Performance Evaluation of Bituminous Concrete by Using CRMB Rubber and Low Density Polyethylene

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Abstract — Promoting recycling cost reduction in road building, and environmental mitigation. The investigation explores substituting bitumen with varying ratios of crumb rubber and HDPE, supplemented with coir for robust tensile properties, aiming at improving Stability & Semi-Dense Bituminous Concrete. Additionally, the study delves into the need for alternative aggregates in road construction due to the depletion of natural resources, proposing the use of china clay waste as a partial replacement for fine aggregate in semi-dense bituminous concrete. The research evaluates the cost-effectiveness of modified asphalt using LDPE, HDPE & CR, concluding CR modified HMA as the most economical. The study also explores the feasibility of using waste PET for green asphalt and evaluates the performance of modifiers in highway construction, emphasizing sustainable practices and solid waste disposal.

Keywords: Bitumen, Coconut Coir, HDPE (High Density Polyethylene), Crumb Rubber, Marshall Mix Design, First Section

I. Introduction

In India, flexible pavement, utilizing bituminous concrete as its surface course, is employed for highway construction. The continuous deterioration of road structures is attributed to inadequate maintenance and insufficient funding, emphasizing the need to adhere to bituminous concrete specifications for its construction, as detailed in Section 509. Flexible pavement, generally less flexure-resistant than rigid pavement, comprises soil sub-grade, sub-base, base, and surface course. The addition of polyethylene to bitumen enhances its stiffness and temperature susceptibility, contributing to increased rutting resistance. The study investigates the utilization of High-Density Polyethylene (HDPE) and crumb rubber to reinforce bitumen mixtures, particularly for road construction. However, the application of volcanic aggregates in bituminous paving mixtures poses challenges due to their considerable heterogeneity, absorption, and limited strength. The study aims to enhance the mechanical performance of asphalt mixtures by modifying binders with rubber from end-of-life tires when using these volcanic aggregates, addressing both environmental and financial considerations. The investigation, conducted through laboratory experiments evaluating compact ability, dynamic stiffness, fatigue resistance, and elastic constants, reveals that the use of tire rubber-modified bitumen makes compaction slightly more challenging. Nevertheless, it also retards the loss of particle size from porous aggregates, enhancing the performance and durability of the mixture, resulting in higher stiffness moduli and increased resistance to fatigue. The essay further discusses the significance of mineral aggregates in bituminous mixtures, highlighting their contribution to the mixture's resistance based on various characteristics. It explores the challenges posed by lightweight volcanic aggregates and the potential benefits they offer, such as low thermal conductivity, resilience to freeze-thaw, and low density. The study aims to bridge the gap in prior research by focusing on the dynamic performance and outcomes of asphalt mixtures using single applications of marginal volcanic rocks. Moreover, the essay addresses the dominance of roads in inland transportation, particularly in the European Union, emphasizing the importance of asphalt surface courses. It points out the challenges faced by the road industry, including a lack of natural resources, environmental obligations, and rising costs due to performance enhancers. The essay underscores the significance of urban mining in recycling garbage and reducing the need for virgin materials in manufacturing, with a specific focus on waste materials in asphalt surface courses. The contributions of the essay include providing an overview of studies focusing on the performance, technology, specifications, and cost considerations of surface courses with waste materials, along with estimating the technical maturities based on available laboratory and field experience. Reclaimed asphalt pavement (RAP) is excluded from the discussion due to thorough examination in prior research.

The research aims to investigate and assess the performance and characteristics of bitumen when incorporating varying amounts of high-density polyethylene as modifiers. Additionally, the study will analyze the adverse effects of aging on modified binders during mixing, evaluate the direct tensile strength of High-Density Polyethylene-bituminous mixtures, and compare the financial implications between standard mixes and modified binders (HDPE). Furthermore, the research seeks to examine the morphology of the mixture and the stability of modified binders with bitumen during storage. Lastly, microstructure analysis will be conducted to assess the homogeneity of modified bitumen, specifically focusing on the binding characteristics when blended with ethylene vinyl acetate.

