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USE OF STYRENE-BUTADIENE-STYRENE (SBS) TO IMPROVE THE HOT STORAGE STABILITY OF CRUMB RUBBER MODIFIED BITUMEN

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ABSTRACT

The need for transportation has been rising concurrently and gradually with the expansion of the global population, because they allow access to almost everywhere, however, the rapid deterioration of highway pavements is another effect of the growing demand for transportation. The main strategy for stopping pavement deterioration is to make the materials used to build highways more durable. To improve the formulation of bitumen modified with low-solubility components, this study investigates how to crumb tyre rubber and polymeric additives such as SBS impact the physical characteristics and hot storage stability of bitumen. Bitumen grade 60-70 was used in this study, and truck tyre rubber was crushed into crumbs with a mesh size of 30. The sample was placed in 35mm and 165mm long aluminium tubes, with the closed end at the top. The Hot storage stability, softening point, and penetration point of crumb rubber mesh no. 30 was found to be optimal at 10% CR content and 3% SBS when stored at higher temperatures at 1, 3, 5, and 7 hour intervals. The grade of bitumen decreases when the CR content remains constant at 10% and the SBS ratio in bitumen increases from 1% to 3%. The addition of SBS content (1%-3%) significantly enhanced the softening point of binder bitumen. The higher the softening point, the more temperature resistance the binder possesses.

Keywords: SBS, CR, HSS, ME, CG, WJ, CRMB, TB.

I. INTRODUCTION

With the growth in world population, the requirement for transportation has been continuously increasing. Since they provide access to practically everywhere, highways continue to be the most frequently used mode of transportation in the world for both passenger and freight traffic (Köfteci, S., Ahmedzade, P., & Kultayev, B. 2014). Rising traffic demand, on the other hand, hastens the deterioration of highway pavements. The principal strategy for preventing pavement deterioration is to increase the quality of roadway construction materials. Bitumen is a construction material used as a binder in flexible pavements (Tayabji, Shiraz D., et al 2010, & Memon, N. A. 2011). Shredded rubber from old tyres has been used in pavement construction since the 1930s. The potential for improving the effectiveness of asphaltic mixes, as well as the possible solution for reducing unnecessary tyres in landfills, has resulted in increased use. Rubber crumbs can be mixed with aggregates in an asphaltic mix (dry process) or combined with bitumen at a certain temperature to function as a binder modifier (wet process). The resilience modulus, fatigue cracking resistance, and rutting resistance of asphaltic mixes have all been found to be improved by the wet process modification of crumb rubber. This is due to changes in the bituminous binder's viscosity, softening point, loss modulus, and storage modulus characteristics (Ibrahim, Mohd Rasdan, et al.,2013 & Presti, D. L., et al 2017). To create a fresh bituminous mixture, the undesired residue is converted when crumb rubber (waste tyre) is used in bitumen modification (Memon, N. A., et al 2021). It is well known that ageing affects the functionality and properties of bitumen binders. The bitumen may become harder for a variety of reasons, including oxidation, volatilization, polymerization, and thixotropy. Field investigations have demonstrated that crumb rubber can enhance the performance of bitumen pavements (Ali, Asim Hassan, et al. 2013 & Lo Presti, D, et al., 2009). Most highway pavement and airport runway applications have been successfully completed using conventional bituminous materials. However, throughout the past ten years, an increase in axle weights, heavy traffic, harsh weather, and construction failures necessitated improving the original bitumen's qualities. Asphalts' resilience to environmental conditions including temperature, air quality, and water may be significantly impacted. The ideal bitumen should be able

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to sustain permanent deformation or rutting at high temperatures while being soft enough to prevent fatigue and excessive thermal strains at low pavement temperatures. By using polymers, which are known to provide bitumen with superior viscoelastic behavior, these flaws in bitumen can be fixed. Bitumen and polymer mixtures create multiphase systems. These systems include phases that are high in polymer, high in asphaltenes that are not absorbed by the polymer, and high in maltenes (Nejad, Fereidoon Moghadas, et al. 2012 & Memon, N. A, et al., 2016).

