

Production of recycled plastic modified bitumen- Effect of base bitumen

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ABSTRACT: In this study, two different viscosity grade base bitumen (VG10 and VG30) and 3 dosages (2%, 3%, and 4%) of recycled low-density polyethylene (RLDPE) were selected for the preparation of the recycled plastic modified bitumen (RPMB). All modified bitumen were evaluated for physical, morphological, and rheological properties. Results state that the softening point of RPMB increases by 8 °C-18 °C depending on the dosage of waste plastic and type of base bitumen. The dispersion of RLDPE, measured by mean particle size, remains unaffected by the dosage of waste plastic and the type of base bitumen. However, the storage stability of RPMB is primarily governed by the density difference between the base bitumen and RLDPE, and is not influenced by the type of base bitumen.

1 INTRODUCTION

The pavement industry is advancing to meet the demand for durable, high-performance roads by improving the quality of bitumen and asphalt mixtures. Enhancing bitumen properties with polymers has become a preferred method globally. Elastomers and thermoplastics are the most common polymer types used for bitumen modification. Among these, use of recycled plastics is gaining popularity in the recent years. The incorporation of recycled plastics in pavement enhances its high-temperature performance while contributing to environmental sustainability (Deb et al. 2024; Kumar et al. 2023).

Incorporation of recycled plastic (RP) in base bitumen can be carried out through dry and wet processes. According to IRC SP:98-2020 (IRC 2020), a maximum of 8% reclaimed plastic (RP) is recommended for use in the dry modification of asphalt mixtures. However, there are currently no established specifications for wet modification.

Literature review indicates that a wide range (0.3-12% by weight of base bitumen) of RP have been used for wet modification of bitumen. The blending is done at temperatures between 150°C and 180°C, using a high-shear mixer that operates at 200–20,000 rpm for 5–3600 minutes. For effective modification, the RP's melting point should preferably be lower than the modified bitumen's production temperature (Rafiq et al. 2021).

Numerous studies have found that modifying the base bitumen with RP significantly enhances the physical, rheological, and mechanical properties of the modified bitumen (Kumar et al. 2023). Low-

density polyethylene (LDPE) is one of the preferred choices to modify the base bitumen (Rafiq et al. 2021; Wahhab et al. 2017). However limited research has focused on the influence of various base bitumen types on the preparation of recycled plastic modified bitumen (RPMB) using RP. The dispersion properties of the RPMB are largely influenced by the compatibility between the RP and base bitumen matrix. The selection of base bitumen grade is critical, as it can affect the overall quality and functionality of RPMB. As a result, the blend's homogeneity and performance under different circumstances may change. Understanding these interactions are essential for optimizing the formulation and performance of RPMB. The purpose of this research is to evaluate the effect of grade of base bitumen on the morphological, rheological, and physical characteristics of RPMB. Variations in the viscosity of the base bitumen could influence the degree of interaction with RP. Morphological analysis will help to evaluate the dispersion and distribution of RP within the base bitumen. Rheological testing will provide insights into the flow behaviour and temperature susceptibility of the RPMB.

2 EXPERIMENTAL

2.1 Materials

In this study, two different viscosity grade (VG) bitumen collected from a single source, viz. VG10 and VG30, were selected as base bitumen. Their properties were evaluated in accordance to IS 73:2013 (BIS 2013). Recycled low-density

polyethylene (RLDPE) was obtained as reprocessed pellets directly from the supplier. The melting point of the RLDPE was determined according to ASTM D3418–21 (ASTM 2021) and found to be 129°C, indicating its suitability for RPMB production. Therefore, RLDPE was incorporated into the base bitumen at dosages of 2%, 3%, and 4% (by weight of bitumen), respectively, for the preparation of RPMB. The blending operation was carried out using a high shear mixer at 1000 rpm for 60 minutes at 170 ± 5 °C (Rafiq et al. 2021).

2.2 Experimental protocols

2.2.1 Physical property

To study the phase change properties of the base bitumen after modifying with RLDPE, softening point test was conducted as per ASTM D36/D36M–14 (ASTM 2008).

2.2.2 Fluorescence microscopy (FM)

The dispersion characteristics of RPMB was studied using fluorescence microscopy. Drop method (Deb et al. 2025) was used to prepare sample glass slides, and fluorescence images were analysed at 10x magnification level.