II. Material Used for Experiential purpose

Crushed mineral aggregates can be found in Tiruvankulam at Palal Aggregates. Mineral aggregates come in sizes between 12.5mm and.075mm. The most crucial aspect of coarse aggregates' mechanical qualities is ensuring that pavements can support severe traffic loads and have a long lifespan. The laboratory studies meet the requirements outlined in MoRTH.

1) Filler: Filler is described as aggregate that passes through a 0.075 mm IS sieve. The purpose of filler is to fill in the gaps in mixtures. Bitumen mixes can be made stiffer and tougher by adding filler. The least amount of deformation due to traffic load will result from this. Several types of fillers, such as limestone dust, cement, stone dust, brick

dust, silica fume, fly ash, marble dust cement, etc., were utilized in bituminous mixtures. Dust made of limestone is employed as filler in the research.

2) Viscosity Grade (VG-30) Bitumen: Bitumen is a group of hydrocarbons that resembles tar and is produced either naturally or through distillation from petroleum. Bitumen is mostly utilized in the construction of roads, where it is combined with aggregate particles to make bitumen concrete as the adhesive or binder. Because of their ability to bind and repel water, bituminous materials are frequently employed in the construction of roads. The penetration grade of VG-30 bitumen is 60/70. It is generally employed to build extra-high-duty bitumen pavements that must withstand heavy traffic loads. Bitumen VG-30 is appropriate for hot climates. VG-30 is obtained for the study from Bharat Petroleum Ltd.
3) Natural rubber modified bitumen (NRMB): The mix has strong elastic recovery when bitumen and natural rubber are blended properly and in a constant proportion. Hence, bitumen's characteristics are significantly enhanced when 2-4 percent natural rubber is added, and rubberized bitumen is discovered to be an excellent binder for sand and debris. Due to overload on the road, the rubberized bitumen formed minimizes permanent damage. Due to improved aggregate retention and bleeding removal, this bitumen improves skid resistance and is unaffected by variations in ambient temperature. Rubber boosts bitumen flow resistance at high temperatures and enhances brittle fracture resistance at low temperatures. The aforementioned characteristics lengthen the useful life of rubberized roads. NRMB is collected for the study from Bharat Petroleum Ltd.
4) China clay waste: The leftovers from making china clay are known as china clay trash. It is mostly manufactured in the Gujarat region of India, in the Kutch district. For every tone of china clay produced, 9 tonnes of garbage are generated on average. By-products of china clay resemble primary aggregates in terms of their characteristics. Particularly, the higher-quality stent possesses characteristics resembling those of broken granite. Kerala Ceramics Ltd. Kundara is the source of the waste china clay used in this study.

III. EXPERIMENTAL STRUCTURE

In the preparation of samples for Marshal Stability Mix Design, a systematic approach was adhered to with the following design steps:

- Selection of aggregates.
- Determination of the proportion of each aggregate size to achieve the desired grading.
- Evaluation of the specific gravity of the aggregate combination and asphalt cement.
- Preparation of trial specimens with varying bitumen contents.
- Determination of the specific gravity of each compacted specimen.
- Execution of stability tests on the specimens.
- Calculation of the percentage of voids and percent voids filled with bitumen in each specimen.
- Selection of the optimum binder content based on the acquired data.
- Evaluation of the design against the specified requirements.

To ensure control over the gradation of the test specimens, all aggregates were segregated into various-sized fractions and stored appropriately. Coarse aggregate, fine aggregate, and filler material were proportioned to meet the relevant standards. The quantity of aggregate chosen was sufficient to produce a batch resulting in a compacted specimen of 63.5 mm height. The aggregates and filler were heated to prescribed temperatures, and the compaction mold assembly and rammer were preheated accordingly. Bitumen was added to the heated aggregate, mixed thoroughly, and compacted using specified procedures. The samples were cured, extracted, measured, and weighed for volume determination. The study employed both dry and wet processes for sample preparation, each detailed in the subsequent subsection. Various apparatus were utilized throughout the sample preparation process.

