International Journal of Advance and Applied Research
www.ijaar.co.in
ISSN – 2347-7075 **Impact Factor – 7.328**
Peer Reviewed **Bi-Monthly**
Vol.10 No.1 **Sept – Oct 2022**

PERFORMANCE OF CRUMB RUBBER MODIFIER WITH ASPHALT AT HIGH TEMPERATURE

[1,2]Arun Kumar
[1]Dr. P. S. Charpe
[1]Department of Civil Engineering, Kalinga University, Raipur
[2]Galgotia College of Engineering & Technology, Gr. Noida
Corresponding Author : **Arun Kumar**

DOI- 10.5281/zenodo.8087866

Abstract

By increasing rigidity and elasticity at high service temperatures, CRM reduces the likelihood of rutting in asphalt. CRM treatment extends the fatigue life of asphalt by increasing the thickness of the asphalt layer around the aggregates, hence decreasing the asphalt's rate of ageing. CRM makes asphalt more effective at low service temperatures by reducing the material's stiffness. All of these improvements may be attributed to how the introduction of CRM particles has altered the chemistry and microstructure of asphalt. CRM, a complex constructed vulcanised compound, may serve a number of purposes in asphalt, depending on the nature of the contact. CRM is made from synthetic rubber and natural rubber, cross-linked with sulphur, and reinforced with Carbon Black. The compound's workability has been improved by the addition of antioxidants, and the commencement of oxidation has been postponed by the addition of aromatic hydrocarbons. CRM is resistant to complete disintegration in asphalt because of its cross-linked structure, yet its structure and integrity may change in reaction to the asphalt.

Introduction

Several studies have examined the effects of interaction context on the final characteristics of CRMA and the kinds of CRM activities. Incorporating a CRM into asphalt at contact temperatures below 165 °C causes the CRM particles to enlarge as they take up the asphalt's low molecular weight components. Because CRM particles may soak up these substances, the asphalt will have lower amounts of them, which might affect the modified asphalt's ultimate properties. CRM particle growth, caused by the particles' uptake of asphalt's light molecular weight components, must be taken into consideration in efforts to boost the material's performance. The expanded particles played a major factor in determining the asphalt's final characteristics. Abdelrahman et al. found that when CRM swelled, it improved the asphalt's stiffness, but that the stiffness decreased after the CRM dissolved into the asphalt binder. By increasing the shearing rate and the contact temperature, Billiter et al. (2017) were able to completely dissolve CRM in asphalt[1]. The approach was used to investigate the effects of CRM dissolution on the asphalt's mechanical qualities. The dissolved CRM was hypothesised to undergo more depolymerization at higher contact temperatures, resulting in a lower mean molecular weight. There are two possible outcomes when CRM and asphalt interact: expansion of CRM or complete destruction of CRM. The fact that either CRM or asphalt may be present during a contact further complicates matters[2]. The dynamics of the interaction may also alter the dissolving process. Here Differential scanning rheometry, thermogravimetric analysis, and gel permeation chromatography were among the many analytical techniques utilised to learn how CRM dissolving in asphalt affects the characteristics of changed asphalt.

Dissolution of Crumb rubber modifier in Asphalt

CRM particles less than 0.075 mm in size (passing through mesh #200) were deemed dissolved. The findings indicated a standard deviation of 0.75, which is statistically significant and indicative of the test's good repeatability.

Effect of Interaction Parameter in Dissolution of Crumb rubber

The influence of interaction mixing speed, duration, & mixing speed on CRM dissolution is shown in Figure1. Different interaction temperatures are shown by the lines, while varied mixing velocities are represented by the symbols[3]. From figure 1 it is observed that at 190°C and the slowest speed of mixing (10Hz), CRM does not dissolve appreciably in asphalt, but that at 215°C, the same speed of mixing results in a dramatic increase in CRM dissolution. Figure 1 further demonstrates that the temperature has a significant impact on the mixing speed and time effect. The rate and depth of CRM dissolution are unaffected by the mixing speed at 160 C.

