Use of Plastic Waste in Road Construction

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Abstract - The present study explores the potential use of plastic waste as a partial replacement for bitumen in road construction. With the rising environmental challenges caused by plastic pollution and the high demand for durable road infrastructure, this research evaluates the stability and flow characteristics of bituminous mixtures modified with plastic. Marshall Stability tests were conducted for both normal and plastic-modified moulds. The results indicate an improvement in stability with increasing plastic content, proving the feasibility of utilizing plastic waste in bituminous roads while maintaining permissible flow values.

***Key Words*:** Plastic Waste, Bitumen, Road Construction, Marshall Stability, Sustainable Development

1.INTRODUCTION

1.1 General

Road infrastructure plays a crucial role in the economic and social development of any country. With rapid urbanization and industrialization, there has been an increasing demand for durable, cost-effective, and environmentally sustainable road construction materials. In recent years, plastic waste has emerged as a significant environmental concern due to its non-biodegradable nature and the challenges associated with its disposal.

Plastic materials such as polyethylene, polypropylene, and polystyrene are widely used in packaging, bottles, bags, and various household items. Unfortunately, improper disposal of plastic waste leads to severe environmental pollution, clogging of drainage systems, and threats to marine and terrestrial life. Given these challenges, innovative solutions for plastic waste management are essential.

One such solution is the utilization of plastic waste in road construction. The concept of plastic roads involves incorporating processed plastic waste into bituminous mixtures to enhance pavement properties. This technique has been successfully implemented in several countries, including India, where cities like Chennai have pioneered plastic road technology. The process not only reduces plastic pollution but also enhances the durability, strength, and water resistance of roads, making it a promising alternative for sustainable infrastructure development.

1.2 Problem Statement

The increasing accumulation of plastic waste has become one of the most pressing environmental challenges worldwide. Traditional methods of plastic disposal, such as landfilling and incineration, have proven to be unsustainable, causing land pollution, air pollution, and greenhouse gas emissions. Despite various efforts to promote recycling and waste segregation, a significant portion of plastic waste remains unutilized and continues to harm the environment.

Conventional road construction methods primarily use bitumen, which is susceptible to wear and tear due to extreme weather conditions, heavy traffic loads, and water seepage. Over time, roads deteriorate, leading to frequent maintenance, increased costs, and disruptions in transportation networks. The need for stronger, more durable roads that can withstand environmental stresses has driven researchers to explore alternative materials that can enhance road performance.

Integrating plastic waste into road construction presents a viable solution to both the plastic waste crisis and road durability issues. However, there are challenges in terms of standardization, implementation, and large-scale adoption of this technology.

Addressing these challenges through systematic research, experimentation, and real-world applications is crucial for ensuring the long-term success of plastic roads.

1.3 Scope

This project focuses on the practical application and performance evaluation of plastic-modified bituminous roads. The study encompasses various aspects, including material selection, processing of plastic waste, mixing techniques, laboratory testing, and field implementation. The scope extends to analyzing the physical and mechanical properties of plastic-modified bitumen, comparing it with conventional road materials, and assessing its environmental and economic benefits.

The research includes both laboratory-based experimental studies and real-world case studies of existing plastic roads. The project aims to provide insights into the feasibility of large-scale adoption, potential challenges, and recommendations for optimizing plastic road construction techniques. Additionally, the study evaluates the cost-effectiveness of plastic roads compared to traditional asphalt roads, considering factors such as initial investment, maintenance costs, and long-term sustainability.

Furthermore, this project aligns with global sustainability goals by promoting eco-friendly construction practices. By reducing plastic waste, conserving natural resources, and enhancing road performance, the project contributes to creating a more resilient and sustainable infrastructure system.

1.4 Objective

- To study the feasibility of using plastic waste in bituminous road construction.
- To prepare bituminous mixes by partially replacing bitumen and aggregates with shredded plastic.
- To evaluate and compare the Marshall Stability and flow values of normal and modified bituminous mixes.
- To contribute to environmental sustainability by finding an alternative solution to plastic waste management.
- To propose a method that could reduce the cost of road construction while improving the quality of roads.

2. LITERATURE REVIEW

The growing concern over plastic pollution and its impact on the environment has encouraged researchers and engineers to explore sustainable methods for waste utilization. One such promising method is the use of waste plastic in road construction. Over the years, several studies have been conducted to investigate the effect of plastic waste on the performance of bituminous mixes.

- Kannur et al. (2025) presented a comprehensive review highlighting the innovative use of plastic waste in infrastructure projects. The study discussed how incorporating plastic into road construction improves pavement durability while also addressing environmental challenges by reducing plastic accumulation.
- AZoBuild (2024) emphasized both the benefits and challenges of using recycled plastic in asphalt. It concluded that while plastic addition can enhance certain properties of bitumen, more research is needed to fully understand its long-term environmental and economic effects.
- According to the International Research Journal of Innovations in Engineering and Technology (2024), roads constructed with plastic-bitumen mixes show improved strength, durability, and resistance to deformation, especially under heavy traffic loads. Similarly, a study in the International Journal of Creative Research Thoughts (2024) supported the use of plastic as a viable material in flexible pavement design due to its positive impact on performance and waste management.
- Rokdey et al. (2023) conducted laboratory tests which indicated that plastic-modified bituminous mixes have better Marshall stability values compared to conventional mixes. They also noted a reduction in required bitumen content, leading to cost savings.
- Chavan (2023) further verified these results through lab experiments and found that plastic-modified samples had superior resistance to fatigue and higher load-bearing capacity. Meanwhile, Sharma & Goyal (2022) demonstrated improved moisture resistance in roads built using plastic-modified bitumen.
- Other sources, such as Verma (2020) and Sultana & Gupta (2019), stressed the environmental benefits of this technique, stating that it not only reuses non-biodegradable waste but also enhances the longevity and quality of roads.

