

# Rheological Characteristics of Reclaimed Asphalt Pavement (RAP) Evaluation using Reclamite Rejuvenating Material

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**Abstract.** Using reclaimed asphalt pavement (RAP) does not only reduce costs but is also environmentally friendly. In its use, it is very important to know the empirical and rheological properties of the asphalt. The testing in this study used a Dynamic Shear Rheometer (DSR) to test asphalt pen 60/70, RAP and Reclamite rejuvenating material mixed with RAP. The results of the pen asphalt 60/70 empirical test met the Bina Marga 2010 General Specifications of Roads and Bridges, while the RAP showed the characteristics of an aging asphalt. In the rheological test based on SUPERPAVE, from the value of the performance grade (PG), it was found that Reclamite reduced the critical temperature value on RAP, so the PG value was the same as the asphalt pen 60/70. The master curve results also showed that Reclamite can reduce the RAP stiffness modulus near the value of asphalt pen 60/70 stiffness modulus. Meanwhile, as seen from the results of the black diagram, the original condition has a range of phase angle ( $\delta$ ) greater than the RTFOT and PAVT conditions because the asphalt has undergone aging. At the same  $S_{bit}$ , asphalt pen 60/70 has a greater ( $\delta$ ) than RAP, while for RAP added with Reclamite, the value is between the RAP and asphalt pen 60/70 value. This illustrates that the Reclamite rejuvenating material makes RAP more viscous.

## 1. Introduction

Reclaimed Asphalt Pavement (RAP) technology is a material produced by pavement scraping containing asphalt and aggregate. Based on a study conducted by asphalt association in America, the average percentage of RAP used in asphalt mixture increased by 15.6% in 2009 and increased to 20.4% in 2014, estimating the amount of RAP used in asphalt mixture is 71,900,000 tons, assuming the asphalt content in RAP is 5%. It equals 3.6 million tons of asphalt and 68 million tons of natural aggregate [7]. Reclaimed pavement performance, in addition to being economical and environmentally friendly, must also be prepared in terms of fatigue, rut, thermal resistance and good durability [2, 3].

Asphalt is a thick liquid which is a hydrocarbon compound where its performance is empirically evaluated based on its rheological properties (chemical composition and physical properties of asphalt) while mechanistically, the performance evaluation is based on its elastic modulus ( $G^*$ ), poisson ratio, performance grade and phase angle ( $\delta$ ). The asphalt rheological properties will affect the pavement performance because the rheological properties of the asphalt during production will continue to change until aging process occurs. The first significant aging of asphalt occurs in the pug mill on drum mix



plant in the form of substantial rheological changes such as a decrease in penetration and an increase in viscosity which occurs during short-term mixing. Asphalt aging continues at the time of asphalt laying until it is opened for traffic. The aging process will be slower in the first two to three years until the pavement approaches density, after that, the aging rate of asphalt decreases over a longer period of time, resulting in rheological changes in asphalt [5].

The SUPERPAVE system requires the determination of asphalt rheological properties to design and evaluate good hot asphalt mix. The main rheological parameters of asphalt performance grade (PG) are dynamic modulus and phase angle at high temperatures and creep stiffness and creep relaxation levels at low temperatures. These parameters are used for the characteristics of RAP and its mix [4]. The main objective of this study is to evaluate asphalt rheology using a dynamic shear rheometer (DSR).

## 2. Materials and Methods

The materials used in this study were Pertamina's asphalt pen 60/70, asphalt extracted from reclaimed materials from scraping in National Road in Karawang and Reclamite rejuvenating material. The testing equipment used is a dynamic shear rheometer (DSR). The making of specimen started from testing the characteristics of asphalt pen 60/70, extracted asphalt and RAP. Then, the RAP was mixed with rejuvenating materials. In the rheological test of asphalt, there are 3 different tests: asphalt pen 60/70 as control asphalt, extracted RAP and RAP added with Reclamite using the DSR testing equipment.

## 3. Results and Analysis

### 3.1. Characteristics of asphalt pen 60/70

In this study the asphalt used was oil asphalt with 60/70 penetration from Pertamina. Some laboratory tests were carried out to determine the basic properties of the asphalt. From the results of the testing, it was found that the characteristics of the 60/70 penetration oil asphalt met the requirements for Type 1 Hard Asphalt Pen 60-70, as stated in Bina Marga 2010 General Specifications of Roads and Bridges. [6, 8].

