used consist of cationic natural rubber latex (L2), 4 hours prevulcanized natural rubber latex (L3), and semi-efficient solid natural rubber compound (KP2). The base asphalt used asphalt penetration 60/70, while the aggregate was obtained from Subang District, West Java, Indonesia. The trials were run at three stages i.e. analysis of pure asphalt and aggregate properties, determination of mixing and compaction temperature, followed with characterization of rubberized hot mix asphalt physical properties by using Marshall and Wheel Tracking Machine. The dosage of natural rubber addition was varied at 3,5,7 and 9%. Hot mix asphalt without rubber addition was used as control. The result showed that the addition of natural rubber into the asphalt penetration 60/70 raised the Marshall stability of rubberized hot mix asphalt. The initial Marshall stability value was 986 kg for pure hot mix asphalt became 1097 kg for 7% of cationic natural rubber latex, 1103 kg for 5% of 4 hours prevulcanized natural latex, and 1110 kg for 7% of semi-efficient solid natural rubber compound. Thus, it could be concluded that the addition of 5-7% natural rubber improved the physical characteristic of rubberized hot mix asphalt as indicated by the increasing of Marshall stability value.

Keywords: Rubberized hot mix asphalt, natural rubber, Marshall stability, latex, compound

1. Introduction

Implementation of rubberized asphalt technology in the road construction currently become main concern of Government especially in main natural rubber producing countries such Thailand, Indonesia, and Malaysia. The policy is intended to increase natural rubber domestic consumption and support national infrastructure project. Therefore, it could be used as reference in an effort to strengthen natural rubber price and protect smallholder from financial crisis. The usage of natural rubber in the asphalt



mixture is potentially increase the natural rubber domestic consumption more than 60.000 ton annually. The large amount of natural rubber could be absorbed has justified Indonesia Government to highly commit in developing rubberized asphalt technology around the country. The commitment is showed by the appointment to conduct a series of rubberized asphalt field trial test.

Rubberized asphalt is produced by the addition of rubber at certain dosage into the hot asphalt [1]. The type of rubber can be derived from either natural or synthetic rubber. Synthetic rubber commonly used in the manufacture of rubberized asphalt are styrene butadiene rubber, styrene butadiene styrene, and ethylene vinyl acetate. While the type of natural rubber covers natural rubber latex, solid natural rubber, and ground tyre rubber [2-4]. The usage of fresh natural rubber as rubberized asphalt additive has some advantages such as environmental friendly and can result better quality of rubberized asphalt physical properties compared to pure asphalt in the terms of improving road elasticity, reducing cracks, increasing softening point and improve adhesiveness with aggregates [5, 6].

In the preparation of rubberized asphalt field trial test, firstly the rubberized asphalt should be mixed with filler and aggregate to form rubberized hot mix asphalt as road pavement materials. Rubberized asphalt act as the binder of aggregate since it has high viscosity which can improve adhesive bonding to the aggregate particles [2, 5]. The raise of rubberized asphalt viscosity is because of the swelling of natural rubber particle during the mixing into the hot asphalt. Meanwhile aggregate is functioned as reinforce materials in the road pavement. The performance of rubberized hot mix asphalt is highly depending on the rubberized asphalt and aggregate characteristic such as friction and cohesion. Friction is obtained for the interlocking force between the aggregate granule while the cohesion is provided from the rubberized asphalt properties being used.

The aimed of the research was to evaluate the performance and characteristic of rubberized hot mix asphalt through laboratory scale investigations based on Marshall analysis. Marshall analysis of an asphalt mixture is a common procedure to determine the load and flow rate of asphalt specimens, beginning with compaction into moulds using manual or automatic Marshall compactors, and conditioned in a water bath at the specified temperature. The result of Marshall analysis in this laboratory scale of research was regarded to be important information since it could be used as recommendation for developing rubberized hot mix asphalt in the higher scale of production.

2. Material and Method

Commercial high ammoniated natural rubber latex concentrate which was obtained from Indonesian Rubber Research Institute was used as raw materials in the preparation of cationic and prevulcanized natural rubber latex. Solid raw rubber type Standard Indonesian Rubber (SIR) 20 which was also provided by Indonesian Rubber Research Institute was used to produce semi-efficient solid natural rubber compound. The base asphalt used hot asphalt penetration 60/70, while the aggregate was obtained from Subang District, West Java, Indonesia. Other additives such as latex and rubber compound chemicals were purchased from local supplier, PT. Multi Citra Chemindonusa, Jakarta.

The trials were run at three stages i.e. analysis of raw materials as asphalt pen 60/70 and aggregate, determination of mixing and compaction temperature, followed with the physical properties characterization of rubberized hot mix asphalt by using Marshall and Wheel Tracking Machine. The dosages of natural rubber addition into hot asphalt pen 60/70 were varied at 3, 5, 7, and 9%. Hot mix asphalt which was produced from the mixture of pure hot asphalt and aggregate was used as control.

