PERFORMANCE EVALUATION OF A PARTIALLY SYNTHETIC BITUMEN COMPOSED OF INDUSTRIAL WASTE

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Abstract- Bitumen is produced from non-renewable natural resources. Depletion of non-renewable resources intrigued researchers to look for alternative binders. Bitumen has been modified with many additives to enhance its properties and performance. The improper disposal of waste materials such as crumb rubber and use engine oil poses a significant threat to the environment. The addition of these industrial waste products to asphalt not only provides a safe and cost-effective way to dispose of them, but also improves the asphalt binder's performance. In this study, various combinations of waste engine oil and crumb rubber have been used with 60-70 penetration grade bitumen to produce a partially synthetic bitumen. Adhesion being one of the key characteristics of the bituminous binder has been assessed by using bitumen bond strength test along with penetration and softening point. The experimental results revealed that partially synthetic bitumen with 35% waste and 40% percent waste improves the adhesion along with conventional properties. Furthermore, the results of partially synthetic bitumen demonstrate that this bitumen is more suitable for cold regions of the country. A detailed and extensive testing program is needed to reach authentic findings but based on the results authors are hopeful that a handsome percentage of waste can replace the virgin binder giving a cost effective and environmentally friendly solution.

Keywords: - Synthetic Bitumen, Adhesion, Waste Engine Oil, Crumb Rubber

1 Introduction

Bitumen is a binding agent used in flexible pavements. Increased road transport volume, environmental and external factors, and construction-phase failures can reduce asphalt pavements' useful life and increase the probability of permanent faults [1]. Mohammad Gohar et al., investigated that the 15% addition of crumb rubber increases the stiffness, viscosity and high softening point and improves the rutting resistance of conventional bitumen [2]. Ahmed Eltwati et al, investigated that, the addition of the WEO-CR rejuvenator improved the overall performance of the mixture by improving the physical and chemical properties of the asphalt binder and the mechanical performance of hot-mixed asphalt (HMA) [3].

Christopher Daniel et al., investigated the use of waste engine oil mixed with reclaimed asphalt. He noticed that asphalt binders blended with Reclaimed asphalt binder (RAB) might have less stiffness and better low temperature qualities due to waste engine oil. Asphalt pavements can also be made softer by used engine oil without harming the pavements' susceptibility to moisture. [4]. Touqeer Shaukat et al., studied the Rheological evaluation of asphalt modified with auto-mobile engine waste oil. He concluded that the increased cohesion of asphalt molecule chains is due to the increased viscosity of asphalt modified with 2.5% filtered waste engine oil. Comparison of master curves shows that binder modified with waste engine oil can better perform at low temperatures to resist fatigue cracking [5]. Jia, X. et al. conclude that waste engine oil residues have a significant impact on the reduction of asphalt binder's low-temperature stiffness and improvement of its low-temperature performance [6]. Birendra Kumar Singh et al. investigated that by lowering the size of the crumb rubber, the resistance to rutting has been enhanced and can improve high temperature performance of bitumen.[7]. Herda Yati Katman et al. conclude that crumb rubber modifications of bitumen enhance bituminous binder properties such as Viscosity, softening point, loss modulus, and storage modulus. Consequently, this enhances the rutting

resistance, resilience, and fatigue cracking resistance of asphaltic mixtures. [8]. M. F. Ahmad et al. evaluate the Bitumen is a petroleum product obtained from the fractional distillation of crude oil, a natural resource. Natural resources are depleting continuously, significantly impacting its price hike and environmental pollution. Asphalt binder has been modified with many modifiers to counter the problem of waste material management, depletion of natural resources, and improving the performance of conventional binder. The use of modified or alternative binders is both cost-effective and environmentally friendly [9]. Feng, Zhao et al. evaluated the waste engine oil-modified bitumen and concluded that WEO reduces the softening point and viscosity of binder while increasing its penetration. He also concluded that an excess WEO adversely affects the binder properties [10]. Liu et al. evaluated the rheological behavior of waste engine oil-modified bitumen and concluded that fatigue resistance and low-temperature performance are improved, but the binder's rutting resistance and high-temperature performance are impaired. They concluded that from chemical tests, there is no evidence of a chemical reaction between bitumen and WEO. They recommended the range of 4-8% WEO modification [11].Liu et al. studied the rheological behaviour of WEO-modified bitumen and determined that the addition of waste engine oil reduces the asphalt binder's elasticity. it shows lower values of complex modulus and higher values of phase angles. WEO improves the fatigue performance but impairs the rutting resistance of bitumen [12].