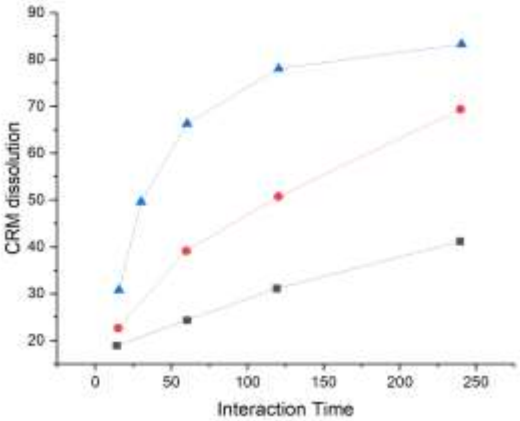

Figure 1 CRM Dissolution Vs Interaction Time

In addition, there seems to be little impact of time on the decline of CRM systems, as shown by the flattening trend line[4]. Nevertheless, the disintegration rate and extent are both greatly affected by the mixing speed between 190 and 220 degrees Celsius.

CRM concentration

Figure 2 illustrates, for a variety of interaction settings, the pace of dissolution as well as the amount of it at three different CRM concentrations (12%, 16%, and 18% by the initial weight of asphalt). The interaction circumstances are shown by the lines, whilst the CRM concentrations are shown by the symbols. At a temperature of 190 degrees Celsius, Figure 2 illustrates that an increase in CRM concentration from 10% to 20% by weight of the asphalt causes a little suppression in the rate of CRM dissolution. This is because aromatic compounds are unable to pass through the CRM structure, which makes its decomposition a more challenging process[5-6]. Nevertheless, at 215 degrees Celsius and 50 hertz, CRM will disintegrate regardless of how much there is.

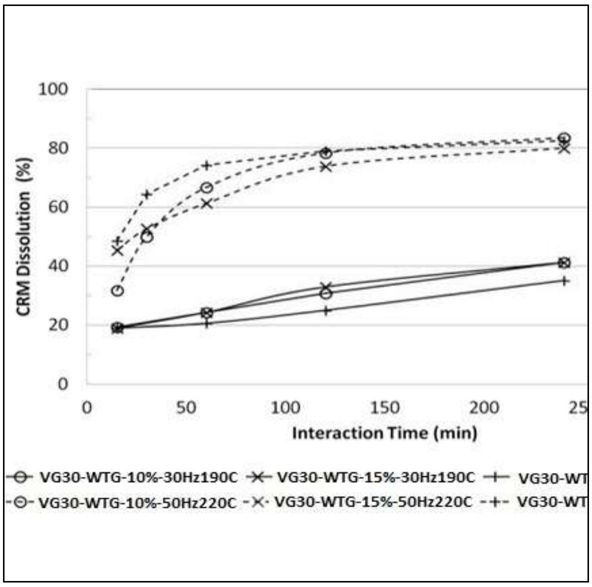

Figure 2 CRM Dissolution vs Interaction at different Percentage

From figure 2 is observed that, the fact that the concentration of CRM has no effect on dissolution when the temperature is 215 degrees Celsius and the frequency is 50 hertz, it is suggests under these conditions, the interaction parameters (mixing speed and temperature) are the most important factors that regulate the CRM's ability to dissolve asphalt[7-9].

Material type

In order to explore the influence that material sources have on the dissolving behaviour of CRM in asphalt, various interactions employing a variety of sources of materials were carried out. Researchers subjected two CRM samples, both with the same asphalt (Figure 3), to analyse the impact of CRM mix. CRM samples were taken from two distinct kinds of tyres: passenger truck (or "TR") tyres and car (or "WTG") tyres. To further investigate how asphalt composition could affect the dissolving pattern of CRM, Figure 4

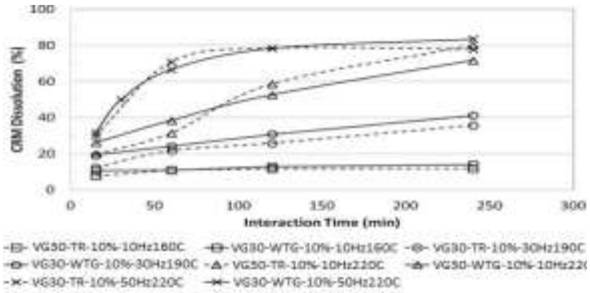

Figure 3: CRM Dissolution vs Interaction Time of different tyre

was created using two asphalt sources of the same PG grade.

