

Laboratory Study of Polymer-Modified Bitumen in Road Construction: A Review on Crumb Rubber Application

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Abstract- *This study assesses the laboratory study of polymer-modified bitumen in road construction by investigating the effect of crumb rubber (usually in the range of 18 to 25% of rubber) was carefully observed at a room temperature of 166⁰C using wet process. For years, asphalt binder has been used as the elemental material for flexible pavement. The increase in axle loads, heavy traffic, severe climate conditions, and construction failures led many researchers to seek some methods to enhance the bitumen modifications. Several laboratory tests conducted include; Penetration, Ductility, Saybolt viscosity, Ring and ball softening point, and Loss on the heating. Three (3) kilograms of natural bitumen and one (1) kilogram of granulated crumb rubber were sourced for the purpose of this study where it was varied at 0%, 2.5%, 5.0%, and 7.5% by weight. At 7.5%, the results showed improvement in the physical properties of the modified asphalt binders in terms of an increase in softening point and viscosity values. Crumb rubber has further enhanced the loss and storage modulus of the asphalt binder. All of the test results fell within the permissible range. Hence, it was decided that crumb rubber is a recommended component for asphalt mixtures.*

Indexed Terms- *Crumb rubber, Bitumen, Wet process, Polymer modified bitumen, Saybolt viscosity test, Ring and ball softening test.*

I. INTRODUCTION

Polymer modified bitumen have been used at many locations of a paving cross section where higher stresses will return due to the continuous movement of axle loads and axle load spectrums. Improvement of the bitumen properties by the modification enhances

asphalt mixture performance, especially resistance to permanent deformation, fatigue and thermal cracking. (Poovaneshravan et al., 2020; Habbouche et al., 2019; Martinho, F.C et al., 2019; Mirsepahi, M et al.,2020). There are two basic processes for adding crumb rubber in asphalt mixture; wet and dry processes. Crumb rubber obtained during processing of the scrap tires can be used for the bitumen modification in “wet process” or added to the asphalt mixture in “dry process”, as substitution of some aggregate blend fraction. Dry process technology is simpler; it does not take advantage of beneficial rubber properties, such as ability to improve visco-elastic performance properties of bitumen. Wet process technology, in which good properties of rubber are utilizing in higher rate, is more complex to be applied in industrial scale and requires the use of special equipment to modify binder (Wang et al., 2020; Nuha, S.M et al., 2012; Nanjgowda, V.H et al., 2020).

Crumb rubber is a polymerized material capable of contorting significantly when contented to stress and recovering its initial shape as soon as stress is terminated. The choice of process depends on the amount of crumb rubber used, its size, the required function, and the type of plants available (Loderer, C., et al., 2018; Crisman et al., 2020; Poovaneshravan et al., 2020; Memon, N.A et al., 2021).

Bitumen is a mixture of hydrocarbons of natural or pyrogenous origin, or combinations of both, frequently accompanied by their non-metallic derivatives, which may be gaseous, liquid, semi-solid or solid, and which are completely soluble in carbon disulphide (CS₂) (ASTM D5291-16).

Various laboratory studies have designated the advantageous effects of adding polymerized material to bituminous binder and using polymer modified binders (PMBs) in flexible pavement. Hence, the use of polymer modified bitumen extends the service life of flexible pavements (Kukileka et al., 2019; Syed, I.A et al., 2019; Alghrafi, Y.M et al., 2021).

Therefore, it is important to investigate the effect of crumb rubber as an additive with bitumen for road construction to determine the strength and quality of asphalt mixture.

II. MATERIALS AND METHODS

The crumb rubber used for research work was sourced at Wawa, Ogun State (Latitude 9° 54' 7.99" N, 4° 25' 9.01" E) and bitumen from Ayobo-Ipaja, Lagos State (Latitude 6° 60' 5.40" N, 3° 24' 3.80" E).

Methods

Numerous laboratory tests conducted on bitumen blended with crumb rubber as an additive include the following;

Penetration

It assists with separating the bitumen grade, measure the consistency of the bitumen kept up at 25°C with accordance to (ASTM D5 / D5M-19a).

Saybolt Viscosity

This test is conducted to determine the viscosity of a fluid which is the property that offers resistance to flow. The result is reported as the viscosity of the sample at a controlled temperature with accordance to ASTM D88-07 and ASTM D7496-11.