The objectives of this research are as follows:

1. To examine the combined impact of WEO and CR on bitumen's conventional properties.
2. To examine the impact of WEO and CR on the adhesion properties of asphalt mixture.
3. Determination of the optimum combination dosage of various constituents for manufacturing of cost effective and environmental friendly partially synthetic bitumen.

2 Experimental Procedures

2.1 Material Preparation and its Mixing Proportion:

The 60/70 pen grade bitumen was collected from PARCO refinery. Waste engine oil was collected from local motor vehicle repairing plants and markets. Using filter paper of grade Whatman 1002-150, waste engine oil was filtered out. CR was extracted from used tire scrape and grind them in shredder plants. After being crushed, the material passes through sieve No. 50/300 microns/0.2997 mm Then, various proportions of used motor oil and crumb rubber were mixed with bitumen. Prior to adding waste engine oil and CR into bitumen, the bitumen is heated to 150°C on a hot plate, where the temperature is kept constant and then mixed using a shear mixer.

Table1: Mixing proportions of WEO and CR

Sr. No	Dosage
1	B+5% WEO+20% CB
2	B+5% WEO+25% CB
3	B+5% WEO+30% CB
4	B+10% WEO+20% CB
5	B+10% WEO+25% CB
6	B+10% WEO+30% CB
7	B+15% WEO+20% CB
8	B+15% WEO+25% CB
9	B+15% WEO+30% CB

2.3 Testing Methodology:

The penetration and softening point tests, which were performed in accordance with ASTM D5 [13] and D36 [14], were used to characterize the impact of WEO and CR. PATTI was used as per ASTM D 4541 to evaluate the bond strength of

bitumen under dry and wet conditions [15]. Then used the burst pressure values in equation 1 to calculate the Pull-off tensile strength (POTS).

$$POTS = \frac{(BP * Ag) - C}{Aps} \qquad 1$$

Burst Pressure (BP), the contact area (Ag), which has a value of 2620 mm2, and C which has a value of 0.286, is the piston constant. Aps has a value of 127 mm2.

3 Research Methodology

This project's research methodology is shown in Figure 1.