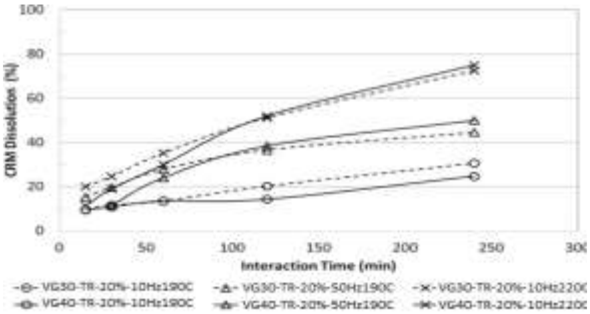

Figure 4: CRM dissolution vs Interaction of Asphalt on the bases of Source

Under the interaction circumstances that were investigated, the findings indicate that the source of the material does not substantially affect the dissolving trend of CRM. This is in spite of the findings of other research, which reveal that truck tyres have a better compatibility with asphalt in contrast to passenger vehicle tyres, owing to the varied amounts of natural rubber included in each kind of tyre[10]. This suggests that during the brief time of contact between asphalt and CRM, as well as in the presence of mixing speed and heat, the interaction conditions are the most important effective characteristics that determine the behaviour of CRM. Viscoelastic Analysis as Function of CRM Dissolution Abdel rhaman has conducted a significant amount of research on the subject, focusing on the question of how the length of contact time affects the viscoelastic characteristics of asphalt. Since the findings of the research that Abdelrahman carried out served as the basis for this study, the bulk of the findings from that research were created again here in order to be able to build upon it. This was done so that the study could expand upon the previous work.

Viscoelastic analysis of CRMA

Figure 3 shows that the CRMA's modulus and phase angle change with time as a function of the dissolved CRM concentration. The progression of time is shown alongside this shift. This growth occurs at both a 12 and 18 percent CRM concentration. Increases in CRMA stiffness and phase angle at low dissolving percentages, as shown at 160 °C or during the early phases of the interaction at 190 °C, may be related to the growth of the CRM particles.

However, it has been proven via previous tests that the physical characteristics of the CRMA begin to deteriorate as the amount of dissolved CRM grows. This might be associated with the size decrease and/or fragmentation of the CRM particles. More than 80% of the CRM disappears once this process reaches steady state. Next, we'll see that the asphalt liquid phase, which now contains the dissolved CRM component, is the primary factor in defining the sample's overall physical properties. This is due to the fact that the dissolved CRM component is present in the asphalt liquid phase. In the sections that follow, I'll provide evidence that backs up my claims. The 20% disintegration rate of the CRM is seen to cause the structure to weaken and eventually collapse in all three dimensions.

Temperature Dependent Viscoelastic Analysis

Using the DSR in temperature sweep mode, we investigated how the dissolution of CRMA samples affected the temperature dependency of their viscoelastic features. However, the findings for the 10% CRM samples are left out since the released component concentration is too low to show any significant differences in the physical characteristics of the CRM in liquid phase samples.

Changes in the physicochemical characteristics of CRMA may be detectable depending on the concentration of CRM. It's possible that the changes are too slight to notice at lower CRM concentrations. However, the alterations may be more noticeable at larger doses. The CRM concentration and other parameters, such as the testing settings, may affect how CRMA's viscoelastic properties change with temperature. In order to properly comprehend the correlation between CRM concentration and the temperature dependency of CRMA's viscoelastic properties, further study is required.

The findings from earlier research showing CRM alteration had a less impact on asphalt's physical characteristics at lower testing temperatures, suggesting that this modification primarily impacts the material's high-temperature capabilities. When comparing the rutting resistance of unmodified bitumen at lower temperatures, mixes containing this component showed a significant increase at 50 °C. The findings show that mixes including unmodified bitumen undergo a shift from viscoelastic solid-like to fluid-like bitumen behaviour towards 50 °C, whereas mixtures containing modified bitumen still tend to display viscoelastic solid-like behaviour. This is supported by the lower temperature for rutting requirements and the lower apparent viscosity of unaltered bitumen. The sensitivity to transition and rutting is in line with the observation that unmodified bitumen has the lowest softening point. Polymer modified bitumen-containing composites were more resistant to rutting than those including other binders, especially at the higher temperature of 60 °C. When compared to combinations including other types of modified binders, those using natural rubber modified bitumen were shown to exhibit much more rutting. It demonstrates that at 60 °C, mixes containing natural rubber modified bitumen respond viscoelastically fluid-like to loading, but the shift from viscoelastic solid-like to viscoelastic fluid-like may occur at a higher temperature in the case of other modified binders.

When CRM is added to asphalt, it forms an internal network within the asphalt matrix, which improves the asphalt's elasticity, durability, and resistance to cracking. The formation of the plateau zone in the phase angle graph of CRMA samples is an indication of the formation of this internal network. At an interaction temperature of 190 degrees Celsius, the asphalt's internal network is well established, and the plateau region is emphasized. However, as the interaction temperature is increased to 220 degrees Celsius, the plateau region starts to contract. This suggests that the internal network is breaking down at higher temperatures.