II. LITERATURE REVIEW

Several studies are conducted to enhance the storage capability of bitumen. In this work, the impact of SBS copolymer and compositions of asphalt on the characteristics of CR/SBS modified asphalts made using the terminal blend (TB) technique are examined. Such CR/SBS modified asphalts, often known as TB binders, had been made by combining 20% CR granules with two base asphalts and varying SBS copolymer concentrations. The materials were subjected to conventional, rheological, force-ductility, rotational viscosity, thermal storage, and fluorescence microscopy tests. The findings demonstrate that unmodified asphalts cannot match the qualities of TB rubberized binders. SBS copolymers were added to TB rubberized asphalts, which further enhanced their characteristics, proving that this method of making high-performance binders is workable. However, compared to the addition of CR, the improvement brought about by the addition of SBS copolymer was less significant (Qian, C., & Fan, W. (2020). Comparing novel high-pressure water jet (WJ) technology to more conventional methods like mechanical shredding (ME) or cryogenic processing, it has been demonstrated that WJ produces CR with a rougher and bigger surface area (CG). When employed as a modifier, this gave bitumen exceptional low-temperature characteristics. As a conclusion of fracture toughness testing at -10 C, the results specifically showed that WJ technology tended to increase strength more than CG and ME. The performance of the material under examination improved in low temperatures as the rubber particle size grew (up to 1000 mm) (Loderer, C., Partl, M. N., & Poulikakos, L. D. (2018).(Yadav, V 2017) In order to increase the storage stability and physical and rheological characteristics of CRMB and to achieve better-desired storage ability, several long-chain amines were doped into crumb rubber in this study. This study suggested that SBS chemically changed asphalt to enhance hot storage stability and other performance characteristics. The outcomes demonstrated that SBS chemically treated asphalt had a high hot storage stability and that other performance traits were significantly improved. Fluorescence microscopy was used to examine the phase morphology of SBS-modified asphalt and SBS chemically modified asphalt (Sun, D., & Lu, W. (2003). According to the literature review, most research is conducted in different parameters from one another. Many factors, like the amount of time, spent mixing, the temperature, and the size of the Crumb rubber particles, might differ from research to study. In this research, crumb rubber and SBS were blended with bitumen to discover the optimal quantity that adds to the hot storage capacity.

III. MATERIALS AND METHODS

A. The raw ingredients used in this study

1. Bitumen (60/70)
2. Crumb rubber
3. SBS

The materials utilized in this study had the physical attributes shown in table 1.

Table 1. Materials and their specific gravity

Materials	Specific Gravity
Bitumen	1.01
Crumb rubber	1.63
SBS	0.94

Figure 1: Bitumen

Figure 2: Crumb Rubber

Figure 3: SBS Material

B. Material and sample preparation

The bitumen modifying method in this study was primarily built in accordance with the (ASTM) requirements. Each powdered crumb rubber sample was sieved through a No. 30 sieve in a laboratory. Following that, the CR ratio for each sample was fixed at 10%, and the SBS was mixed into the bitumen at the following ratios: (0%, 1%, and 3%). The hot bitumen was placed in a steel tank over the hot plate. The hot plate temperature was set between (170°C and 200°C). The crumb rubber powder and SBS were then gently mixed in a steel tank with a 3000rpm high shear mixer. The time required to combine CR and SBS with bitumen was increased from 60 to 90 minutes. The procedure is continued until the mixture is homogenous. The samples were then placed in metal tubes (EN 13399). The dimensions of the aluminum tubes were (35mm in diameter and 165mm in length). The tubes were sealed from the bottom and placed in a (140°C to 150°C) oven. These samples were kept upright in a microwave using a steel stand at 1, 3, 5, and 7 hours intervals. By optimizing the various SBS percentages (0%, 1%, and 3%), the best quantity of SBS was identified. The optimum proportion of SBS was found to be 3% bitumen and 10% crumb rubber based on the results of frequent bitumen testing.

