Improvement of Bituminous Mix for Flexible Pavement using Plastic Waste

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Abstract- **Plastic waste management has become a pressing global issue, particularly in countries like India where production rates are alarmingly high. This research explores the feasibility and benefits of incorporating plastic waste into bituminous mixtures for flexible pavement construction as a sustainable solution. The study objectives include preparing bituminous mix samples with and without plastic waste, evaluating the properties of aggregate coated with plastic waste, and assessing stability and workability using Marshall Stability tests. Methodology involves collecting materials, preparing specimens, and conducting tests according to relevant standards. Results indicate that plastic waste enhances resistance to wear and impact in aggregates and improves asphalt binder-aggregate adhesion. Marshall Stability tests demonstrate increased stability with the addition of plastic waste, while higher bitumen content enhances cohesion and flowability. These findings suggest the potential for sustainable utilization of plastic waste to enhance the performance of bituminous concrete mixes for road construction, contributing to environmental preservation and resource efficiency.**

Index Terms: **Plastic Waste Bituminous Mix, Marshall Stability Test, Improvement of Bituminous Mix, Workability.**

I. INTRODUCTION

Plastic waste management stands as a critical global concern, posing significant environmental challenges such as land, marine, and air pollution. In India, where plastic waste production is alarmingly high according to the Central Pollution Control Board, urgent action is imperative. A promising solution lies in innovatively incorporating plastic waste into bituminous mix for flexible pavement construction. This approach not only addresses the escalating plastic waste crisis but also yields numerous benefits.

The objective of this research is twofold: first, to prepare bituminous mix samples using plastic waste alongside conventional mixtures without plastic waste; and second, to evaluate the properties of aggregate coated with plastic waste. Through this comparative analysis, we aim to assess the viability and efficacy of utilizing plastic waste in pavement construction.

Incorporating insights from recent literature, research endeavors underscore the potential of utilizing plastic waste in bituminous mix for flexible pavement construction. Studies by Dr. Vimlashamnugam, K. & Kumar, D. S. (2022) and Panga V. (2022) elucidate methods to enhance road longevity and durability through the integration of plastic waste. Veera Reddy, P. et al. (2019) provide a comprehensive review of studies examining the utilization of plastic waste in bituminous mix for pavement construction, highlighting its growing significance in the field. Furthermore, economic analyses conducted by Chand, S. et al. (2019) offer valuable insights into the cost-effectiveness of employing plastic waste in bituminous road construction, reinforcing its potential benefits. These scholarly contributions enrich our understanding of the feasibility and efficacy of incorporating plastic waste into bituminous mixtures, guiding the pursuit of sustainable solutions in infrastructure development.

By integrating shredded PET bottles, polyethylene bags, and assorted mixed plastics into bituminous mixtures, pavement performance undergoes a significant enhancement. These blends exhibit superior properties such as enhanced stiffness, durability, and stability. Moreover, incorporating plastic waste into pavement construction contributes to mitigating environmental harm caused by plastic accumulation in landfills, marine ecosystems, and air pollution from incineration. Such initiatives also align with the principles of a circular economy by reducing reliance on virgin materials and promoting resource conservation.

Additionally, the adoption of plastic waste in bituminous mixtures holds the potential for cost-effectiveness in construction projects. Plastic waste materials are often readily available at low or no cost, thereby offering a sustainable alternative to traditional construction materials. As this approach gains momentum, stringent testing protocols ensure the quality, durability, and performance of asphalt pavements. Tests such as asphalt content determination, rutting and deformation assessment, cracking resistance evaluation, and moisture sensitivity measurement are conducted to guarantee the efficacy of the bituminous mixtures.

In essence, the integration of plastic waste into bituminous mix for flexible pavement construction represents a proactive step towards sustainable infrastructure development. By leveraging innovative solutions to address the plastic waste crisis, we not only enhance pavement performance but also contribute to environmental preservation and resource efficiency, laying the groundwork for a more resilient and eco-friendly future.

II. OBJECTIVES

- To Prepare Bituminous Mix Samples using Plastic Waste and without Plastic Waste.
- To Check the Properties of Aggregate Coated with Plastic Waste.
- To Evaluate Stability and Workability of Mix Samples Prepared using Plastic Waste with Marshal Stability Test.