2.1. Analysis of pure hot asphalt pen 60/70 and aggregate properties

The properties of pure hot asphalt pen 60/70 was evaluated in accordance of General Specification established by Directorate General of Highways consisting of following parameters Penetration (SNI 2456:2011), Kinematic Viscosity (SNI 6440-2000), Softening Point (SNI 2434:2011), Ductility (SNI 2432:2011), Flash Point (SNI 2433:2011), TFOT (SNI 06-2440-1991), Penetration after TFOT (SNI 2456:2011), Softening Point after TFOT (SNI 2434:2011), Ductility after TFOT (SNI 2432:2011). Thus the quality of the aggregate being used in the research was analysis referred to General Specification of

Road and Bridge, Division VI Asphalt Pavement, Department of Public Work 2007. Sieve analysis of aggregate was used to determine its gradation of aggregate particle size.

2.2. *Production of rubberized hot mix asphalt*

2.2.1. *Preparation of rubberized asphalt additives based on natural rubber.* Preparation of rubberized asphalt was begun with the synthesise of cationic and prevulcanized natural rubber latexes, also semi-efficient natural rubber compound as asphalt additive. Cationic natural rubber latex (L2) was made by adding the combination of anionic/non-ionic surfactants followed with strong acid solution into high ammoniated natural rubber latex until the pH value of the latex reached 3 and the ammonia content was reduced. Thus, prevulcanized natural rubber latex (L3) was obtained by mixing latex chemicals dispersion into high ammoniated natural rubber latex concentrate at 70°C for 4 hours. Latex chemicals dispersion consisted of mixed (activator, accelerator, antioxidant) and sulphur dispersions. Semi-efficient natural rubber compound was processed by using laboratory scale two roll open mill. SIR 20 was masticated into softened rubber matrix. The process was continued with the addition of rubber chemicals such as processing oil, activator, antioxidant, accelerator, and vulcanizing agent. The rubber compound then remilled and homogenized. Before being added into hot asphalt, the rubber compound was cut into smaller size.

2.2.2. *Preparation of rubberized asphalt with addition of natural rubber.* The dosage of the addition of natural rubber as rubberized asphalt additive were varied at 3, 5, and 7% for natural rubber latex types and 3, 5, 7, and 9% for solid rubber compound. Hot asphalt pen 60/70 was placed in a stirred reactor and heated to 140°C by means of an electronically controlled hotplate, by using silicon oil bath as jacket heater. After the asphalt had been heated to temperature of 140°C, the natural rubber latex either cationic or prevulcanized was added and stirred into the hot melted asphalt. The procedure was continued with poured the rubberized asphalt into a mixer followed with stirring at 150°C for 15 minutes. Whereas, for the rubberized asphalt based on rubber compound the mixing was run at agitated big hole blender at 150°C for 15 minutes. The mixing was continued by using agitated small hole blender at 150°C for 10 minutes.

2.2.3. *Production of rubberized hot mix asphalt at laboratory scale.* In the manufacture of rubberized hot mix asphalt, it was designed to use Asphaltic Concrete (AC) Wearing in accordance to General Specification of Directorate General of Highway 2010 Revision 3 as asphalt concrete layer. Thus, aggregate gradation was selected from ideal or middle type (between upper and lower limits). The rubberized hot mix asphalt was prepared through the following steps: the aggregate composition and asphalt content were determined based on AC-Wearing specification, mixing of rubberized asphalt with aggregate and followed by mixture compaction based on the standard mixing temperature.

2.3. *Characterization of rubberized hot mix asphalt physical properties*

Characterization of rubberized hot mix asphalt was conducted by analysing the physical properties in an Marshall Testing instrument. The observation was continued by testing on rubberized hot mix asphalt resistance to deformation by using Wheel Tacking Machine (WTM). Parameters resulted from Marshall testing included optimum asphalt content, Marshall stability, flow, void filled with asphalt, void in mineral aggregat, and void in mix.

3. **Result and Discussion**

3.1. *Analysis of pure asphalt pen 60/70 and aggregate physical properties*

The properness of ingredients in rubberized hot mix asphalt strongly effect its final properties. Characteristic of pure asphalt pen 60/70 and aggregate are summarized at Table 1 and Table 2 respectively. Excellent ingredients are expected could result superior rubberized hot mix asphalt which has high stiffness at high temperature to minimize deformation, low stiffness at low temperature to reduce possibility of road surface cracking, and increase adhesiveness between rubberized asphalt and

aggregate. Based on Table 1, it could be known that the pure asphalt pen 60/70 used in the research fill the standard requirement of hot asphalt as state in General Specification established by Directorate General of Highways. The asphalt pen 60/70 was selected as base asphalt due to its high demand on Indonesian road construction project since it can facilitate high traffic load and hot tropical weather.

