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Use of Waste Tyre Rubber in Flexible Pavement as Bitumen Binder

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ABSTRACT

Nowadays waste tyre rubber from vehicles has been a global issue. Recycling this tyre rubber can be one strategy towards this issue. The waste tyre rubber can be utilised as a crumb rubber modifier (CRM) in the flexible pavement through mixing it with asphalt, which may additionally lead to minimising the price of materials for flexible pavement construction. This paper presents the details of various tests performed to decide the effect on the engineering properties of bitumen (of 60/70 penetration grade) after adding crumb rubber into it. The tests include different percentages of crumb rubber (0%, 5%, 10%, 15%, and 20%) by weight of bitumen into it. Testing of rubberized bitumen suggests that 15% crumb rubber modifier at 180°C blending temperature have a significant effect on engineering and rheological properties of modified bitumen including improved consistency, high-temperature susceptibility and high adhesive properties.

Keywords: Asphalt, Crumb Rubber Modifier (CRM), Engineering Properties, Rheological Properties, Rubberized Bitumen, Waste Tyre Rubber

1. INTRODUCTION

Amidst the transportation on flexible pavement, it undergoes structural damage due to application of traffic load on repeat mode, which leads to the formation of fatigue cracking of asphalt bound layer and rutting along wheel tracks. Through the years, the improvement of modified asphalt materials to enhance the general overall performance of pavement has been the focal view of several researchers. One of the steps taken in this direction can be theutilization of scrap or discarded tyre rubber of automobiles in the construction of pavement. As disposal of tyre rubber is also a primary issue, its utilization in pavement ought to reduce environmental pollution and maximize natural resource conservation.

Crumb rubber can be received via shredding scrap tyre into a material free from fibre and steel. It can be produced by two techniques: Ambient grinding and the Cryogenic process. In ambient grinding,the material is loaded interior to the crack mill or granulator at ambient temperature. The cryogenic process requires freezing the scrap tyre with the usage of liquid nitrogen till it becomes brittle and then cracking the frozen rubber into smaller particles with a hammer mill.

It is estimated that India discards about 275,000 tyres per day and regrettably most of these are disposed of in an environmentally unfriendly manner [1]. Bitumen of 60/70 penetration grade is used generally in the maximum location of India and due to excessive traffic loading and hot weather conditions, pavement distresses appear pretty early in-service life of the flexible pavement. Therefore, the use of crumb rubber in bitumen modification can be considered as sustainable science that would radically change traditional bitumen into a new bitumen mixture notably resistant to rutting and fatigue deformations [3].

Currently, researchers on applications of rubberized bitumen binder in the flexible pavement have stated many advantages. These consists of accelerated bitumen resistance to rutting due to excessive viscosity, softening point, improved bitumen resistance to surface-initiated cracks and reduction of fatigue cracking, reduction of temperature susceptibility and improved durability as well as a reduction in road pavement maintenance value. The properties of rubberized bitumen binder at a wide range of temperature are highly dependent on the chemistry of bitumen binder, the crumb rubber content, size and texture of rubber particles and blending circumstances [5].

The viscous-elastic properties of bitumen are decidedusing the differing percentages between asphaltenes and maltenes fraction. According to the microstructure and the colloidal system of bitumen, asphaltenes are diffused into an oily matrix of maltenes and encased by a shell of resins whereby its thickness varies with the temperature that is being tested. As a result, bitumen mechanical properties and microstructure are influenced by bitumen composition, blending temperature, and the degree of aromatisation of maltenes and asphaltene concentration [6, 13]. Previous research has shown that the foremost mechanism of bitumen-rubber interaction is the swelling of the rubber particles because of the absorption of the mild fractions of oil into the rubber particles and stiffening of the residual binder. Also, the elevated property of rubberized bitumen is possible to depend on the interaction between crumb rubber and bitumen binder. Crumb rubber particles swell when combined with the bitumen to structure a viscous gel, aim to enhance the viscosity of the rubberized bitumen binder.

This research aims to decide the impact of incorporating crumb rubber modifier (CRM) on the engineering properties of modified bitumen binder. The physical and rheological properties of the bitumen binder are modified using various percentages of CRM that have been decided and assessed with different laboratory tests.

2. BASIC METHODOLOGY

Materials:

Crumb Rubber iscollected from Gill Rubber Pvt. Ltd., located at Nagpur. These crumb rubbers were used to modify bitumen 60/70 penetration grade which was collected from Shivhare Petrochem located at Nagpur, Maharashtra. In this study, crumb rubber size 30 mesh (0.6 mm) was used to reduce segregation.

