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UTILIZATION OF PLASTIC WASTE-BITUMEN MIXES FOR FLEXIBLE PAVEMENT

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Abstract: This study explores the use of plastic waste—PET bottles, sanitary pad plastics (PP/PE), and LDPE garbage bags—in bituminous mixes to enhance flexible pavement performance. Plastic was added at 8%, 10%, and 12% by weight of bitumen. Tests including Marshall Stability, Penetration, Softening Point, and Ductility were conducted per Indian Standards. Results indicate improved strength, durability, and thermal resistance compared to conventional mixes. This approach promotes sustainable road construction while addressing plastic waste management.

Keywords: Plastic Waste, Bitumen, Flexible Pavement, PET, LDPE, Polypropylene, Sustainable Roads, Waste Recycling, Pavement Strength.

I. INTRODUCTION

The ever-increasing generation of plastic waste has emerged as one of the most pressing environmental challenges of the 21st century. Globally, millions of tons of plastic are produced annually, a significant portion of which ends up in landfills or the natural environment due to inadequate waste management systems. In India alone, an estimated 3.5 million tonnes of plastic waste is generated every year, of which a large fraction remains unrecycled. Given the non-biodegradable nature of plastics, their long-term accumulation poses severe risks to ecosystems, human health, and urban infrastructure. As a response to this crisis, civil engineering researchers and practitioners are exploring innovative and sustainable methods for incorporating plastic waste into construction materials—one of the most promising being its integration into bituminous road pavement.

The concept of using plastic-modified bitumen (PMB) in road construction has been tested and implemented in various regions, most notably in India. The pioneering initiative was carried out in Tamil Nadu, where local engineers developed techniques to shred and blend waste plastics into bitumen mixes. Roads constructed with plastic-enhanced bitumen in the region demonstrated enhanced properties such as greater resistance to rutting, cracking, and moisture-induced damage. These early implementations laid the groundwork for further research into plastic-modified pavement as a viable solution for both improving road quality and managing plastic waste.

The engineering rationale behind incorporating plastic into bitumen is based on its ability to enhance certain key performance characteristics. Plastics such as PET (Polyethylene Terephthalate), LDPE (Low-Density Polyethylene), and PP/PE (Polypropylene/Polyethylene)—commonly found in discarded water bottles, garbage bags, and sanitary pads—have favourable thermal and adhesive properties. When processed and blended in suitable proportions with bitumen (typically 8%, 10%, and 12% by weight of bitumen), these polymers interact with the bituminous binder to improve viscoelastic behaviour, increase Marshall Stability, and decrease susceptibility to temperature variations. This results in pavements that are more durable, flexible, and resistant to cracking, potholing, and fatigue failure.

Beyond the technical advantages, the adoption of plastic waste in road construction aligns with several national and international sustainability agendas. Specifically, it supports the United Nations Sustainable Development Goals (SDGs), including Goal 11 (*Sustainable Cities and Communities*) and Goal 12 (*Responsible Consumption and Production*). Domestically, it reinforces initiatives such as the Swachh Bharat Mission, Plastic Waste Management Rules (2016), and policies advocating circular economy practices in infrastructure development. The approach also holds significant promise in reducing reliance on non-renewable resources like crude oil-based bitumen and conserving natural aggregates.

This research aims to analyse and validate the performance of flexible pavements modified with three major types of post-consumer plastic waste—PET, sanitary pad plastics (PP/PE), and LDPE garbage bags. The experimental program includes the preparation of bituminous mixes with varying plastic content, followed by standardized laboratory testing procedures as per the Indian Roads Congress (IRC) and Indian Standard (IS) specifications. Tests conducted include the Marshall Stability Test, Penetration Test, Softening Point Test, and Ductility Test—each selected to evaluate critical parameters such as load-bearing capacity, temperature susceptibility, elasticity, and overall stability of the bituminous mixes.

Through a comparative study of conventional versus plastic-modified mixes, this thesis aims to demonstrate that plastic incorporation can significantly improve pavement performance while also addressing the critical need for sustainable waste utilization. The findings of this research are expected to provide valuable insights for policymakers, urban planners, and civil engineers seeking cost-effective, eco-friendly solutions for infrastructure development.