III. LITERATURE REVIEW

The literature on incorporating plastic waste into bituminous mix for flexible pavement construction underscores its potential benefits and feasibility. Dr. Vimlashamnugam, K. & Kumar, D. S. (2022) explore methods to enhance road longevity through the integration of plastic wastes, highlighting its potential for improving infrastructure durability. Panga V. (2022) investigates the use of processed plastic waste as an additive in bituminous pavements to enhance durability and resistance to wear, showcasing the effectiveness of varying percentages of plastic waste in bituminous mixtures. Veera Reddy, P. et al. (2019) provide a comprehensive review of studies examining the utilization of plastic waste in bituminous mix for pavement construction, emphasizing its growing significance in the field. Additionally, studies by Sharma, A. & Suresh, S. (2019) and Kalekar, P.S. & Gite, V.V. (2019) present experimental findings on the performance of bituminous pavement incorporating plastic waste, highlighting its potential benefits in terms of durability and performance. Moreover, Sahoo, U.C. & Babu, G.L.S. (2019) assess the environmental impact, while Chand, S. et al. (2019) conduct an economic analysis, both emphasizing the importance of considering sustainability and cost-effectiveness. Furthermore, guidelines provided by Indian Road Congress (2013) and standards outlined by the Bureau of Indian Standards (2013) and Ministry of Road Transportation & Highways (2013) offer regulatory frameworks and specifications for utilizing plastic waste in road construction, providing a comprehensive understanding of the topic's practical implications. Overall, the literature suggests that incorporating plastic waste into bituminous mix for pavement construction holds promise for enhancing infrastructure sustainability and mitigating environmental impact.

IV. METHODOLOGY

The methodology begins with the collection of aggregates, bitumen, and clean, shredded plastic waste. These materials are evaluated based on specific standards (MORT&H, IS 73:2000) and tested accordingly. The plastic waste is cleaned, shredded, and used to coat the aggregates. Following this, a bituminous mix is prepared as per MORT&H specification, with aggregates and fines mixed to achieve the specified gradation. Six representative specimens are prepared, three without plastic waste and varying bitumen content, and three with plastic waste and the same varying bitumen content. These specimens are heated, bitumen is added, and the mix is compacted. A Marshall Stability and Flow test is conducted on these compacted specimens, where a vertical load is applied until failure occurs. The stability and deformation are measured, and if the specimen thickness varies, the measured stability values are corrected. The results are then analyzed to conclude the experiment. This methodology provides a comprehensive approach to understanding the use of plastic waste in bituminous mixes. Systematic flow chart of methodology shown in **"Fig.- 1"**.

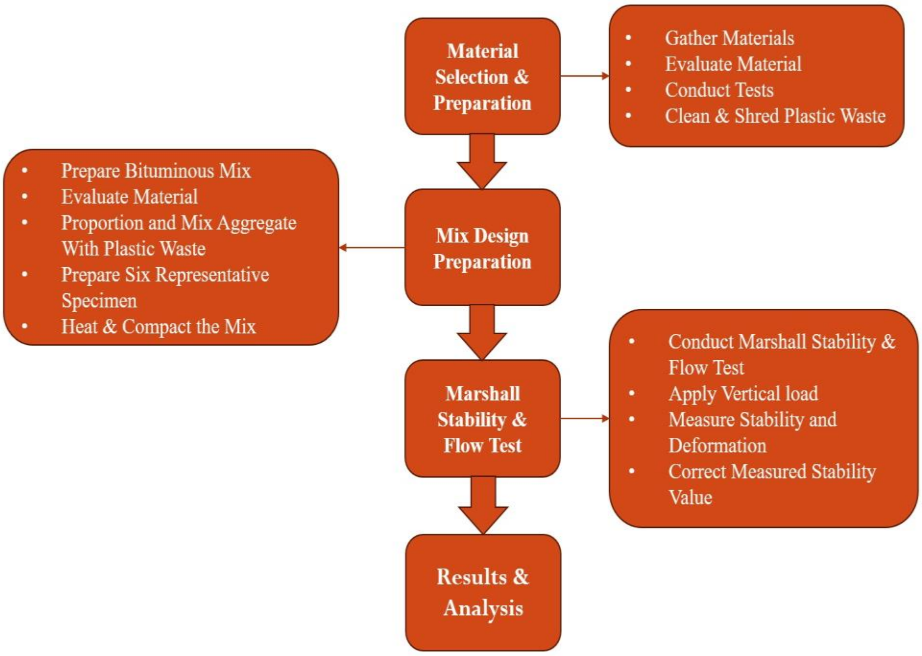

Fig. 1- Flow Chart Evaluate Stability and Workability of Mix Samples Prepared using Plastic Waste

V. RESULTS AND ANALYSIS

Plastic waste in aggregates improves resistance to wear and impact, crucial for stability in asphalt mixes. Specific gravity remains uniform across both aggregate types, ensuring predictability in asphalt mix performance. Absence of stripping in aggregates with plastic waste suggests enhanced asphalt binder-aggregate adhesion, potentially boosting pavement durability. Results of tests on aggregates shown in **"Table-1"**.