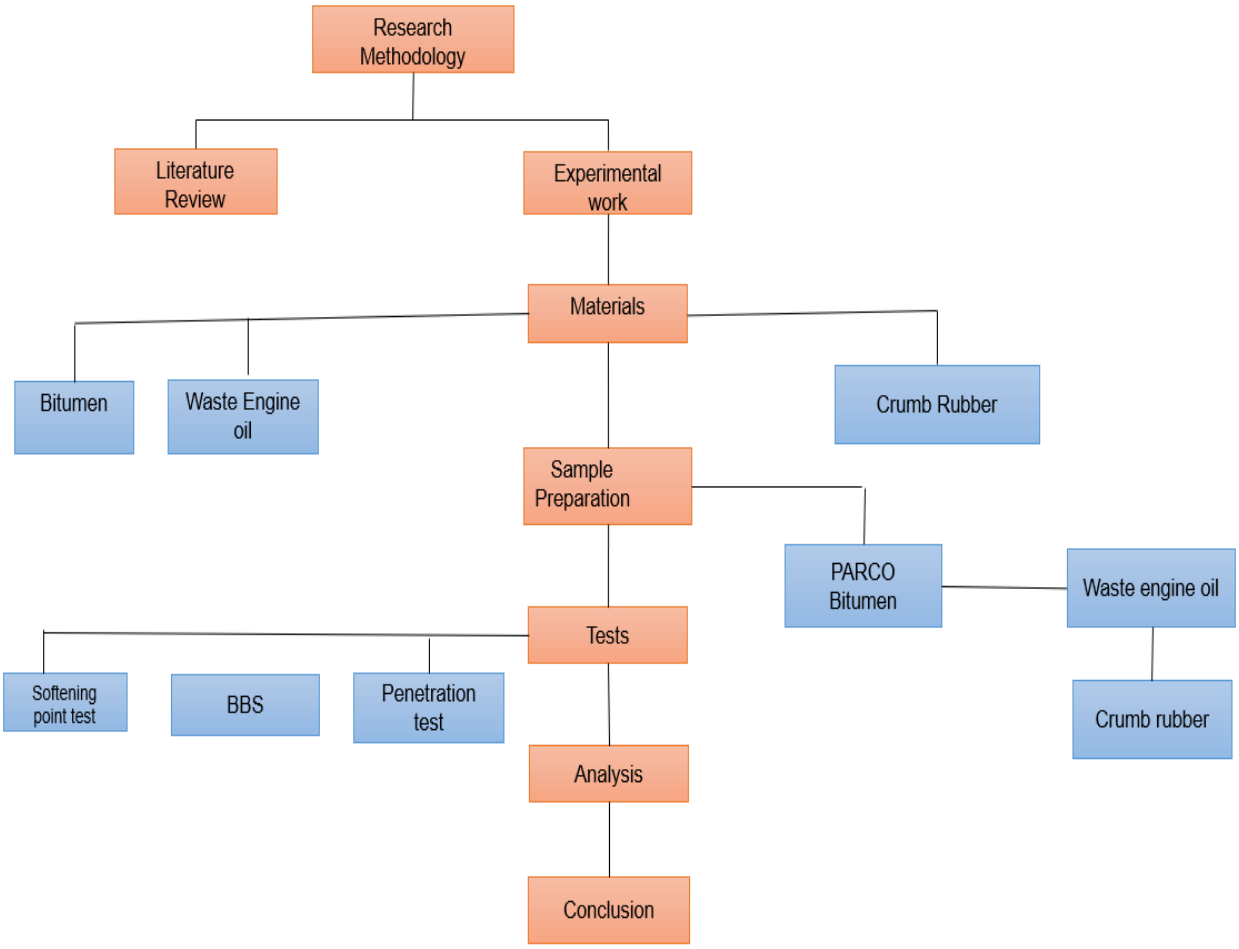

Figure 1: Research Methodology

4 Results

4.1 Conventional Testing:

In this method, for investigating the impact of modifiers on bitumen, conventional testing was conducted. The penetration and softening point test are performed to determine whether modified bitumen becomes soft or hard. Figure 2 depicts the experimental results of conventional testing.