### 3.2. Characteristics of RAP

Testing the characteristics of asphalt was done by separating the asphalt from RAP material with Trichloroethylene (TCE) liquid using an evaporator. Testing of RAP from extraction showed an asphalt content of 5.15%. Meanwhile, seen from the test of asphalt properties, there was a decrease in penetration value to 10dmm, an increase in softening point of 80°C and reduced sensitivity to elastic in the form of decreasing ductility value to 38cm. This shows that the asphalt contained in the RAP has undergone an aging process.

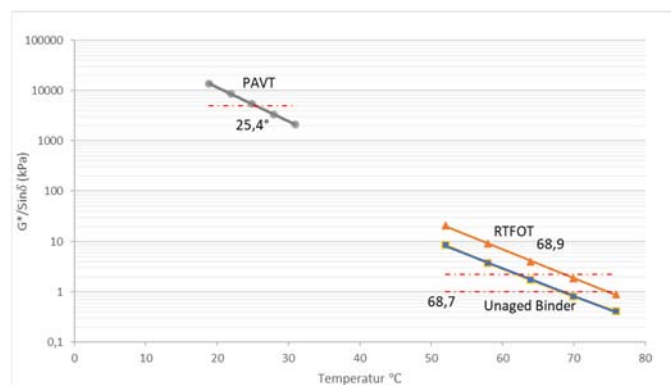
### 3.3. Asphalt Rheological Properties Using DSR

Mechanistic rheology testing ( $G^*$  and  $\delta$ ) was carried out using a DSR equipment referring to AASHTO T315 [1]. The tests were carried out on three asphalt conditions: 1. Original, which showed the first stage of conveying and storage; 2. Conditions after RTFOT which showed the second stage of aging at the production in the asphalt mixing unit and implementation in the field; 3. Conditions after PAVT which showed the final stage of aging during the pavement service period. In this study, the temperature ranges and loading frequency were carried out based on the requirements stated in the M320 AASHTO specifications.

**3.3.1. Temperature Sweep.** DSR temperature sweep testing is usually carried out to verify asphalt grade in PG system, related to the mechanistic behavior of asphalt, SUPERPAVE set limits on the value of  $G^*$  and  $\delta$  on the rut parameter and fatigue crack parameter. For example DSR temperature sweep testing for RAP added with Reclamite can be seen on Table 1 dan Figure 1.

**Table 1.** DSR Testing Results for RAP added with Reclamite.

No.	Temperature (°C)	Original			RTFOT			PAVT		
		G* (kPa)	$\delta$ (°)	G*/Sin $\delta$ (kPa)	G* (kPa)	$\delta$ (°)	G*/Sin $\delta$ (kPa)	G* (kPa)	$\delta$ (°)	G*/Sin $\delta$ (kPa)
1.	18,9	-	-	-	-	-	-	8,92.10 <sup>6</sup>	41,43	13480
2.	22	-	-	-	-	-	-	6,01.10 <sup>6</sup>	44,26	8605
3.	24,9	-	-	-	-	-	-	3,94.10 <sup>6</sup>	47,31	5354
4.	28	-	-	-	-	-	-	2,56.10 <sup>6</sup>	50,26	3330
5.	31	-	-	-	-	-	-	1,66.10 <sup>6</sup>	53,26	2069
6.	52	8426	82,28	8,503	20620	77,48	21,13	-	-	-
7.	57,9	3801	84,66	3,817	9096	80,93	9,211	-	-	-
8.	63,9	1728	86,55	1,731	4006	83,77	4,03	-	-	-
9.	69,9	820,1	87,91	0,8206	1853	85,92	1,858	-	-	-
10.	75,9	408,8	88,74	0,4089	900,9	87,48	0,9018	-	-	-

**Figure 1.** RAP added with Reclamite Critical Temperature Based on Rut Parameter and Fatigue Crack Parameter using DSR.