Table- 1 Results of Tests on Aggregate

Aggregates	% of Plastic Waste	Los - Angeles Abrasion Value (%)	Aggregate Impact Value (%)	Specific Gravity	Stripping Value (%)
Without Plastic	0	16.88	14.89	2.62	2%
With Plastic	5	14.57	12.33	2.6	Nil
	10	11.8	10.56	2.6	Nil
	15	10.67	9.84	2.73	Nil

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The test results indicate that the bitumen meets the required physical specifications for the Marshall stability test, demonstrating adequate ductility, penetration value, softening point, flash point, and fire point. Results of tests on bitumen shown in **"Table-2"**.

Table -2: Results of Tests on Bitumen

Test	**Result**	**Range**
Ductility	77.50 cm	Minimum 40 cm
Penetration Value	83 cm	80-100 mm
Softening Point Test	48.25 ^{0}C	45-60 ^{0}C

Flash Point Test	280 ^{0}C	>157 ^{0}C
Fire Point Test	302^{0}C	

Results obtained from Marshall Stability Test shown in **"Table-3"**. To analyze the test results plots were made between Marshall Stability Value (MSV) vs % Bitumen Content as shown in chart-1 and Marshall Flow Value (MSV) vs % Bitumen Content as shown in **"chart-2"**.

Table -3: Marshall Stability Test Results

Sample	Bitumen Content (%)	Plastic Content (% by Weight)	Marshal Stability (kg)	Marshall Flow Value (.25 = 1 MFV)
BM_1	4.5	0	830	12.8
BM_2	5.5	0	1060	13.6
BM_3	6.5	0	1150	14.8
BM_4	4.5	5	1580	15.6
BM_5	5.5	10	1790	17.6
BM_6	6.5	15	1920	20.4

Results obtained from Marshall Stability Test shown in **"Table-3"**. To analyze the test results plots were made between Marshall Stability Value (MSV) vs % Bitumen Content as shown in **"chart-1"**.and Marshall Flow Value (MSV) vs % Bitumen Content as shown in **"chart-2"**.

As the percentage of bitumen content increases from BM1 to BM3 in **"chart-1"**, there is a noticeable improvement in Marshall stability. This indicates that higher bitumen content leads to better cohesion and strength in the bituminous concrete mix.

Introducing plastic content in **"chart-1"**, shows a significant increase in Marshall stability compared to samples without plastic. This suggests that the addition of plastic contributes positively to the strength and stability of the mix, likely due to the reinforcing properties of the plastic fibers.

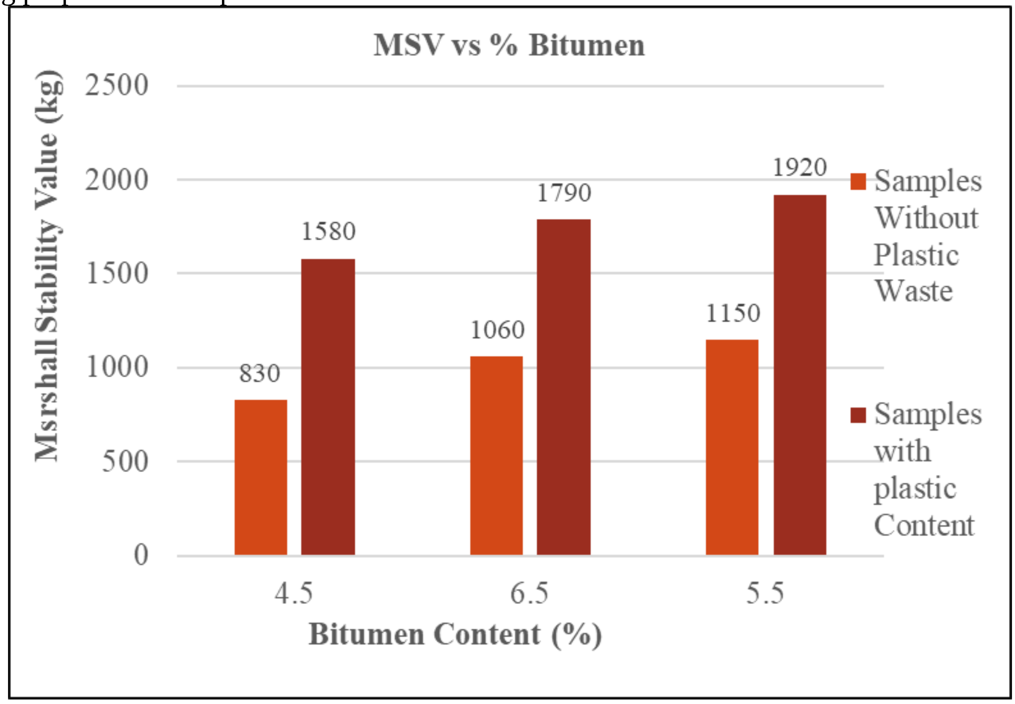

Chart -1 Comparison of MSV of Samples with Plastic Waste and Without Plastic Waste