2.2.3 Storage stability test

The phase separation behaviour of modified bitumen under high-temperature storage is critical for road construction applications. In this test, samples were conditioned in aluminium tubes (25.4 mm diameter, 136.7 mm length) at 163 ± 5 °C for 48 ± 4 hours, followed by freezing at 6.7 ± 5 °C for 4 hours to solidify the material and limit dynamic movement (BIS 15462 : 2019 2019). The tube was divided into three portions after solidification, and samples from the top and bottom sections were examined using a standard DSR at 10°C intervals between 40°C and 70°C (0.1% strain, 10 rad/sec frequency). The separation ratio index (SR) was computed using the complex shear modulus (G^*) values. To ensure phase stability the value of SR should be between 0.8 to 1.2. (Wahhab et al. 2017).

3 RESULTS AND DISCUSSION

3.1 Softening point analysis

The incorporation of RLDPE in base bitumen significantly increases the softening point of RPMBs, with modifications at different dosages resulting in an average increase of 16–40%. This increase in the softening point was attributed to the viscosity of different grades of base bitumen which influence the softening point of RPMB relative to

base bitumen. The increase in softening point of VG10 ranged between 11.2 °C to 17.8 °C, while for VG30 it was between 8 °C to 14 °C. This difference in the increase may be attributed to the variation of interaction between the RLDPE and the bitumen matrix.

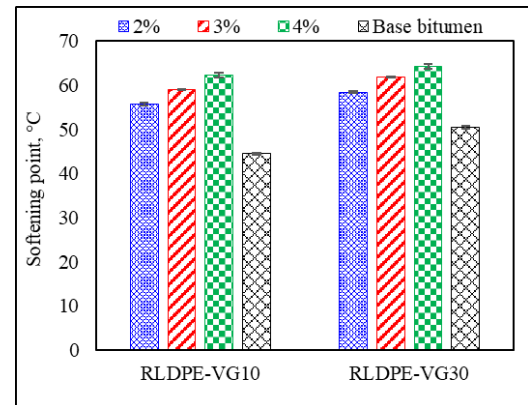


Figure 1: Softening point results of the modified bitumen

3.2 Mean particle size (MPS) analysis

The size of the dispersion RLDPE within the base bitumen was quantified by analysing the mean particle sizes of the dispersed polymers. The evaluation of the MPS was carried out by using java based software ‘ImageJ’ developed by US National Institutes of Health (NIH) (Deb et al. 2025). The conversion of the RGB images to binary images calculated the MPS of the polymers in the modified bitumen, as shown in Figure 2.

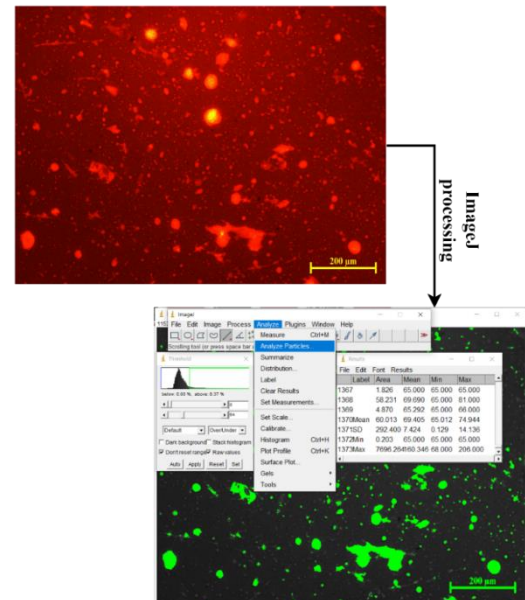


Figure 2: FM image processing by ImageJ

Figure 3 presents the MPS measurements for varying dosages of RLDPE used as a modifier for VG10 and VG30 base bitumen. The results indicate that the MPS of the polymers is independent of the dosage of waste plastic added to

the base bitumen. Although slight variations in MPS are observed between the two base bitumen types; these differences are likely attributable to adjustments in the threshold limits applied during image processing by the ImageJ software (Deb et al. 2025).

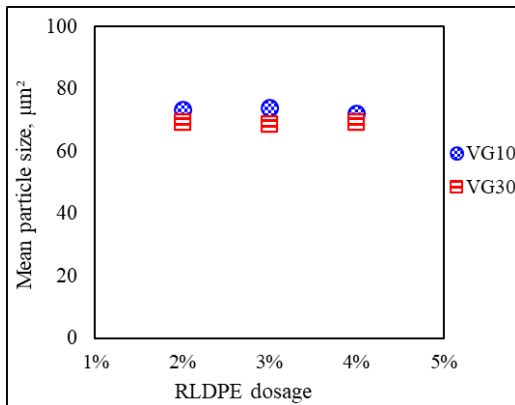


Figure 3: MPS of modified bitumen at different dosages

A statistical analysis (Table 1) was conducted to evaluate the influence of base bitumen type and waste plastic dosage on the dispersion characteristics of RLDPE modified bitumen, using softening point and fluorescence microscopy results. Analysis of variation (ANOVA) was performed at 95% (p-value>0.05) confidence level to determine the significance of these factors on the dispersion behaviour.