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Figure 4: High Shear Mixer

Figure 5: Aluminum Tube Containing SBS-CRMB

IV. RESULTS AND DISCUSSION

The test results of prepared SBS-CR modified blends with bitumen grade (60/70) which are obtained from the laboratory after determination of their physical properties (i.e penetration test, softening point test) are shown below figures at 0%, 1%, and 3% SBS.

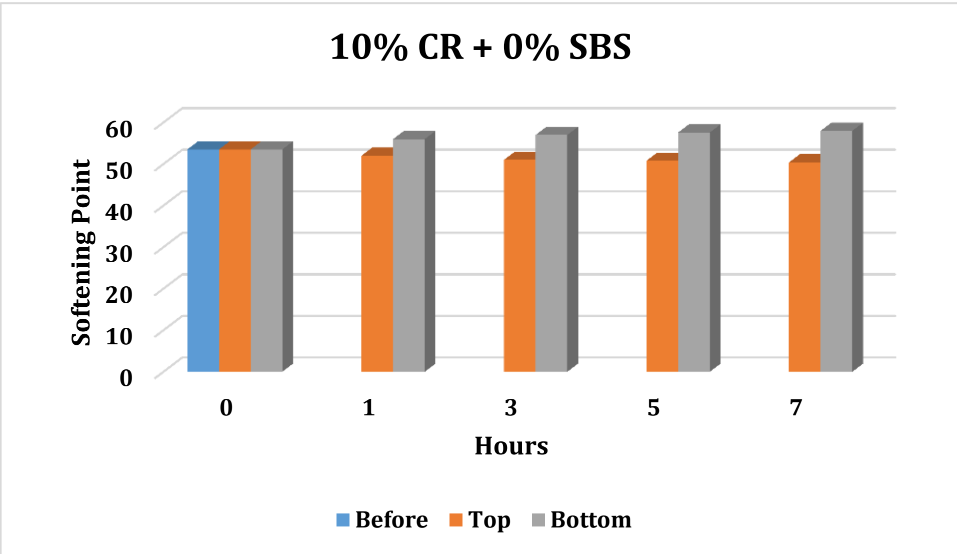

Figure 1: Softening Point at 10% CR and 0% SBS

The CR particles are distributed in the bitumen when 10% CR and 0% SBS by weight of base bitumen are used. After storage at increased temperatures for 0, 1, 3, 5, and 7 hours, the findings were fairly close in most situations. Still, the optimal storage stability was determined to be at 1 and 3 hours, which was shown to be more stable than basic bitumen.

The penetration levels start to decline when relative to the base bitumen with 10% CR and 0% SBS component, as seen in the figure above. High- and low-density CR particles settle towards the bottom and top of the aluminium tube, respectively. In this situation, 1 and 3 hours of storage stability produced the greatest outcomes.

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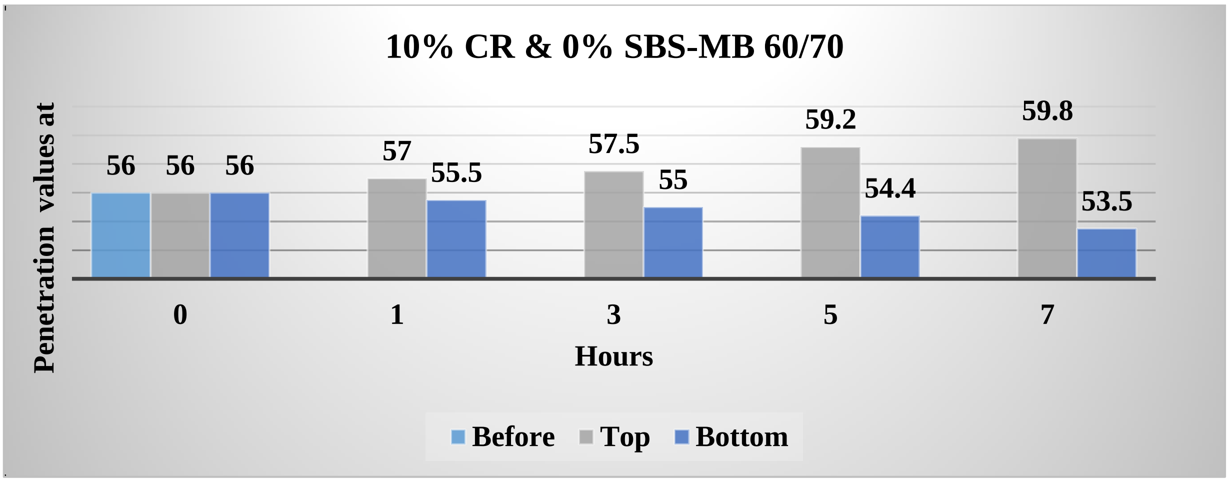