II. OBJECTIVES

The primary aim of this research is to evaluate the feasibility and effectiveness of incorporating plastic waste into bituminous mixes to enhance the performance of flexible pavements. The study is designed with the following specific objectives:

1. To evaluate the performance of bituminous mixes modified with three types of plastic waste—PET, PP/PE (sanitary pad plastics), and LDPE (garbage bags)—at varying proportions (8%, 10%, and 12%).
2. To conduct standardized laboratory tests (Marshall Stability, Penetration, Softening Point, and Ductility) to assess the mechanical and thermal behaviour of plastic-modified bitumen.
3. To compare the results of plastic-modified mixes with conventional bituminous mixes in terms of strength, durability, and deformation resistance.
4. To determine the environmental and economic benefits of utilizing plastic waste in road construction, supporting sustainable infrastructure and effective waste management.

III. LITERATURE SURVEY

The incorporation of PET from plastic water bottles into bituminous mixes has been widely studied to enhance pavement strength and durability. Dr. A. Gupta et al. (2018) from IIT Kharagpur conducted an extensive study that demonstrated the addition of 2% PET improved the Marshall Stability, tensile strength, and elasticity of the mix. The modified mix reduced surface cracks and increased the load-bearing capacity of flexible pavements.

The use of sanitary pad waste, primarily consisting of polypropylene (PP) and polyethylene (PE), has been explored to improve road construction quality in humid and high-rainfall regions. Dr. P. Rajkumar et al. (2020) from IIT Madras observed that incorporating 3–4% sanitary pad waste significantly enhanced moisture resistance and fatigue strength.

The thermal stability of PP and PE helped maintain pavement performance under extreme temperature variations.
Low-Density Polyethylene (LDPE) from garbage bags has shown positive results in increasing bitumen mix flexibility and reducing thermal cracking. Prof. V. Mehta et al. (2016) from IIT Delhi found that a 5% addition of LDPE enhanced ductility and elasticity, making roads more resistant to heavy traffic and heat. Dr. N. Kapoor et al. (2019) from IIT Roorkee supported these findings by confirming improved water resistance and extended pavement life using LDPE-modified bitumen.

A comparative evaluation of different plastic wastes—PET, PP/PE, and LDPE—was performed to identify the most effective combination for flexible pavements. Dr. M. Sinha et al. (2021) from IIT Guwahati concluded that PET offered the best tensile strength, LDPE improved flexibility, and PP/PE contributed to better moisture resistance. A recommended mix of PET (2%), PP/PE (3%), and LDPE (5%) showed balanced, high-performance characteristics across various environmental conditions.

To assess the environmental and economic viability of plastic road construction, Prof. R. Jain et al. (2022) from IIT Kanpur conducted a life-cycle cost analysis. Their findings revealed that plastic-modified roads not only extended pavement lifespan but also reduced overall construction and maintenance costs by 15–20%, supporting sustainable road infrastructure development.

The addition of High-Density Polyethylene (HDPE) from discarded containers has been evaluated for its structural benefits in bitumen mixes. Dr. R. Sharma et al. (2017) from IIT Hyderabad found that a 3% HDPE content enhanced Marshall Stability and improved the rheological properties of bitumen. The study concluded that HDPE modification could effectively prevent deformation and prolong fatigue life under heavy traffic.

IV. METHODOLOGY

This research investigates the potential of using plastic waste materials in bitumen mixes to enhance the performance of flexible pavements. The methodology adopted for this study includes material selection, plastic waste processing, sample preparation, and a series of laboratory tests performed in accordance with Indian Standards (IS).

1. Material Collection and Preparation

Three types of plastic waste were selected for this study:

- **PET (Polyethylene Terephthalate)** from used plastic water bottles,
- **PP/PE (Polypropylene/Polyethylene)** from sanitary pad waste,
- **LDPE (Low-Density Polyethylene)** from used garbage bags.

The collected plastic waste was cleaned, dried, and shredded into small pieces (2–4 mm) to facilitate uniform blending with the bitumen.