The composition of the released CRM components from the asphalt depends on various factors, such as the type of tires used to produce the CRM, the processing method, and the degree of degradation of the CRM during its service life. These components can interact with the asphalt's molecules and form a complex internal network that improves the asphalt's performance. The use of CRMA in asphalt has become increasingly popular as a sustainable solution for road construction. It offers numerous benefits, such as reducing the need for landfill space, conserving natural resources, and enhancing the performance properties of asphalt. However, the use of CRMA in asphalt requires careful consideration of the processing conditions and the quality of the CRM to ensure the desired performance.

Conclusion

In order to optimise the production process and achieve the desired performance improvements in asphalt binders, it is crucial to understand the behaviour of this liquid phase at different temperatures and mixing conditions, as its composition and characteristics are crucial in determining the performance properties of CRMA. This study demonstrates that, When the CRM is dissolved in the asphalt, it creates a homogenous mixture that can improve the overall performance of the asphalt. The intermediate interaction temperature of 190°C is crucial for ensuring that the CRM is fully integrated into the asphalt. At this temperature, the CRM will dissolve quickly and form a homogenous mixture with the asphalt. A fast mixing speed is also important for creating a more homogenous CRMA. The faster the mixing speed, the more evenly the CRM will be dispersed throughout the asphalt. This can help to improve the overall performance of the CRMA and ensure that it has enhanced high service temperature characteristics.

Incorporating CRM into asphalt binders in the form of CRMA has been shown to improve the performance characteristics of the resulting pavement, such as increased stiffness, reduced rutting, and improved fatigue resistance.

By creating a more homogenous CRMA, the distribution of CRM within the asphalt binder can be improved, leading to more consistent and predictable performance. The enhanced high service temperature characteristics of CRMA can also help to improve the durability and longevity of asphalt pavements, particularly in areas with high temperatures and heavy traffic loads. This can help to reduce the need for frequent maintenance and repairs, ultimately saving time and money for road builders and municipalities.

Reference

1. Abdelrahman, M.A. and S.H. Carpenter, *Mechanism of interaction of asphalt cement with crumb rubber modifier*, in *Transportation Research Record: Journal of the Transportation Research Board*. 1999, Transportation Research Board of the National Academies: Washington, D.C. p. 106-113.
2. Bahia, H.U., H. Zhai, and A. Rangel, *Evaluation of Stability, Nature of Modifier, and Short-Term Aging of Modified Binders Using New Tests LAST, PAT, and Modified RTFO*, in *Transportation Research Record: Journal of the Transportation Research Board*. 1998, Transportation Research Board of the National Academies: Washington,
D.C. p. 64-71.
3. Lu, X.H. and U. Isacsson, *Effect of ageing on bitumen chemistry and rheology*.
Construction and Building Materials, 2002. 16(1): p. 15-22.
4. Liu, M., et al., *Changes in Corbett Fraction Composition During*

Oxidation of Asphalt Fractions, in *Transportation Research Record: Journal of the Transportation Research Board*, D.C. Washington, Editor. 1998, Transportation Research Board of the National Academies: Washington, D.C. p. 40-46.

5. Bahia, H.U., H. Zhai, and A. Rangel, *Evaluation of Stability, Nature of Modifier, and Short-Term Aging of Modified Binders Using New Tests LAST, PAT, and Modified RTFO*, in *Transportation Research Record: Journal of the Transportation Research Board*. 1998, Transportation Research Board of the National Academies: Washington,
D.C. p. 64-71.

6. Huang, S.C. and A.T. Pauli, *Particle size effect of crumb rubber on rheology and morphology of asphalt binders with long-term aging*. Road Materials and Pavement Design, 2008. 9(1): p. 73-95.

7. Branthaver, J.F., et al., *Binder Characterization and Evaluation Volume 2: Chemistry*. 1993, National Research Council: Washington, DC.

8. Cortizo, M.S., et al., *Effect of the thermal degradation of SBS copolymers during the ageing of modified asphalts*. Polymer Degradation and Stability, 2004. 86(2): p. 275-282.

9. Zhang, H.L., H.C. Wang, and J.Y. Yu, *Effect of aging on morphology of organo- montmorillonite modified bitumen by atomic force microscopy*. Journal of Microscopy, 2011. 242(1): p. 37-45.

10. Siddiqui, M.N. and M.F. Ali, *Studies on the aging behavior of the Arabian asphalts*. Fuel, 1999. 78(9): p. 1005-1015.