

Analysis Rheological Characteristics of Nano Calcium Carbonate Modified Asphalt Mixture using Reclaimed Asphalt (RAP)

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Abstract— Rheological properties and empirical of nano calcium carbonate modified asphalt 60/70 using reclaimed asphalt are very important to know before using it in hot asphalt mixtures. Dynamic Shear Rheometer testing to test the performance and characteristics of unmodified and modified pen 60/70 with nano calcium carbonate percentages of 0%, 3%, 6%, 9%, 12%, 15%, 20% using 0%, 25%, 50%, 75% reclaimed asphalt. Common rheological indices obtained Dynamic Shear Rheometer tests are modulus (G^*), angle (δ) before, and after RTFO. The rut factor ($G^*/\sin\delta$) is used to assess the rut ability of modified asphalt as an index of high temperature performance, and the fatigue factor ($G^* \cdot \sin\delta$) is used to assess fatigue performance. The empirical test obtained the increasing content nano CaCO_3 and RAP asphalt content obtained a decreasing penetration value, which indicates that the mixture is getting harder and shows the asphalt mixture becoming less sensitive of temperature. Results of DSR test showed the increasing content of RAP asphalt and nano CaCO_3 became thicker, with increasing temperature rutting value ($G^*/\sin\delta$) decreased, which implies binder performance will be negatively affected terms rutting resistance so that it becomes susceptible to permanent deformation. Increasing the value of $G^*/\sin\delta$ causes better performance of rutting. All samples showed higher rutting resistance at lower temperatures.

Keywords— Reclaimed Asphalt (RAP), Nano Calcium Carbonate, Dynamic Shear Rheometer.

I. INTRODUCTION

RAP is old asphalt pavement that has been damaged and recycled for reuse as asphalt mixture material. A certain amount of RAP is added new aggregate, mixed with asphalt to asphalt pavement material. Utilization of RAP is known to result in savings in material costs, energy, maintaining pavement surface elevation and preserving natural resources. The use of RAP is known to continue to increase from year to year. Currently, almost 91 million tons of old pavement are being stripped and almost 80% of it is used as RAP (F. Xiao., 2006).

Nanomaterial-modified asphalt binders improve performance by providing additional resistance to stresses in flexible pavements, permanent deformation or grooves, thermal cracking pavement, moisture damage, and fatigue cracking (Jaafar MA, Joni HH, Karim Hussein, 2022).

Modified asphalt assumed to be one of most solutions pavement durability. Modified asphalt several methods using materials at different levels of modified. Using modified asphalt allows for improved fatigue and rutting properties for types of surfaces very heavy loads, and service environmental conditions (Sarsam, S. I., 2013). The inclusion modified asphalt can increase viscosity of the binder, reduce the thermal vulnerability the binder, and increase cohesion of the asphalt cement.

The aim of this research is to evaluate modulus (G^*) and angle (δ) values modified asphalt using test results with a Dynamic Shear Rheometer before and after RTFO.

II. METHODS AND MATERIALS

In this research, the materials used was asphalt pen 60/70 produced by Pertamina, modified with Nano Calcium Carbonate (Nano CaCO_3) material and mixed with RAP asphalt which was used as a result of the extraction of reclamation material from the erosion of the Palimanan Kanci Toll Road in Cirebon. Rheology testing uses Dynamic Shear Rheometer tool. Testing of objects starts from characteristics of modified pen 60/70 with Nano Calcium Carbonate (Nano CaCO_3) levels of 0%, 3%, 6%, 9%, 12%, 15%, 20% and asphalt content extracted from RAP of 0%, 25%, 50%, 75%. Rheology testing was carried out on 56 test objects using the DSR testing tool RTFO (Rolling Thin-Film Oven).

III. ANALYSIS AND RESULTS

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A. Physical properties of pen 60/70 asphalt

The asphalt in this research is pen 60/70 Pertamina's production. In the laboratory several tests are carried out to determine basic properties of asphalt. Characteristics of pen 60/70 asphalt from penetration testing, softening point, flash point, specific gravity were found to be 64.0, 50.2, 243.5, 1.033, fulfilling the in General Specifications for Highways.

B. Properties Physical of Asphalt RAP

Determine of amount the asphalt content in RAP, extraction carried out with Trichloroethylene (TCE) liquid using a Reflux Extractor, showing an average result of 5.16%. Results of penetration test, softening, flash point, specific gravity were found to be 60.4, 56.6, 313, 1.072. Based on the test results, it shows that the RAP asphalt is an aging process.