Sample The blending process involves two types of bitumen: molten bitumen and aggregate. In the wet process, shredded polymer is added to the hot bitumen at around -163°C, and the blend is mixed uniformly. This wet blending is facilitated using a blending machine consisting of a cylindrical mould, a base plate, and a hammer. The wet process results in modified bitumen with enhanced properties such as increased surface area and improved binding characteristics. Conversely, in the dry process, modified bitumen is achieved by blending shredded polymer with aggregate at 160°C. The dry blending utilizes a blending machine comprising a cylindrical mould, a base plate, and a hammer. The difference between the wet and dry processes lies in the state of the polymer during blending, either in a molten state in the wet process or added to hot aggregate in the dry process. Both processes contribute to the creation of modified bitumen with desirable properties for use in asphalt mixtures.

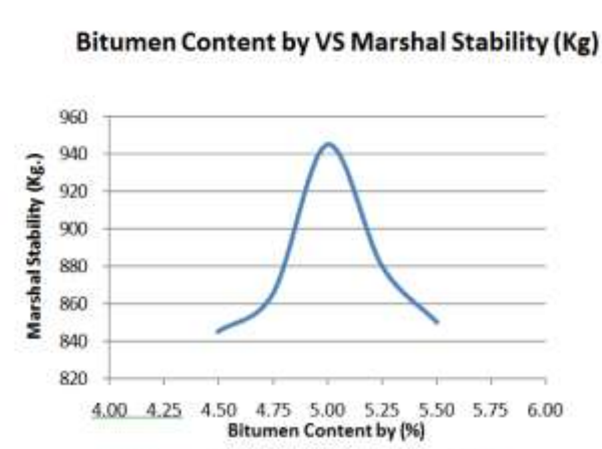
IV. ANALYSIS & RESULTS

This chapter deals with results obtained for penetration, softening, ductility, flash and fire and specific gravity tests on 60-70 grade Bitumen and modified bitumen. Also the results obtained from Marshal Stability test, on various samples for Semi Dense Bituminous Concrete (SDBC).Ministry of Road, Transport and Highways (MORTH) which provides specifications for all road and bridge works. In this chapter experimental results are compared with MORTH specifications for Semi Dense Bituminous Concrete (SDBC). According to MORTH specification, SDBC should have following characteristics as specified in table

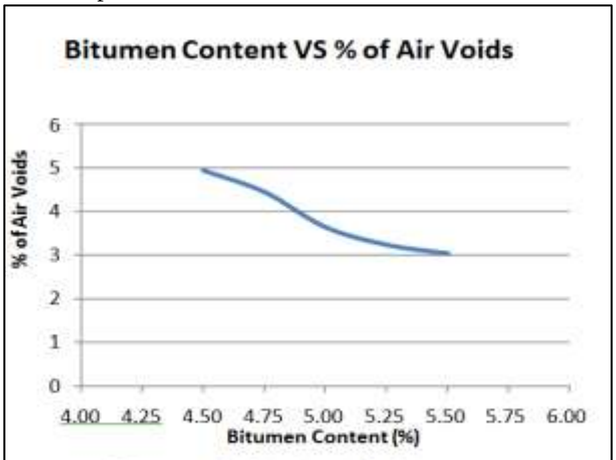
Nominal Maximum Particle Size (mm)		1. Minimum VMA, Percent Related to 2. Design Air Voids, Percent					
		3.	3.0	4.	4.0	5.	5.0
6.	9.5	7.	14.0	8.	15.0	9.	16.0
10.	12.5	11.	13.0	12.	14.0	13.	15.0
14.	19.0	15.	12.0	16.	13.0	17.	14.0
18.	25.0	19.	11.0	20.	12.0	21.	13.0
22.	37.5	23.	10.0	24.	11.0	25.	12.0