Figure 2: Penetration values at 10% CR and 0% SBS

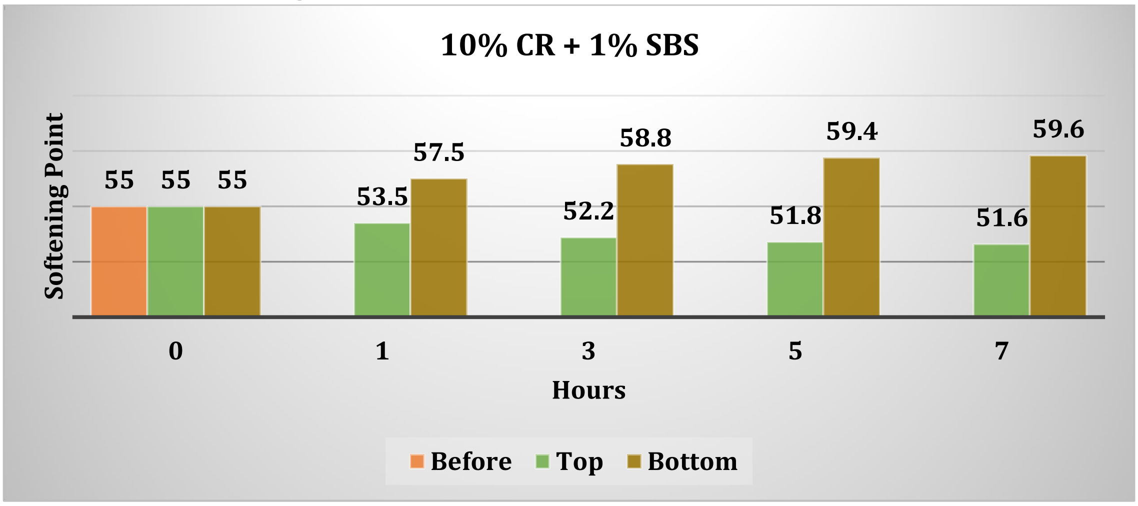

Figure 3: Softening point at 10% CR with 1% SBS

The above figure illustrates, it can be concluded that using 10% of CR and 1% SBS by the weight of base bitumen, the CR and SBS particles are dispersed in the bitumen. The results were compared with 0 hours of storage stability. After analyzing the results, the softening point was increased up to 4.6°C i.e 55 to 59.6°C.