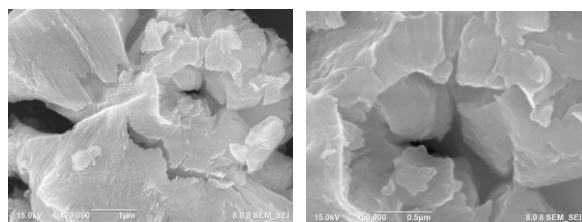
Figure 1. RAP Asphalt Distillation Extraction



Figure 2. RAP Extraction Testing

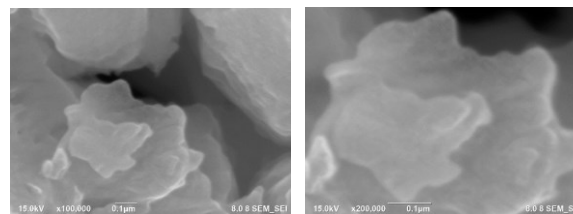
C. Scanning Electron Microscopy (SEM) Testing for Nano Calcium Carbonate (CaCO₃)

The results of physical testing of calcium carbonate nanomaterial (CaCO₃) in the form of scanning electron microscopy (SEM) testing at the LIPI Physics Research Center Laboratory, PUSPITEK Complex, Serpong, South Tangerang with magnifications of 20,000x, 50,000x, 100,000x and 200,000x can be seen in Figure 3.



20,000 x

50,000 x



100,000 x

200,000 x

Figure 3. SEM test results for nano CaCO₃

The mineral content contained in nano calcium carbonate (CaCO₃) Advanced SEM Test results is as in Figure 4.

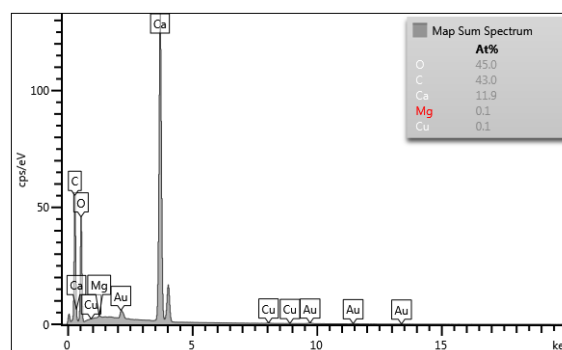
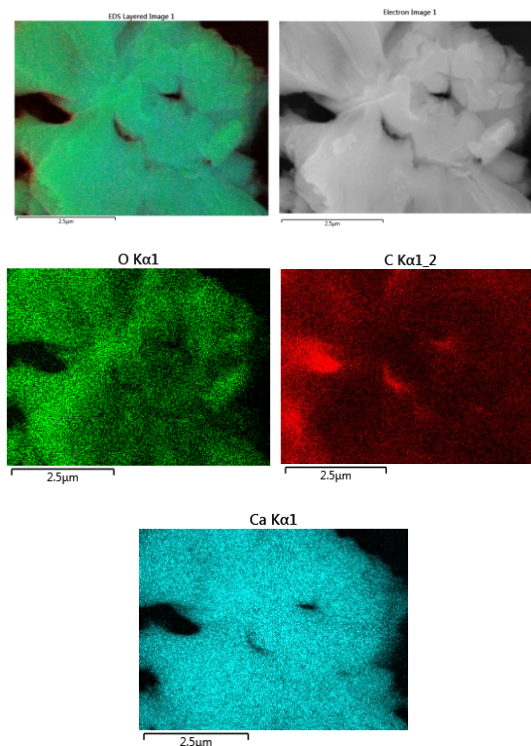


Figure 4. Mineral Content in Calcium Carbonate (CaCO₃)

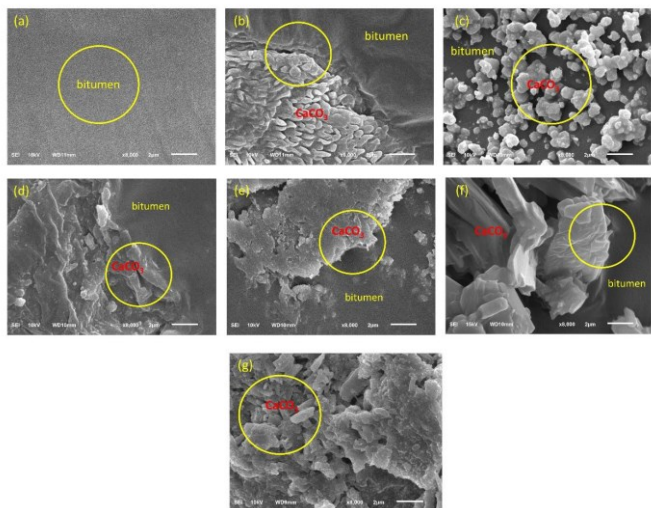


Figure 5. SEM image results of bitumen samples without (a), and with variations in nano CaCO₃ 3% (b), 6%(c), 9%(d), 12%(e), 15%(f) and 20%wt(g). The area inside the yellow circle is the image capture between interactions.