Table 1: percent voids in mineral aggregate (VMA)

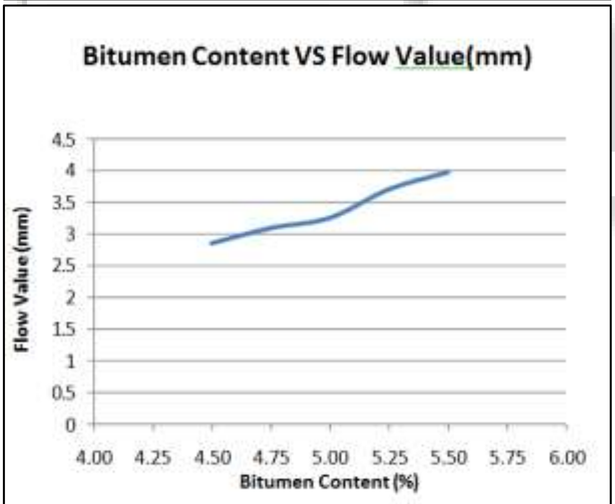
The following graphs are plotted to find out the Optimum Binder Content



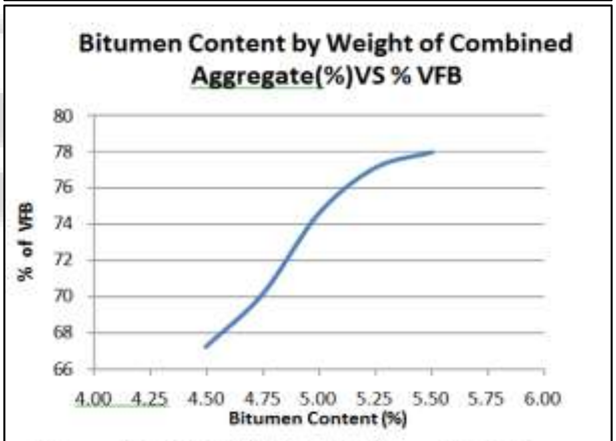
Bitumen % VS Marshal Stability Value



Bitumen % VS Air voids %



Bitumen % VS Flow value



Bitumen % Vs Voids filled with bitumen%(VFB)

The graphical representation depicted in the aforementioned figure delineates the discernible trends in both Marshall stability and flow value as they undergo variations across increasing percentages of bitumen.

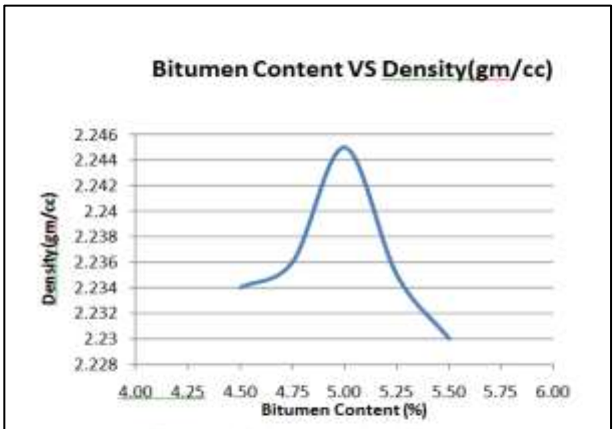


Figure 4.3 Bitumen % VS Density

The visual representation above elucidates the dynamic changes in both air voids filled with bitumen and density, showcasing the discernible differences as the percentage of bitumen increases.