Ring and ball softening point

The softening point of bitumen can be determined using a ring-and-ball contraction submerged in refined water (30-80°C) or USP glycerin (over 80-157°C) with accordance to ASTM D36 / D36M-14.

Ductility

This test gives a measure of adhesive property of bitumen and its ability to stretch prior to breaking when subjected to plastic deformation with accordance to ASTM D113-17.

Loss on heating

This controls the volatility of bitumen and determines the degree to which it may have been cut by a low molecular weight with accordance to ASTM D6/D6M-95 (2018).

III. RESULTS AND DISCUSSIONS

This section is represented in tables and graphs which are revised with American Society of Testing Materials specifications.

Table 1: ASTM specification for softer grades of bitumen (160/220)

Bitumen 160-220	Specification	Test Method (ASTM)
Penetration @ 25°C	160-220	D.5
Softening point	35/43	D.36
Ductility@ 25°C	100 Min	D.113
Loss on heating (wt) %	0.2 Max	D.6
Flash point (°C)	218 Min	D.92

Table 2 shows the result of the penetration and softening point tests for the crumb rubber bitumen mixture with a decrease in penetration value and increase in softening point values. This indicate that the higher the content of crumb rubber in the mix, the stiffer the asphaltic concrete obtained after production.

Table 2: Penetration and Softening indices of polymer modified bitumen

Crumb rubber content (%)	Penetration Value (mm)	Softening point value (°C)
0.0	187	32
2.5	164	33
5.0	138	36
7.5	123	39

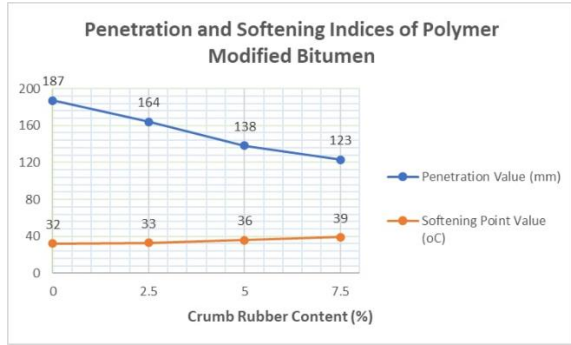


Fig 1: Crumb rubber content versus penetration and softening point indices

Table 3 reveals a decrease in ductility values with rapid increase in viscosity values. This indicates that the bitumen is of softer grade which causes reduction in ductility values with its modification. The values from loss on heating were consistent for 0 and 2.5%-120, 5 and 7.5%-125 in terms of the binder volatility. Hence, it can't be used in a tropical region as binder aging is caused by oxidation.

Table 3: Ductility, Viscosity and Loss on heating values

Crumb rubber content (%)	Ductility value (cm)	Viscosity value (Secs)	Loss on heating Value (g)
0	72	22	120
2.5	54	112	120
5	42	200	125
7.5	28	277	125

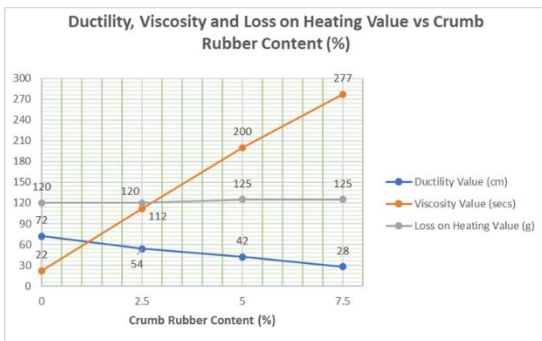


Figure 2: Crumb rubber content versus Ductility, Viscosity and Loss on heating values

CONCLUSION

Based on the result, it can be concluded that crumb rubber can be utilized to modify bitumen and improves the physical properties (ductility and penetration) of modified bitumen. 7.5 percent of crumb rubber (CR) content was the maximum useful amount that could be added to the prepared CR-modified bitumen. The results from the experiment show that, the addition of 7.5 percent of crumb rubber could increase softening point and viscosity value while it reduces ductility and penetration value. These properties indicate that the hot mix asphalt using crumb rubber could have more strength and durability than using non-modified bitumen. The blending time and temperature doesn't have any significant effect on the rheological properties of modified bitumen. It is hereby recommended that such penetration grades of bitumen be used in colder regions such as: Canada, Russia to prevent the occurrence of excessive brittleness and more skid resistance. It can be used in spray application works and damp proof treatment.

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