Based on the SEM results, there are differences in the distribution of CaCO₃ particles. This difference in distribution causes differences in physical properties asphalt and CaCO₃ composites. The better of particle distribution, the better the resulting mechanical properties where there is a synergistic effect asphalt and CaCO₃. The superior mechanical of CaCO₃ can improve mechanical properties of asphalt if the particles are well distributed as in the 6% sample. Apart from that, the bond that occurs between CaCO₃ and asphalt occurs physically, not chemically.

D. Modified Asphalt Testing (60/70 pen asphalt+Nano CaCO₃+RAP Asphalt)

Mixing nanomaterials with pure asphalt using a mechanical mixer speed at 1500 rpm and temperature at 145°C ± 5°C, mixing time of 45 minutes. Next, the properties of Pen 60/70 Asphalt Mixture and Nano Calcium Carbonate (CaCO₃) and RAP Asphalt were tested RTFO. Based on the results, as the nano CaCO₃ content and RAP asphalt content increase, the penetration value decreases, this indicates that the mixture is getting harder and shows the asphalt mixture is less sensitive of temperature.

E. Properties of Asphalt, Modified Asphalt Rheological

Referring to T315, mechanistic rheological test (G* and δ) was carried from using Dynamic Shear Rheometer. This test carried out on unaged and RTFO asphalt as a representation of the performance asphalt at medium and high temperatures based of the requirements on the AASHTO specification regarding the temperature range and loading frequency. Figure 6, Figure 7, Figure 8, Figure 9 are results.

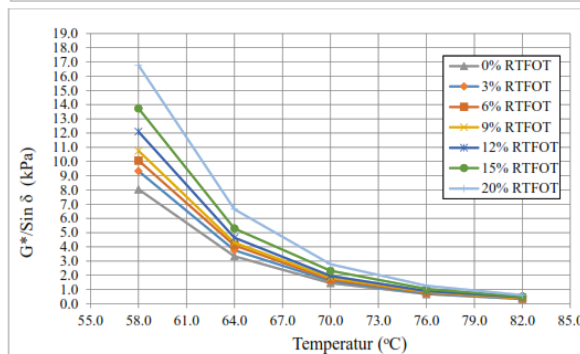
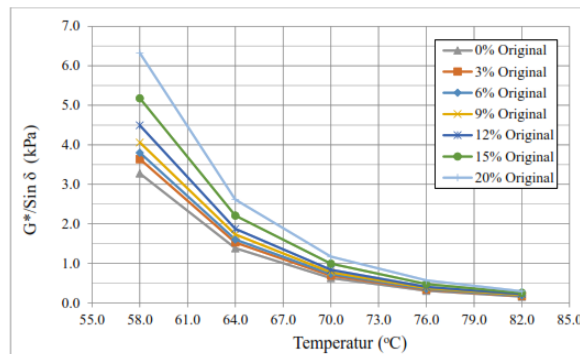


Figure 6. G*/Sin δ value with 0% RAP Asphalt Content

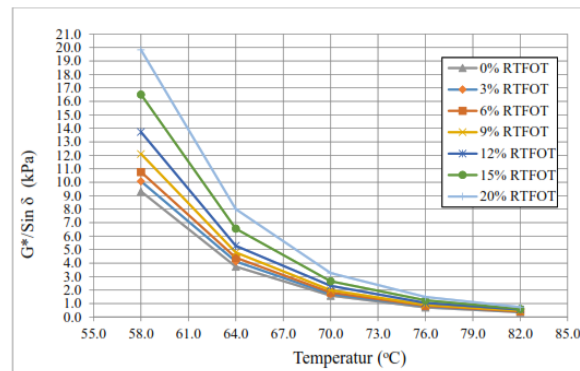
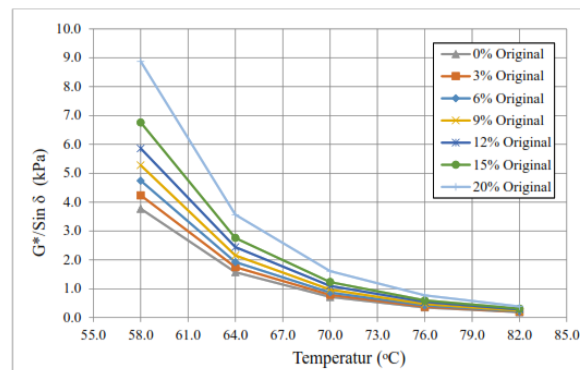