Table 1. Physical properties of asphalt pen 60/70.

Parameters	Quality standard	Test result
Penetration at 25°C (0,1 mm)	60 – 70	63
Kinematic viscosity at 135°C, cSt	Min 300	408
Softening point, °C	Min 48	49,2
Ductility at 25C, cm	Min 100	≥140
Flash point, °C	Min 232	324
Weight loss, %	Max 0.8	0.0292
Penetration after TFOT (0,1 mm)	Min 54	81.0
Softening point after TFOT (°C)		51.6
Ductility after TFOT (cm)	Min 100	≥100

Table 2. Physical properties of aggregate

Testing parameters	Testing method	Test result of aggregate, mm		
		10-20	5-10	0-5
Abrasion, %	SNI 03-2417-2008	19		
Equal to sand, %	SNI 03-4428-1997			61
Bulk Density		2.65	2.65	2.69
SSD Density	SNI 03-1969-2008	2.69	2.69	2.72
Apparent Density	SNI 03-1970-2008	2.76	2.77	2.77
Absorbance, %	SNI 03-1969-2008	1.5	1.7	1.2
Fine aggregate angularity, %	SNI 03-6877-2002			49
Coarse aggregate angularity, %	ASTM D 5821 2001	100/100		
Adhesiveness to asphalt, %	SNI 03-2439-2011		95+	
Flat and oval particles, %	ASTM D 4791 2005	0.0		
Weathering, %	SNI 03-3407-1994	1.5	0.6	1.5
Sieve analysis, % escape	ASTM C 136:2012			
¾" (19,1 mm)		100		
½" (12,5 mm)		65	100	
3/8" (9,5 mm)		19	100	100
#4 (4,76 mm)		2.2	32	96
#8 (2,36 mm)		1.9	2.7	80
#16 (1,18 mm)		1.8	2.0	60
#30 (0,60 mm)		1.6	1.7	45
#50 (0,30 mm)		1.5	1.5	30

#100 (0,149 mm)	1.2	1.2	19
#200 (0,075 mm)	0.9	0.9	11

Further, data were shown in Table 2 indicate that the aggregate has good strength and durability or (abrasion < 25%). Aggregate with high abrasion value is not allowed due to easily break during compaction or the impact of high traffic load. The density value of the aggregate was related to its absorbance. Low density of aggregate resulted large volume and required large amount of asphalt in order to create mechanical bond between asphalt film and aggregate. The aggregate has no flat and oval particles which means it proper to be used as road pavement ingredients since it not easily broken and could maintain road pavement stability. Sieve analysis or gradation test illustrate the composition of coarse and fine aggregate. The result showed that fine aggregate (0-5 mm) dominates. This information is used as base to design the gradation of the rubberized asphalt hot mix.

3.2. Mixing and compaction condition on rubberized hot mix asphalt preparation

The addition of natural rubber either in the latex or solid form increase the viscosity of the rubberized asphalt. Consequently, the raise of the rubberized asphalt viscosity determined the condition of rubberized hot mix asphalt mixing and compaction mainly the temperature. Table 3 described the kinematic viscosity (135°C), mixing temperature (at 170 cSt), and compaction temperature (at 280 cSt) of rubberized hot mix asphalt respectively. The arranged temperature and viscosity were based on commonly practice [7]. The correlation which can be understood from Table 3 is that the increasing of natural rubber dosage in rubberized asphalt caused the high value of kinematic viscosity, mixing and compaction temperatures. Semi-efficient natural rubber compound (KP2) which made from solid raw natural rubber (SIR 20) produced highest kinematic viscosity values at the same dosage of natural rubber addition to asphalt pen 60/70. While, prevulcanized natural rubber latex (L3) gave lowest kinematic viscosity since it contained a lot of water (serum phase) on its mixture.

The higher mixing and compaction temperature of rubberized hot mix asphalt could accelerate aging process and reduced workability of rubberized hot mix asphalt during field implementation. High temperature of compaction trigger the occurrence of asphalt cement oxidation. The oxidation process of an asphalt as road pavement is not desirable since it create stripping and cracking surface which can shorten the pavement service life. High mixing and compaction operation temperature can thermally degrade the natural rubber particle in the rubberized asphalt mixture [8].