Table1: Conventional Properties of Base Bitumen (60/70 Penetration Grade)

Properties	Desirable values for base bitumen	Actual value of base bitumen	Testing standard specifications
Penetration Value (at 25°C, mm)	60-70	66	IS 1203 (Bureau of Indian Standards 1978a) [7]
Softening point (°C)	45-55	48	IS1205 (Bureau of Indian Standards 1978b) [8]
Viscosity (Poise)	2400-3600	2600	IS 73, ASTM [9]
Specific Gravity	0.9-1.02	0.99	IS 1202(Bureau of Indian Standards 1978) [10]

***Specific Gravity of Crumb Rubber =1.029**

Preparation of Crumb Rubber Modified Binder:

In this procedure rubberised bitumen binder was prepared by mixing bitumen of 60/70 penetration grade with CRM (0%, 5%, 10%, 15%, 20% by weight of bitumen) passing through a 30-mesh sieve. The propeller mixer is used to mix the bitumen and crumb rubber at a blending temperature of 180°Cfor 90 minutes of continuous blending. The blending speed provided to the setup was 350 revolutions per minute [12].

Tests Conducted:

A series of binder tests have been carried out on the modified bitumen binder to decidethe highest quality mixture parameters of mixing temperature and CRM content. The binder checks encompass Viscosity test as per IS 1206-1978, penetration test at 25°C as per IS 1203(Bureau of Indian Standards 1978a), softening point test as per IS 1205 (Bureau of Indian Standards 1978b), ductility test as per IS 1208.

3. RESULTS AND DISCUSSION

The different tests were carried out as per specifications and the results are discussed in this section in details.

Penetration Test

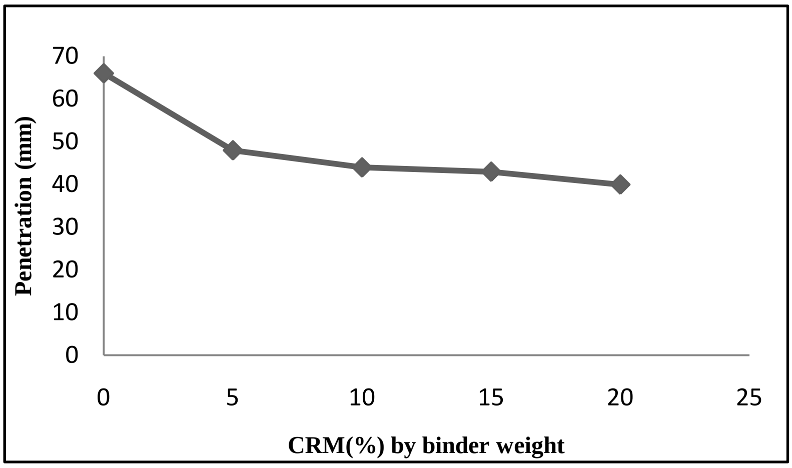

Figure 1: Penetration Value vs. CRM Content

From the above illustration between the penetration values versus CRM content, it was found that the penetration value of rubberized bitumen binder relies upon their relation with crumb rubber content. Results indicate that minimization in penetration takes place with the enlargement of crumb rubber content in bituminous specimens. (18-62) % reduction for (5-20) % rubber content material respectively can be seen in the penetration value of CRM modified bitumen binder sample compared to unmodified bitumen sample.

Test consequences showed that the CRM content in the rubberized bitumen led to a decrease in the penetration values, agreeing with the findings of preceding studies [12]. These outcomes are won due to Crumb rubber content material performing a study impact on penetration discount with the aid of growing the stiffness of crumb rubber modified bitumen binder. This would make the binder extra resistant to high-temperature susceptibility whichleads to high resistance to everlasting deformation like rutting. Previous studies have proven that blending temperature about 180°C beautify the particle dimension of rubber and led to an increase in rubber mass through the interaction and swelling of the rubber in bitumen at some point of the mixing process, which led to minimizingthe penetration values of rubberized bitumen pattern.

Softening Point Test

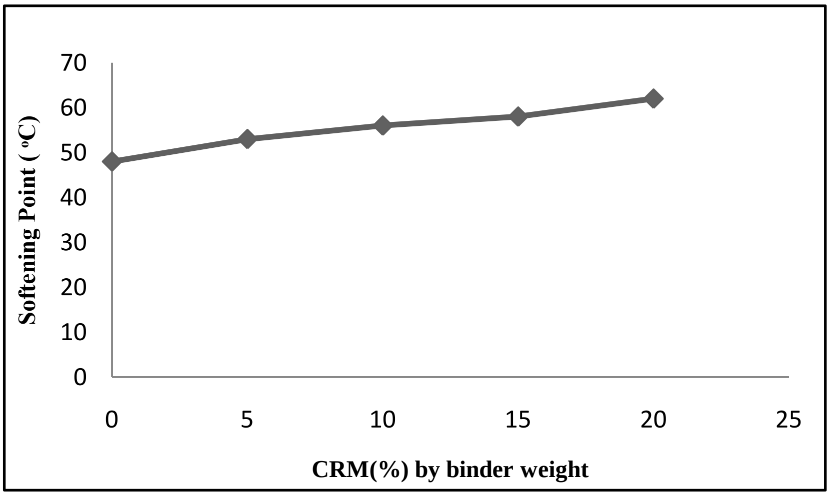

Figure 2: Softening Point vs. CRM Content

Graphical representation of Softening point value versus CRM content shown in figure 2 illustrates that at 180°C the increase in crumb rubber content leads to a high softening point of modified bitumen samples of about 5°C-14°C for 5%-20% rubber content respectively. The reason for this variation might be the increase of rubber content in the mix due to which an increase in asphaltenes/resin ratio occurred which enhanced the stiffness properties of bitumen and make the modified binder less susceptible to temperature changes.