Figure 7. G*/Sin δ value with 25% RAP Asphalt Content

IV. CONCLUSION

Based on the description above, it can be concluded:

- Penetration Value from test results increases with increasing RAP Asphalt Content and Nano CaCO₃ Content, and the Softening Point and Flash Point values increase. The empirical properties of 60/70 pen asphalt meet the requirements the General Specifications for Highways.
- The higher the temperature, and angle (δ), lower the Modulus (G^*) value is obtained, higher the RAP asphalt content and nano CaCO₃ content, the higher Complex Modulus (G^*) value obtained.
- Nano CaCO₃ modified asphalt mixture using RAP asphalt has several specific characteristics that are beneficial, including increasing fatigue performance, strength and stiffness, making it more resistant to deformation and cracking, increasing water resistance, making it more resistant to water damage. Due to the synergistic effect nano CaCO₃ and interaction between nano CaCO₃ and asphalt.
- Overall, the nano CaCO₃ modified asphalt mixture using RAP asphalt has several favorable characteristics that make it a promising road construction material. The mixture can improve strength, stiffness, fatigue performance asphalt and water resistance, while reducing asphalt consumption.

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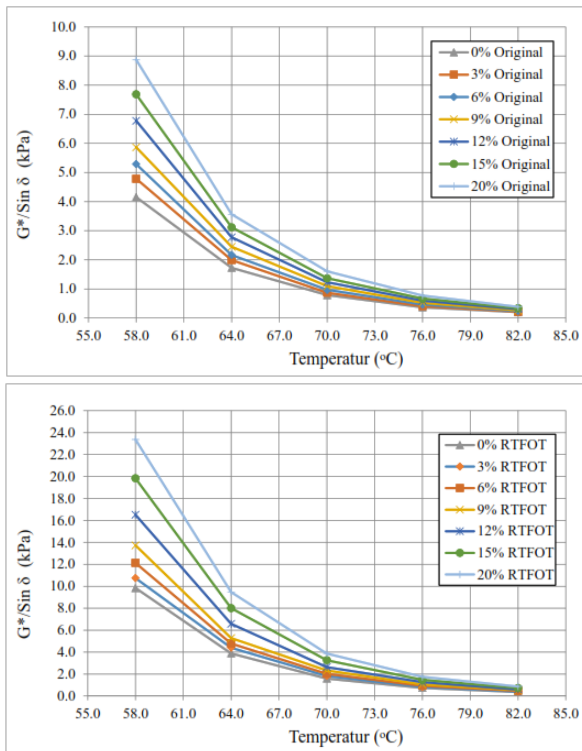


Figure 8. $G^*/\text{Sin } \delta$ value with 50% RAP Asphalt Content

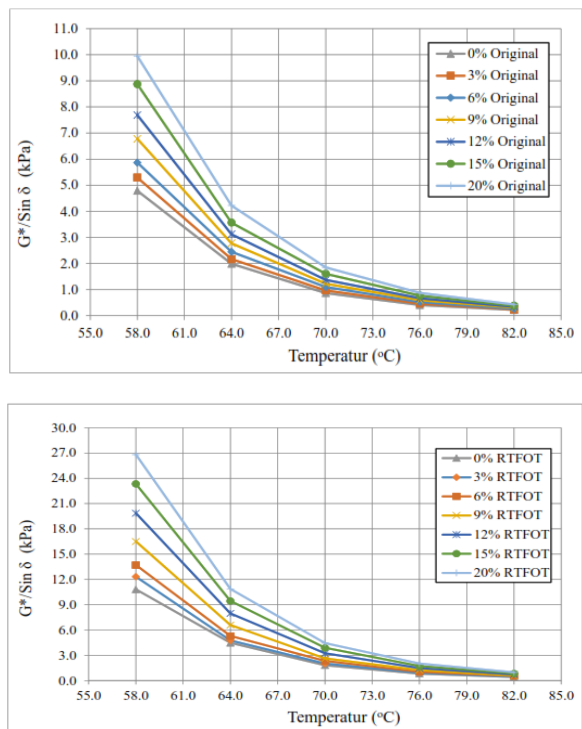


Figure 9. $G^*/\text{Sin } \delta$ value with 75% RAP Asphalt Content

Dynamic Shear Rheometer test results show the RAP and nano CaCO₃ asphalt content increases the thicker, with increasing temperature, the rutting value ($G^*/\text{sin}\delta$) decreases uniformly which implies the binder performance will be negatively affected terms of rutting resistance so that it becomes susceptible to deformation permanent. Increasing the $G^*/\text{sin}\delta$ leads to better performance rutting. At lower temperatures, the samples rutting resistance higher.