S.No	LDPE %	Bitumen %	Marshal stability (Kg)	low value (MM)	Bulk Density (gm/cc)	Air voids % Vv	VMA	VFB %
1	3%	5.0	1050	3.10	2.24	3.86	15.04	74.12
2	6%	5.0	1120	3.88	2.25	3.43	14.66	76.23
3	9%	5.0	1190	3.91	2.25	3.21	14.48	77.18

Table 2: Results of Marshal Stability Mix Design for SDBC with LDPE Modified Bitumen

From the above results it is observed when the percentage of modifier (LDPE) increased the Marshal Stability Values, Flow Values VFB are also increased and the Air Voids percentages are decreased. It is found that when the percentage of LDPE is 9% then Marshal Stability value is higher compare than other percentage of LDPE In this section the properties such as Marshal stability value, Flow value, Bulk Density, % Air Voids, VMA, VFB for the modified bitumen (CRMB) in varying percentage 8%, 10% and 12% are calculated for the 5 % bitumen content and the properties and results are listed below (table 3)

S.No	LDPE %	Bitumen %	Marshal stability (Kg)	low value (MM)	Bulk Density (gm/cc)	Air voids % Vv	VMA	VFB %
1	8%	5	1065	3.10	2.23	3.87	14.99	74.12
2	10%	5	1190	3.62	2.24	3.86	15.03	74.35
3	12%	5	1180	3.76	2.26	3.98	15.24	73.25

Table 3: results obtained from marshal stability mix design for SDBC with CRMB modified bitumen

In this section the properties such as Marshal stability value, Flow value, Bulk Density , % Air Voids , VMA, VFB for the modified bitumen (LDPE+CRMB) in varying percentage 5%,10% and 15% are calculated for the 5 % bitumen content and the properties and results are listed below (table 4):

S.No	LDPE %	Bitumen %	Marshal stability (Kg)	low value (MM)	Bulk Density (gm/cc)	Air voids % Vv	VMA	VFB %
1	3% +2%	5	1110	3.36	2.24	3.86	15.06	74.32
2	6%+4%	5	1150	3.80	2.26	3.82	15.10	75.44
3	9%+6%	5	1210	3.96	2.29	3.37	14.79	77.59

Table 4: Results obtained from marshal stability mix design for SDBC with LDPE and CRMB modified bitumen

Based on the aforementioned findings, it is evident that increasing the modifier percentages (LDPE & CRMB) from 5 to 15 percent leads to an augmentation in the Marshal Stability Values, Flow Value, Bulk Density, and VFB, accompanied by a reduction in the percentage of Air Voids. Specifically, it was determined that the highest Marshal Stability Value was achieved upon the addition of LDPE at 9% and CRMB at 6% (total 15%).

V. Conclusion

- The combination of crumb rubber with 60/70 grade bitumen at different percentages (2, 4, 6, 8, 10, 12) resulted in notable changes: decreased penetration and ductility, increased softening point and specific gravity.
- Higher CRMB percentages correlated with decreased penetration/ductility and increased softening point/specific gravity. Flash/fire point initially rose, then fell with increasing CRMB percentages. Key findings include:
- LDPE and CRMB addition boosted Marshal Stability and flow in bituminous mixes. Optimal Marshal Stability: 9% LDPE for LDPE-modified bitumen; 10% CRMB for CRMB-modified bitumen; 15% (9% LDPE, 6% CRMB) for combined LDPE-CRMB modification.
- Marshal Stability increased by 11.11%-25.92% for LDPE (3%-9%) and 12.69%-25.92% for CRMB (8%-12%) at 5% bitumen content. LDPE-CRMB mixes (5% LDPE 3%, 2% CRMB; 10% LDPE 6%, 4% CRMB; 15% LDPE 9%, 6% CRMB) showed Marshal Stability increases of 17.46%-28.04% at 5% bitumen content.

LDPE-CRMB blends exhibited higher Marshal Stability compared to other mixes.

This study noted decreased air voids (beneficial for road strength) and increased Void Filled with Bitumen (VFB) with higher bitumen percentages. Density and Marshal Stability initially increased, then decreased. The research focused on semi-dense bituminous concrete using 60/70 grade bitumen, LDPE, CRMB, and LDPE + CRMB modifications. Future studies could explore alternative modifiers (e.g., natural rubber, latex powder, waste polymer, HDPE additives) for further enhancement of bitumen properties in dense and regular bituminous concrete.

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