Table 3. Mixing and compaction of rubberized hot mix asphalt

Natural rubber dosage	Kinematic viscosity at 135°C (cSt)	Mixing temperature at viscosity 170 cSt (°C)	Compaction temperature at viscosity 280 cSt (°C)
Asphalt pen 60/70	408	157	145
Cationic natural rubber latex (L2)			
3	544	164	152
5	724	172	188
7	968	188	172
Prevulcanized natural rubber latex (L3)			
3	439	158	146
5	451	160	147
7	650	177	161
Semi-efficient natural rubber compound (KP2)			
3	554	167	153

5	583	169	155
7	890	194	170
9	1070	198	181

3.3. Physical properties of rubberized hot mix asphalt based on natural rubber addition

The result of rubberized hot mix asphalt physical characteristic by using Marshall apparatus and Wheel Tacking Machine compared to pure asphalt pen 60/70 are listed at Table 4, Table 5, and Table 6 respectively. Generally, the utilization of rubberized asphalt as one of rubberized hot mix asphalt ingredient increased the quality of the hot mix mixture. The better quality of rubberized hot mix asphalt compared to hot mix based pure asphalt pen 60/70 are shown mainly by the raise value on Marshall stability. The initial Marshall stability value was 986 kg for pure hot mix asphalt became 1097 kg for 7% of cationic natural rubber latex (L2), 1103 kg for 5% of 4 hours prevulcanized natural latex (L3), and 1110 kg for 7% of semi-efficient solid natural rubber compound (KP2). The lower void filled with asphalt which indicate relatively higher rubberized asphalt content tend to rise the film thickness making the rubberized asphalt hot mix more durable and resistant to moisture damage [9].

Void in mix value was also decrease due to the voids among the aggregates particle were filled with natural rubber particles. Cationic natural rubber latex (L2) highest percentage of void in mix because it was predicted to have smallest natural rubber particles. Void in mix value was also effected by temperature of compaction. At high temperature of compaction, rubberized asphalt was easily to cover the aggregate surface and increase its homogeneity. Marshall flow values showed slightly increase on rubberized hot mix asphalt than hot mix based on pure asphalt. Similar to void in mix value, the value of void mineral aggregate was also reducing due to addition of natural rubber as asphalt modifier. Natural rubber particles as asphalt modifiers could act as lubricating agent allowing sliding of aggregate with each other which enhance Marshall flow. The compactness values of all rubberized hot mix asphalt relatively unchanged although it had higher temperature of compaction.

Table 4. Physical properties of rubberized hot mix asphalt based on cationic latex (L2)

Parameters	Pure asphalt pen 60/70	Cationic latex L2 dosage (%)		
		3	5	7
Optimum asphalt content, %	6.03	6.00	6.00	6.13
Compactness, ton/m ³	2.35	2.36	2.35	2.35
Void Mineral Aggregate, %	18.04	17.69	18.07	18.05
Void in Mix (Marshall), %	4.80	4.39	4.79	4.47
Void filled with asphalt, %	76.3	75.2	72.6	75.3
Stability, Kg	986	1027	1047	1097
Flow, mm	3.8	4.0	3.8	4.1

Table 5. Physical properties of rubberized hot mix asphalt based on prevulcanized latex (L3)

Parameters	Pure asphalt pen 60/70	Prevulcanized latex L3 dosage (%)		
		3	5	7
Optimum asphalt content, %	6.03	6.03	6.00	6.08

Compactness, ton/m ³	2.35	2.37	2.37	2.36
Void Mineral Aggregate, %	18.04	17.3	17.3	17.4
Void in Mix (Marshall), %	4.80	4.2	4.4	4.1
Void filled with asphalt, %	76.3	75.6	74.8	76.4
Stability, Kg	986	1046	1103	1052
Flow, mm	3.8	4.0	4.4	4.5

Table 6. Physical properties of rubberized hot mix asphalt based on rubber compound (KP2)

Parameters	Pure asphalt pen 60/70	Rubber compound KP2 dosage (%)			
		3	5	7	9
Optimum asphalt content, %	6.03	6.08	6.05	6.10	6.05
Compactness, ton/m ³	2.35	2.35	2.36	2.36	2.37
Void Mineral Aggregate, %	18.0	18.0	17.5	17.7	17.3
Void in Mix (Marshall), %	4.8	4.5	4.2	4.2	4.0
Void filled with asphalt, %	76.3	74.9	76.2	75.8	76.9
Stability, Kg	986	1036	1099	1110	1106
Flow, mm	3.8	4.4	4.2	4.3	4.4

4. Conclusion

Referred on the results of the laboratory experimental and analytical investigation, the following conclusion have been drawn that the addition of 5-7% natural rubber either in the latex form (cationic or pre-vulcanized) and solid rubber compound could improve the physical characteristic of rubberized hot mix asphalt as indicated by the increasing of Marshall parameter value. The higher marshal value gives better rubberized asphalt quality. The standard value of Marshall parameter for rubberized asphalt based on fresh natural rubber does not yet exist because it is still under review by Directorate General of Highway (Dirjen Bina Marga).

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