Generally, for both samples with and without plastic waste, an increase in bitumen content corresponds to a higher flow value as shown in chart-2. This indicates that higher bitumen content results in greater flowability of the bituminous mixture.

When comparing samples with the same bitumen content, those with plastic waste (BM4, BM5, and BM6) tend to have higher flow values compared to samples without plastic waste (BM1, BM2, and BM3). This suggests that the addition of plastic waste may influence the flow characteristics of the asphalt mixture, potentially leading to increased flowability

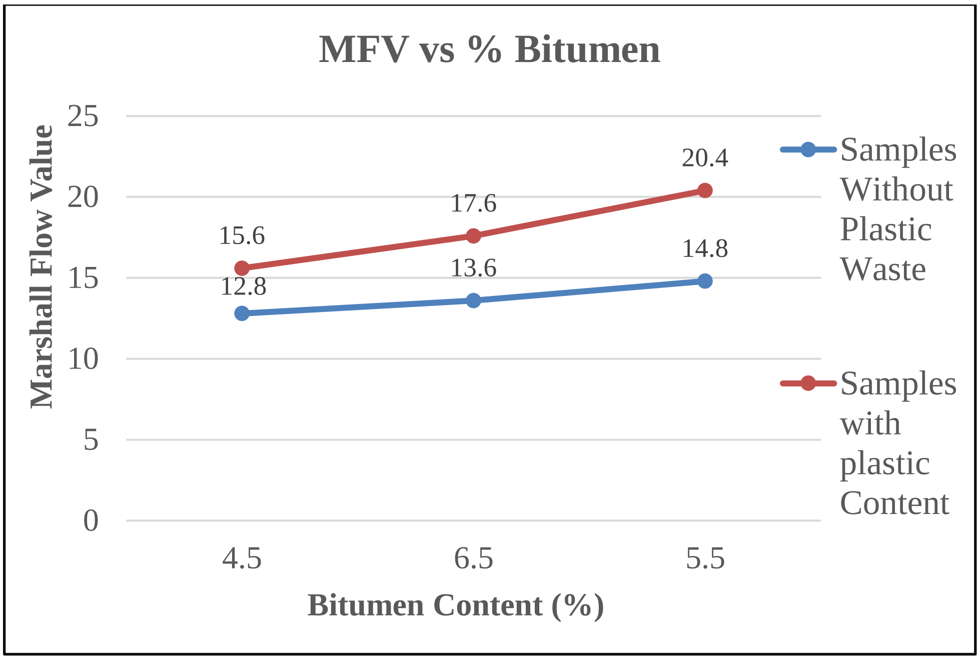

Chart -2 Comparison of MFV of Samples with Plastic Waste and Without Plastic Waste

VI. CONCLUSION

Increasing bitumen content enhances Marshall stability, indicating improved cohesion and strength in bituminous concrete mixes. The addition of plastic waste significantly boosts Marshall stability, likely due to the reinforcing properties of plastic fibers. Higher bitumen content generally leads to greater flowability, regardless of the presence of plastic waste. Plastic waste incorporation influences flow characteristics, resulting in increased flowability in asphalt mixes. Optimal bitumen-plastic ratios can be explored to balance stability and flow characteristics effectively. These findings highlight the potential for sustainable utilization of plastic waste in enhancing the performance of bituminous concrete mixes for road construction.

VII. FUTURE SCOPE & LIMITATIONS

Future Scope-

- Assessing the long-term durability and environmental sustainability of plastic-modified bituminous concrete mixes through field trials and accelerated lab testing.
- Evaluating the environmental footprint of plastic-incorporated mixes versus conventional ones, considering carbon emissions and energy consumption, using life cycle assessments.
- Exploring new methods like microwave processing or chemical modification to efficiently integrate different plastic waste types into bituminous mixes, improving sustainability and cost-effectiveness.

Limitations-

- The study assesses only Marshall stability and flow values, neglecting key factors like rutting resistance and fatigue performance crucial for asphalt mix evaluation.
- With only six samples, the study's findings may lack generalizability due to the limited variability in asphalt mixtures tested.

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