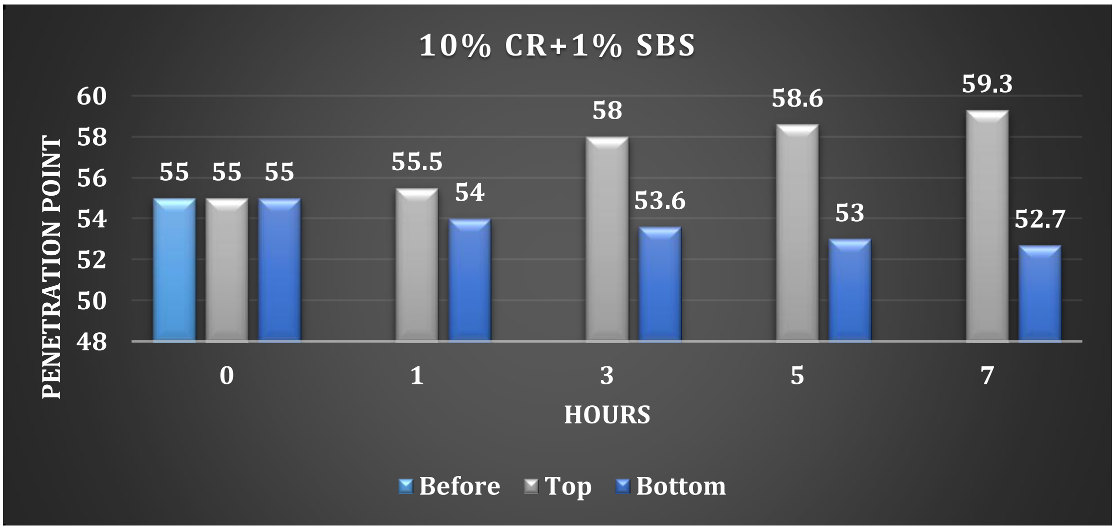

Figure 4: Penetration values at 10% CR with 1% SBS

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According to Figure 4, the penetration values begin to drop when compared to the base bitumen with 10% CR and 1% SBS content. Low-density CR and SBS particles settle in the top section of the aluminium tube, whereas high-density particles settle at the bottom. The findings were compared to storage stability of zero hours. Following an analysis of the data, the penetration value was reduced to 2.4mm.

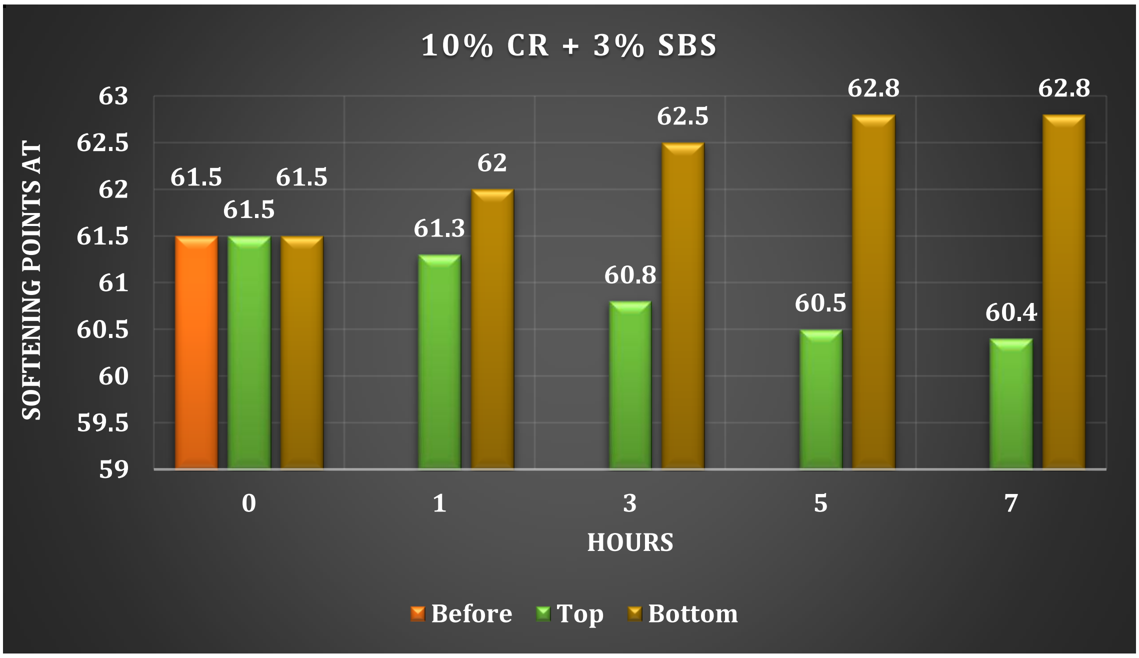

Figure 5: Softening point at 10% CR with 3% SBS

From the above-shown figure, it can be determined that 10% CR and 3% SBS by weight of base bitumen are used to distribute the CR and SBS particles in the bitumen. The results in all the cases were extremely close, and the ideal storage stability was discovered to be at 1, 3, and 5 hours after storing at increased temperatures for 0, 1, 3, and 5 hours, respectively. Because there is more space in the aluminum tube for the CR and SBS particles to spread out and because of their lower density, which causes them to settle at the top of the tube and cause the bitumen to harden and have a higher softening point, the top section exhibits a greater difference than the bottom section.