2. Bitumen and Aggregate Selection

- **VG-30 grade bitumen** was selected as the base binder for all mixes.
- Aggregates conforming to IS: 2386 (Part I–IV) standards were used for preparing the mix.

3. Plastic Waste Integration

The dry process method was employed to incorporate plastic waste into the bitumen mix:

- Plastic waste was added to the heated bitumen (at 160–170°C) in varying proportions of **8%, 10%, and 12%** by weight of bitumen.
- The mix was stirred continuously to ensure uniform dispersion of plastic material.

4. Sample Preparation

- Bituminous concrete samples were prepared using standard aggregate gradation as per **MORTH specifications**.
- The mix was compacted using a Marshall Compactor with 75 blows on each side.
- Specimens were prepared for each plastic variant and plastic percentage.

5. Laboratory Testing

The samples prepared were subjected to the following tests to evaluate the mechanical and physical properties of the plastic-modified bitumen:

- **Marshall Stability Test** (IS: 1203) – to determine strength and flow value.
- **Penetration Test** (IS: 1203) – to assess the hardness of the bitumen.
- **Softening Point Test** (IS: 1205) – to evaluate temperature susceptibility.
- **Ductility Test** (IS: 1208) – to examine the bitumen's flexibility and bonding.

IV. RESULTS AND DISCUSSION

4.1 Results Of Tests

The performance of bitumen mixes modified with three types of plastic waste—**PET bottles**, **sanitary pad plastics**, and **garbage bags**—was evaluated at different proportions of 8%, 10%, and 12% by weight of bitumen. The results were compared against conventional bitumen mixes without plastic additives. The following observations were made from laboratory tests conducted for assessing **Marshall Stability**, **flow value**, **softening point**, **ductility**, and **water absorption**:

The **Marshall Stability** value increased significantly with the addition of plastic waste up to 10% for all plastic types.

Maximum stability was observed at **10% plastic content**, with **PET-modified mix** showing the highest strength, followed by garbage bag and sanitary pad-modified mixes. At 12%, a slight reduction in stability was noticed, possibly due to brittleness induced by excess plastic.

Table 4.1: Plastic Content in Bitumen.

Mix Type	PET Bottle (%)	Sanitary Pads (%)	Garbage Bags (%)	Total Plastic (%)
8% Mix	3.2	2.4	2.4	8
10% Mix	4.0	3.0	3.0	10
12% Mix	4.8	3.6	3.6	12

Table 4.2. Marshall Stability Test of Bituminous Mix-(8,10,12%) (ASTM D1559)

Sample	Bitumen (g)	PET Bottle (%)	Sanitary Pads (%)	Garbage Bags (%)	Total Plastic (%)	Stability (kN)	Flow (mm)
8% Mix	100	3.2	2.4	2.4	8	8	3.2
					10		

10% Mix	100	4.0	3.0	3.0		10	3.6
12% Mix	100	4.8	3.6	3.6	12	12	4.0

Table 4.3. Summary of Modified Bitumen Behaviour

Test	**Pure Bitumen**	**8% Mix**	**10% Mix**	**12% Mix**
Penetration (mm)	81	65.0	57.0	51.0
Softening Point (°C)	48.5	49.5	53.0	56.5
Flash Point (°C)	98	260.0	280.0	300.0
Fire Point (°C)	1.023	280.0	300.0	320.0
Marshall Stability (kN)	251	8.0	10.0	12.0
Marshall Flow (mm)	263	3.2	3.6	4.0