Alongside, the optimum blending temperature leads to the increase in rubber volume through the interaction and swelling of rubber into the bitumen during the blending process that leads to an increase in softening point values of rubberized bitumen sample. This increase of softening point in this study was similar to the findings of Mashaan and Karim [13]. The main role in increasing the softening point can be performed by crumb rubber content, regardless of its type and particle size. A stiff bitumen binder can be obtained due to an increased softening point which holds the ability to enhance its recovery after elastic deformation. Also, due to an increase in binder molecular weight when the crumb rubber interacted with the bitumen binder increase in softening point occurred.

Viscosity Test

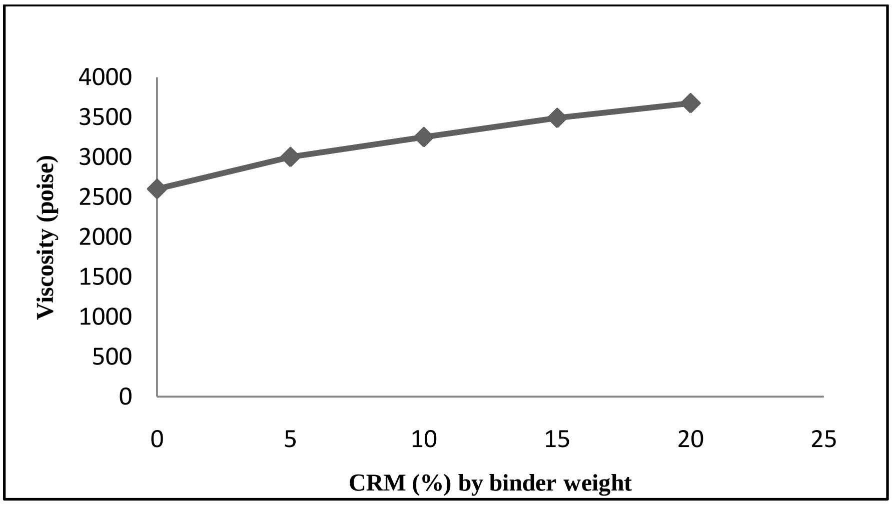

Figure 3: Viscosity vs. CRM Content

Viscosity can be categorised as the rheological property of the bitumen and is a measure of flowresistance of bitumen. Viscosity can greatly influence the potential of the resulting paving mixes at the application temperature. The graphical representation (figure 3) shows an increase in viscosity at different CRM content in modified samples ata mixing time of 90 minutes.

In this study, it was found that the viscosity of bitumen increases with the increase of rubber content from5% to a high CRM content of about 20%. Such an increase in viscosity with increased crumb rubber content has been shown by Mashaan and Karim [13]. Also, the increase in viscosity may have occurred due to the addition of CRM content at an optimum temperature that led to the increase in elasticity and breakdown of crosslink of rubber, this phenomenon would make the binder thicker and more elastic. During sample preparation selection of desirable blending,the temperature is highly appreciated which would maintain an acceptable viscosity that enables the bitumen binder to coat the aggregate effectively. In return,this would help to ensure better workability of rubberized bitumen that reduces the permanent deformation. The increase in viscosity may also be due to the number of rubber resins in the bitumen which enhances the viscous flow of modified bitumen sample during the interaction process.

According to previous studies, an increment in crumb rubber content leads to an increase in viscosity at 135°C. Bureau of Indian Standards suggests that the specification of maximum viscosity at 135°C should not be more than 3699Poise for virgin bitumen. In this study,the viscosity of the 20% rubber content sample has exceeded the limit and thus it is not recommended.

CONCLUSION

Based on the research that has been carriedon the use of tyre rubber as bitumen binder as crumb rubber modifier, the following conclusions have been drawn:

i. According to laboratory binder tests, it is clear that the crumb rubber content performed an extensive position in bettering the overall performance and rheological properties of rubberized bitumen binders. It can additionally enhance the performance properties of bitumen pavement resistance towards deformation in the course of building and road services.
ii. The effects of binder assessments performed on rubberized bitumen modified at 180°C showed the increase in viscosity, softening point as well as a reduction in penetration that notably influences the performance properties of rubberized bitumen.
iii. An increment in crumb rubber content material with the aid of 20 %, confirmed a corresponding increase in viscosity value that is greater than IS Specification limits (3600 poise).Therefore, crumb rubber modifier

content material of 20% and above is now not suitable as far as ease of pavement construction involved due to the high viscosity of rubberized binder.

iv. The conclusions derived from this research will also include the promotion of sustainable improvement through recycling of waste materials to produce new materials in an environment-friendly manner.

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