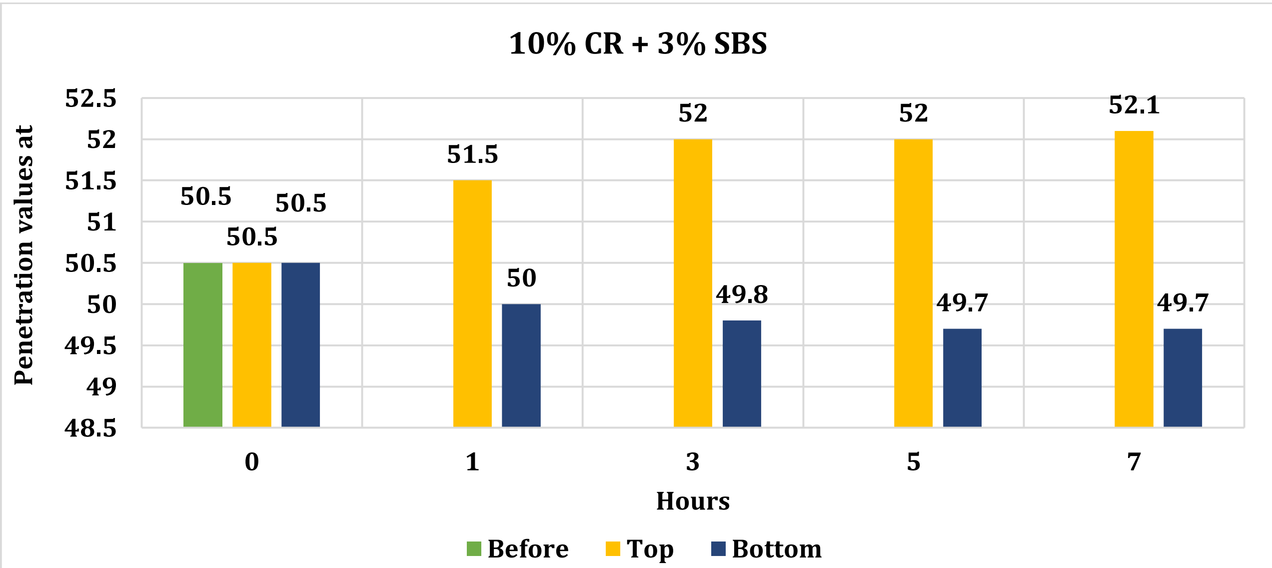

Figure 6: Penetration values at 10% CR with 3% SBS

As illustrated by Figure, as compared to base bitumen that contains 10% CR and 3% SBS, the penetration levels start to decline. Low-density CR and SBS particles settle near the top of the aluminum tube, while high-density particles are transported to the bottom. The best penetration values were discovered at 1, 3, and 5 hours of storage stability compared to zero hours of stability. The difference in penetration grade between the top and bottom sections of this portion was extremely small. We have chosen this entire region as an optimal penetration grade for this reason.

V. CONCLUSION

The use of crumb rubber with bitumen modifications has significant advantages, including improved physical and mechanical properties of the bitumen, which leads to an increase in the durability of bitumen roads. In this study, modified bitumen was used with the SBS to improve bitumen storage stability in hotter regions, as climate change has posed a serious threat to bitumen roads. According to the above results, the optimal value for the physical properties of bitumen (softening and penetration) was obtained by mixing 3% SBS. It is very useful on the roads, especially in warmer climates. Because of the stiffness of crumb rubber particles, 10% crumb rubber content significantly increases the softening point of base bitumen and decreases the penetration grade of base bitumen. When the CR content remains constant at 10% and the SBS ratio in bitumen rises from 1% to 3%, the grade of bitumen falls. The inclusion of SBS content (1%-3%) increased the softening point of binder bitumen considerably. The higher the softening point, the more resistance the binder has to the temperature.

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