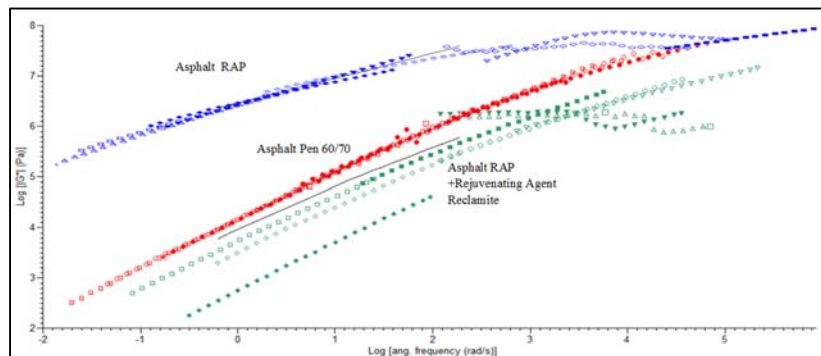
Based on these limits, a critical temperature was obtained for each asphalt condition to be used as seen in Table 2.

**Table 2.** Asphalt Pen 60/70, RAP and RAP added with Reclamite Performance Grade.

No.	Condition	Requirement	SUPERPAVE Criteria	Hasil Uji °C		
				Asphalt Pen 60/70	RAP	RAP + Reclamite
1	Original Binder	Min 1,00 kPa	Rutting	65,3	110,7	68,7
2	RTFOT	Min 2,20 kPa	Rutting	63,6	120,2	68,9
3	PAVT	Max 5000 kPa	Fatigue	23,7	52,8	25,4

Based on Table 2, the performance grade can be known based on the value of  $G^* / \sin \delta$  in the original condition. For asphalt pen 60/70, the PG value is 64. RAP has a PG value of 106, while RAP added with Reclamite has a PG value of 64. The change in the value of PG on RAP added with Reclamite showed a decrease in the value of PG which resulted in the same PG value as asphalt pen 60/70. This indicates that there has been a good rejuvenation process on RAP added with Reclamite.

**3.3.2. Master Curve.** The relationship between Bitumen Stiffness Modulus ( $S_{bit}$ ) and shifting factor was analyzed using a master curve which can also show the degree of asphalt sensitivity to changes in temperature and loading frequency.



**Figure 2.** Master Curve of Asphalt Pen 60/70, RAP and RAP added with Reclamite.

According to figure 2 Master Curve, asphalt pen 60/70 has a gentler slope. This indicates a wider temperature range and loading time, so it is easy to apply in the field. RAP added with Reclamite also approaches the 60/70 asphalt pen master curve, which means that Reclamite can increase the temperature range and loading time when compared to RAP without any rejuvenating material because the RAP has undergone aging.

The target Sbit value can be found by using speed of 5,65 Km/H (critical point) at frequency 0,10 Hz, where the log (frequency) = (-1). Then, make a vertical line cutting the master curve. Next, make a horizontal line to get the value of  $G^*$  (complex shear modulus) which will later be converted into the target Sbit value (stiffness modulus), the results can be seen in Table 3.

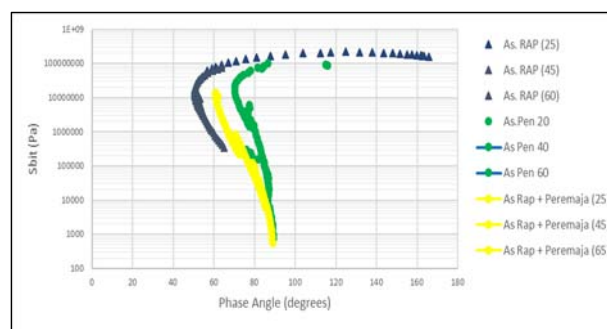
**Table 3.** Target Asbuton Stiffness Modulus (Sbit) of Asphalt Pen, RAP and RAP added with Reclamite based on the shift factor.

Asphalt Type	Target $G^*$ (Pa)	Target Sbit (Pa)
Asphalt Pen 60/70	180.300	540.900
RAP	20.100.000	60.240.000
RAP + Reclamite	73.450	220.350

The results obtained as a minimum target stiffness modulus of RAP after the addition of Reclamite becomes smaller even though it is not the same as the asphalt pen 60/70. Meanwhile, the RAP stiffness modulus is greater than the asphalt pen 60/70's because the RAP has undergone aging, so that it is stiffer.