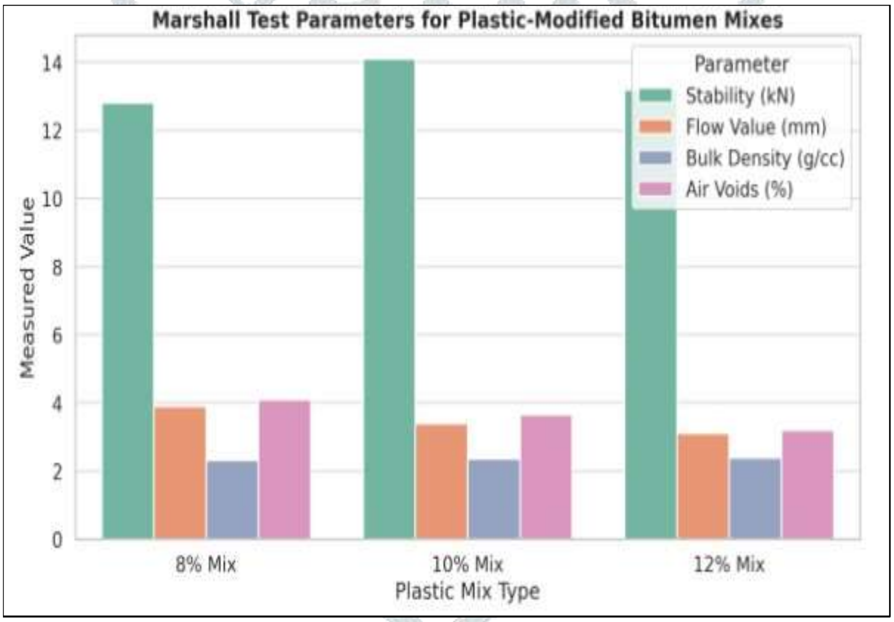

Fig.(a)

Result: Stability improves linearly from 10 to 14 kN.

4.2 Samples

Fig. Sample (a)

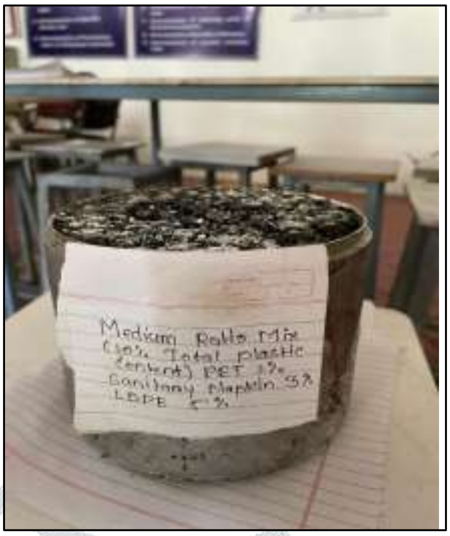

Fig. Sample (b)

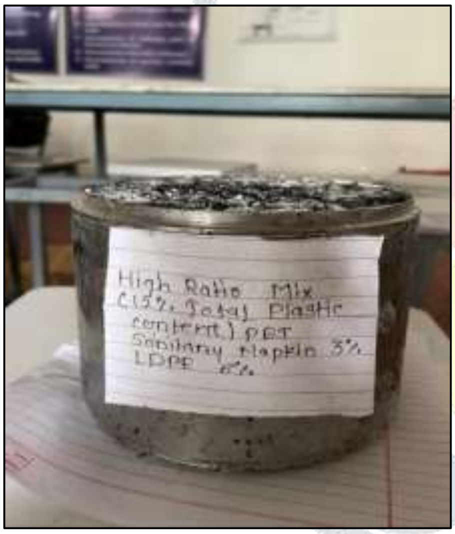

Fig. Sample (c)

Fig. Oven Drying Aggregate

VII. CONCLUSION

The present study effectively establishes the potential of incorporating plastic waste—specifically pet bottles, sanitary pad plastics, and garbage bags—as modifiers in bituminous mixes for flexible pavement construction. Through a series of standardized laboratory tests, including Marshall stability, penetration, softening point, and ductility, it has been demonstrated that the addition of plastic waste significantly enhances the performance characteristics of bitumen.

The modified bitumen exhibited improved thermal stability, increased resistance to deformation, and enhanced load-bearing capacity. Notably, the optimum performance was observed at 10% plastic content, which offered a balanced combination of strength and flexibility while maintaining acceptable ductility levels. This indicates that plastic-modified bitumen is not only feasible but also practical for use in real-world pavement construction.

Overall, this study presents a cost-effective and environmentally responsible solution for modern road construction, highlighting the dual benefit of performance enhancement and plastic waste utilization.

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