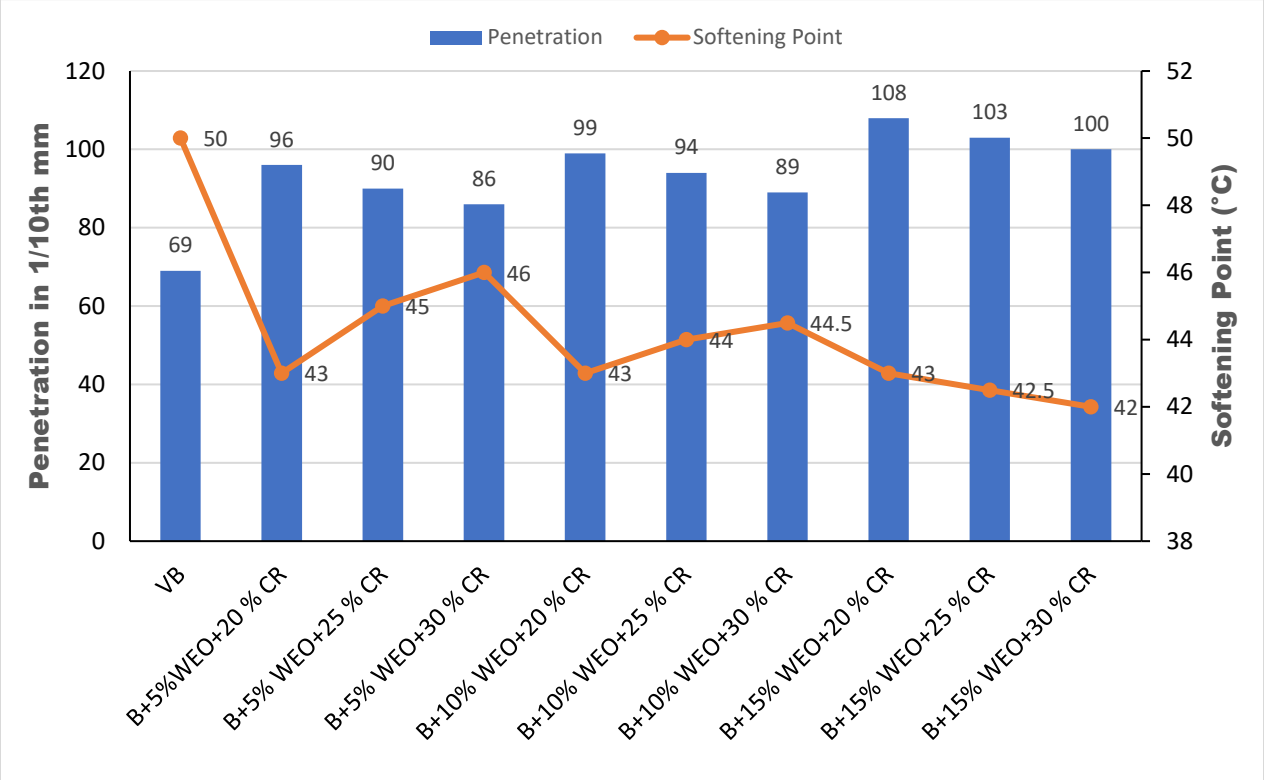

Figure 2: Effect of penetration and softening on partially synthetic bitumen

In Figure 2, The addition of 5% WEO with 20%, 25%, and 30% CR by total binder content increases the penetration value by 28%, 23%, and 20%, respectively, while the softening point decreases by 14%, 10%, and 8%. In 10% WEO with 20%, 25%, and 30% CR, a 30%, 26%, and 22% increase in penetration value and an 8%, 14%, and 12% decrease in softening point value were observed. Similarly, the addition of 20%, 25%, and 30% CR with 15% WEO resulted in a 36%, 33%, and 31% increase in penetration value and a 16%, 15%, and 14% decrease in softening point, respectively. Its mean that increasing the dosage of WEO results in higher penetration values and a lower softening point, whereas increasing the dosage of CR results in lower penetration values and a higher softening point. The addition of WEO softens the binder, whereas the addition of crumb rubber hardens and stiffens it, thereby enhancing its conventional properties.

4.2. Evaluation of Adhesion by using BBS Test:

The effect of WEO and CR on adhesion were experimentally evaluated by using PATTI. To determine the bonding strength of the binder to the aggregate surface, a Bitumen Bond Strength (BBS) test was performed for both dry and wet conditions. For dry conditioning, in figure 3, the addition of 5% WEO with the inclusion of 20%,25% and 30% CR by total binder content, after 24 hours of dry conditioning, POTS values decrease by 38 %,27% and 13%, In 10 % WEO with the inclusion of 20%,25% and 30% CR, a decrease of 67%,50% and 38% in value of POTS was observed at dry condition. Similarly, when 15% WEO was mixed with 20%, 25%, and 30% CR, the POTS value of the dry sample decreased by 72%, 58%, and 50%, respectively, when compared to the virgin binder