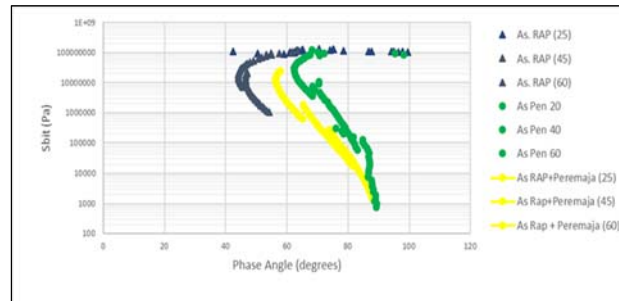
### 3.4. Black Diagram

The Black Diagram illustrates the relationship between Stiffness Modulus (Sbit) of Asphalt and Phase Angle ( $\delta$ ) in three conditions: original, RTFOT, and PAVT. The results can be seen on figure 3 until figure 5.



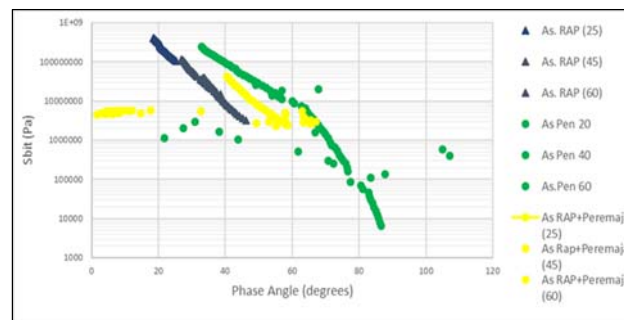
**Figure 3.** Black Diagram of the Original condition of RAP, Asphalt Pen 60/70 and RAP added with Reclamite.

Based on the black diagram, the original condition has a value of ( $\delta$ ) ranging from 40 -160. This means that the addition of Reclamite on RAP affects the Sbit value, where the Sbit value will decrease, as well as the increasing phase angle value. The phase angle increase in RAP added with Reclamite shows that the asphalt is more viscous compared to RAP without Reclamite.



**Figure 4.** Black Diagram of the RTFOT condition of RAP, Asphalt Pen 60/70 and RAP added with Reclamite.

Based on the black diagram in RTFOT condition, it can be seen that there is a phase angle decrease ranging from 40 to 100. This occurs because the specimen has undergone aging. This shows that the asphalt is getting harder. Same as the original condition, when RAP is added with Reclamite, the phase angle increases and Sbit decreases.



**Figure 5.** Black Diagram of the PAVT condition of RAP, Asphalt Pen 60/70 and RAP added with Reclamite.

On the black diagram in PAVT conditions, it can be seen that the phase angle value decreases with a range from 0 to 80. This was due to asphalt condition that continued to age. The same as the original and RTFOT conditions, when Reclamite is added to RAP, the phase angle increases and Sbit decreases.

#### 4. Conclusion

Based on the results of the study, it can be concluded that:

1. The empirical characteristics of asphalt pen 60/70 met the requirements of the Bina Marga 2010 General Specifications of Roads and Bridges, Whereas, on RAP there was a decrease in penetration value and softening point, as well as a reduced asphalt elasticity. This shows that the RAP had undergone aging.

2. Rheological characteristics for asphalt pen 60/70, RAP and RAP added with Reclamite using DSR:

- Based on the performance grade value from the temperature sweep, it was found that the PG value of RAP before it was added with Reclamite had a PG value of 106. But after the addition of Reclamite, the PG value was the same as asphalt pen 60/70. This shows that rejuvenating material can reduce the critical temperature value on RAP.

- The master curve illustrates that asphalt pen 60/70 had a smaller asphalt stiffness modulus than RAP, but after Reclamite was added to RAP, the asphalt stiffness modulus was smaller than asphalt pen 60/70, so the addition of Reclamite can reduce the stiffness modulus of RAP.

- Black diagram, in the original condition, had a large phase angle ( $\delta$ ) value range, where at the same sbit, the asphalt pen 60/70 had a greater ( $\delta$ ) value than RAP. Meanwhile, for RAP added with Reclamite, the value was between the value of RAP and asphalt pen 60/70. This illustrates that Reclamite makes RAP more viscous. Meanwhile, the RTFOT and PAVT conditions had a smaller range of ( $\delta$ ) value. This is because in RTFOT and PAVT conditions, the specimen was conditioned to undergo aging, which made the asphalt more elastic than the original condition.

## 5. References

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