Table 1: ANOVA results

Parameter	Variable	p-value	Level of significance
ΔSP	Type of base bitumen	0.245	No
MPS	Dosage of RLDPE	0.963	No

Based on Table 1, the p-values of the analyzed variables exceed 0.05, indicating that the type of base bitumen and the dosage of RLDPE are independent factors in the modification of base bitumen using recycled waste plastics. Here, it should be noted that the MPS has been used for comparative purpose and is not intended to provide limiting criteria.

3.3 Phase separation characteristics

The results of the separation index (SR) are represented in Figure 4 and 5. At lower temperatures (40°C), the binder remains stiff, minimizing its flow and resulting in stable SR values for both top and bottom specimens. As the temperature increases (>50°C), the binder's flowability rises, amplifying the impact of polymer content. The SR value of the modified bitumen in the top of the separation tube were higher than the values obtained for the lower part. The observed behaviour is attributed to the density difference

between the binder and RLDPE. This confirms that SR is a dependent function of both the material's density and temperature. This is in agreement to the results obtained by Wahhab et al. (Wahhab et al. 2017).

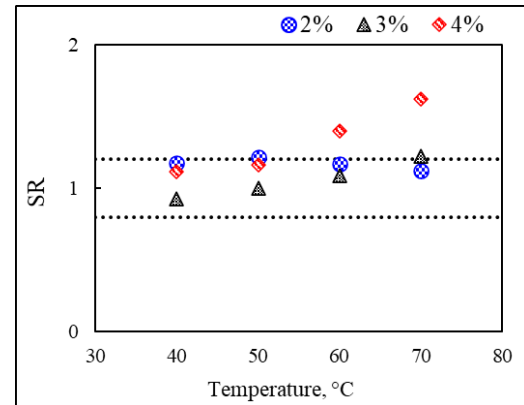


Figure 4: SR results for the RLDPE-VG10 modified bitumen

This phenomenon was found almost identical for both RLDPE modified VG10 and VG30 bitumen. It was found that at 2-3% RLDPE dosage, the SR values of the modified bitumen remain within the recommended limit (0.8-1.2) for all the test temperatures. At 4% dosage, phase separation was observed in the modified bitumen (both VG10 and VG30). This suggests that the choice of base bitumen does not significantly influence the storage stability of the RLDPE-modified bitumen.

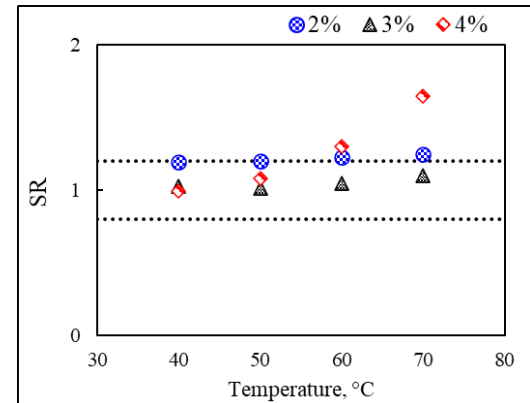


Figure 5: SR results for the RLDPE-VG30 modified bitumen

4 CONCLUSION

In this study, two different grades of base bitumen were used to understand the dispersion characteristics of RPMB. Based on the results and analysis, following conclusions were drawn:

- Inclusion of RLPDE leads to varying degree of increase in softening point of the base bitumen. With VG10 as the base bitumen, the increase in SP ranged between 11.2 °C to 17.8 °C, while for VG30 it was between 8 °C to 14 °C.

- The dispersion of RLDPE polymers into the base bitumen, quantified by mean particle size, was found independent of both the dosage of waste plastic and the type of base bitumen.
- The storage stability of RPMB is primarily influenced by the density difference between the base bitumen and RLDPE. The influence of the type of base bitumen was not evident.

Future research should focus on evaluating the dispersion characteristics of various forms of RLDPE obtained from different sources. Additionally, it is essential to assess the compatibility of RL with different base binders, as variations in their sources may influence their interaction and performance.

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