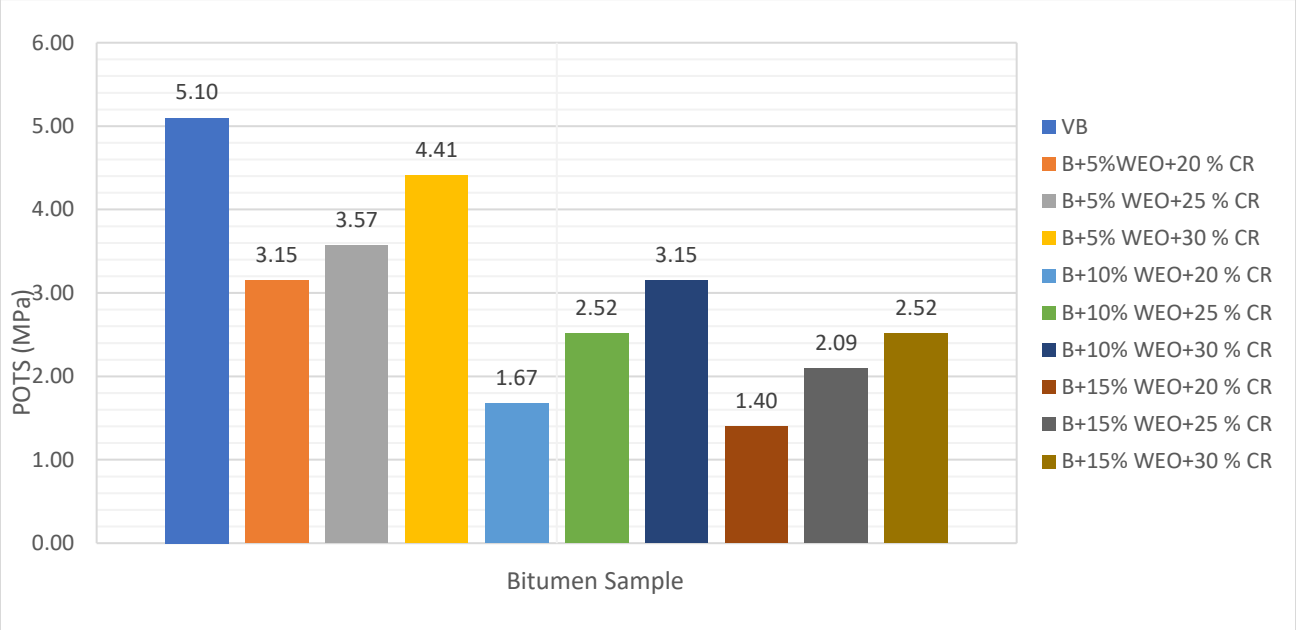

Figure 3: Effect of POTS at dry condition

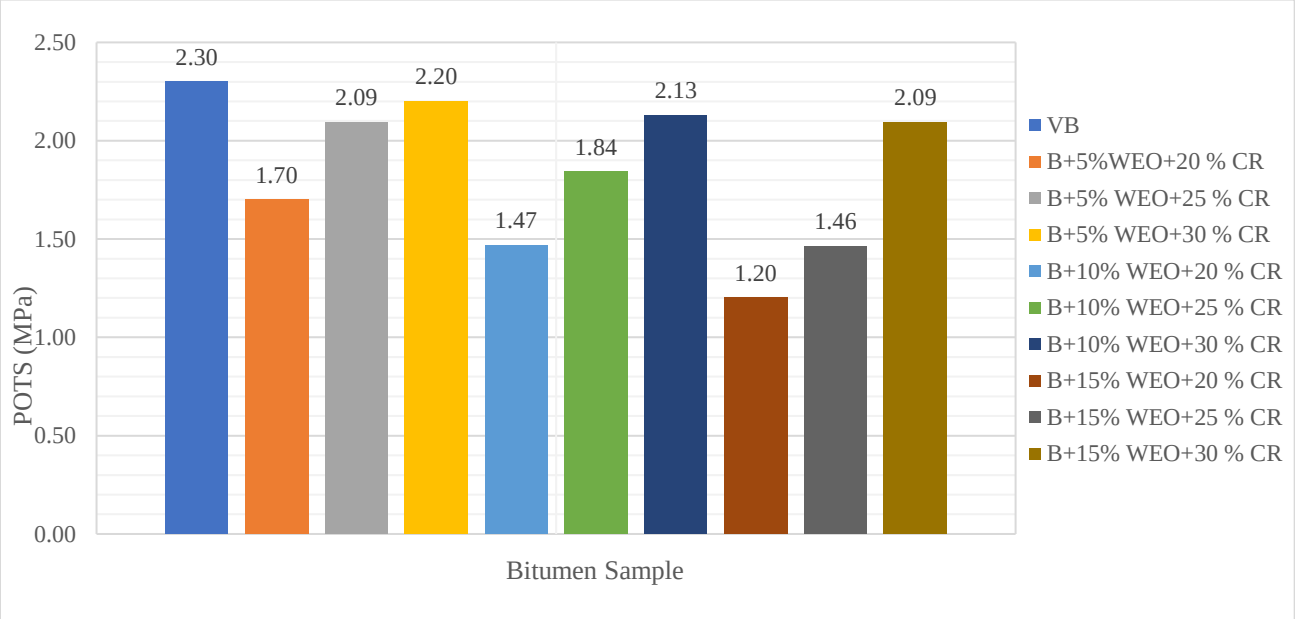

Figure 4: Effect of POTS at Wet condition

In Figure 4, The addition of 5% WEO with the inclusion of 20%,25% and 30% CR, by the total binder content, POTS values decrease by 26 %,11% and 4% at wet condition. In 10 % WEO with the inclusion of 20%,25% and 30% CR, a decrease of 36%,19% and 7% in POTS values was observed. Like that, in 15 % WEO with the inclusion of 20%,25% and 30% CR, a decrease of 47% ,36% and 17% in POTS value of wet sample was observed. However, compared to dry condition, the partially synthetic bitumen showed lower values after water conditioning, because, Water permeates the bitumen-bitumen interface as well as the bitumen-aggregate interface, thereby weakening the bond. It means that due to the incorporation of crumb rubber, an increase in the value of POTS authenticates a stronger association between aggregates and binder specimen and a decrease in the value of POTS indicates a weaker bond between aggregates and binder specimens as a result of the incorporation of waste engine oil. Increased WEO dosage results in a lower POTS value, whereas increased CR dosage results in a higher POTS value, and vice versa.

5 Conclusion

In the light of results attained, the results of partially synthetic bitumen demonstrate that this bitumen is more suitable for cold regions of the country, conclusions are summarized as:

1. From conventional testing, i.e., Penetration Test, Softening Point Test, it has been observed that of WEO in the binder increases its penetration values, decreases its softening point, and decreases the consistency of bitumen because waste engine oil softens the bitumen but with the addition of crumb rubber, improved the properties of partially synthetic bitumen.
2. When compared to virgin binder, the addition of 35% waste by total binder content, decreases the POTS value of dry sample by 13%, and the value of POTS dropped by 38% when 40% waste was added. For the wet sample, the addition of 40% waste by weight of binder, decreases the POTS value of wet sample by 4%, and the addition of 40% waste, a decrease of 7% in value of POTS was observed. Wet strength and dry strength decrease with increase in WEO which depicts that WEO induces moisture damage. However, addition of crumb rubber resulted in improvement in the resistance against moisture providing better adhesion.
3. The optimum percentage of industrial waste which can be used for the production of partially synthetic bitumen lies between 35% and 40% contributing to a significant saving in non-renewable resources.
4. This scope of this study was very limited so a detailed and extensive testing program is needed to reach authentic findings but based on the results authors are hopeful that a handsome percentage of waste can replace the virgin binder giving a cost effective and environmentally friendly solution.

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