3. METHODOLOGY

The methodology adopted in this research involves a systematic approach to evaluate the feasibility and performance of incorporating waste plastic into road construction materials. The study was conducted in three main phases: collection and preparation of materials, testing of individual components, and preparation and evaluation of bituminous mixes using the dry process.

3.1 Collection and Preparation of Materials

The essential materials used in this study included coarse aggregates, paving-grade bitumen (VG-30), and shredded waste plastic (such as LDPE or HDPE). Aggregates were collected from a nearby quarry and cleaned before testing. Bitumen was sourced from an authorized supplier, ensuring compliance with standard paving specifications. Plastic waste was collected, cleaned to remove dirt or impurities, and shredded into uniform pieces of appropriate size for blending.

3.2 Testing of Aggregates and Bitumen

Before incorporating the materials into road mix designs, a series of laboratory tests were carried out to examine the fundamental properties of aggregates and bitumen:

- **Aggregate Impact Test** was conducted to evaluate the toughness of aggregates and their ability to resist sudden shocks.
- **Los Angeles Abrasion Test** determined the abrasion resistance of aggregates, reflecting their durability.

Simultaneously, the bitumen was subjected to the following tests:

- **Penetration Test** to assess the hardness or softness of the bitumen sample.
- **Ductility Test** to measure the stretch ability of bitumen before breaking, which indicates flexibility.

These tests ensured that both the aggregates and bitumen met the standard requirements and were suitable for further experimentation.

3.3 Preparation of Plastic-Modified Bituminous Mix

In this study, the dry process was used to prepare plastic-modified bituminous mixes. This method involves mixing shredded plastic waste with hot aggregates before blending with hot bitumen. The process included the following steps:

- Aggregates were heated to approximately **160–170°C**, after which shredded plastic was added.
- The plastic melted and coated the surface of the aggregates, forming a polymer-aggregate mix.
- Bitumen, heated to around **155°C**, was then added and thoroughly mixed to form a homogeneous bituminous mixture.

Various proportions of plastic (typically ranging from **5% to 8%** by weight of bitumen) were tried to observe their influence on mix performance. Each prepared sample was molded and cured in a water bath for 24 hours before performance testing.

3.4 Evaluation Using Marshall Stability Test

To assess the performance of the prepared bituminous mixes, the **Marshall Stability Test** was conducted. This test evaluates two key properties of the mix:

- **Stability** – the maximum load the mix can withstand before failure, indicating its strength.
- **Flow** – the amount of deformation the mix undergoes at maximum load, reflecting its flexibility and resistance to cracking.

The results obtained from the Marshall test helped determine the optimal plastic content that could improve the strength and stability of the bituminous mix without compromising its workability and flexibility. The study confirmed that the inclusion of plastic waste enhanced the performance characteristics of the road mix, making it a sustainable and practical solution for modern road construction.

4. RESULT & DISCUSSION

This section presents the outcomes of various experimental tests conducted to evaluate the performance of conventional and plastic-modified bituminous mixes. The results are discussed under relevant test categories for aggregates, bitumen, and Marshall stability of plastic-bitumen mixes.

4.1 Aggregate Test Results

4.1.1 Aggregate Impact Test

The aggregate impact test determines the toughness and resistance of aggregates to sudden shocks.

- **Initial weight of sample (W1)** = 350 gm
- **Weight of sample passing through 2.36 mm sieve after impact (W2)** = 80 gm
- **Aggregate Impact Value** = (80/350) × 100 = **22.85%**

According to IS standards, an impact value less than 30% is considered acceptable for road construction. Therefore, the tested aggregate is suitable for pavement works, exhibiting good resistance to impact.

4.1.2 Los Angeles Abrasion Test

This test evaluates the hardness and abrasion resistance of the aggregates.

- **Initial weight of aggregate sample (W_1)** = 5000 gm
- **Weight of sample retained on 1.7 mm sieve (W_2)** = 3600 gm
- **Abrasion Value** = ((5000 - 3600) / 5000) × 100 = **28%**

Since the permissible limit is below 30%, the aggregates tested are within acceptable limits and suitable for bituminous road surfaces, especially in areas with high vehicular load.

4.2 Bitumen Test Results

4.2.1 Penetration Test

This test measures the consistency of bitumen under specified conditions.

Table – 1: Penetration Values

Test Temperature: 25°C

Dial Reading	Test I	Test II	Test III
a. Initial	0.0	0.0	0.0
b. Final	65.2	66.1	65.8
Penetration Value (mm)	65.2	66.1	**65.8**

Average Penetration Value = 65.8 mm

The result indicates that the bitumen is of medium grade, offering good balance between hardness and flexibility. This makes it suitable for varying temperature and traffic conditions.

4.2.2 Ductility Test

This test evaluates the elongation ability of bitumen.

Table – 2: Ductility Values

Test Temperature: 27°C

Dial Reading	Bitumen I	Bitumen II	Bitumen III
a. Initial	0	0	0
b. Final	58.5	60.0	59.2
Penetration Value (mm)	58.5	60.0	59.2

Average Ductility = 59.2 mm

The bitumen used belongs to **VG 30 grade**, and the ductility result suggests it has sufficient elongation capacity to handle temperature-induced stresses in road pavements without cracking.

4.3 Marshall Stability Test Results

Marshall Stability Test was conducted to determine the strength and flow characteristics of the bituminous mix modified with varying percentages of plastic waste.

4.3.1 Mix Design Details

Table – 3: Plastic partially replacing aggregates

Mould	Plastic (%)	Bitumen (gm)	Plastic (gm)
1	5%	114 gm	30 gm
2	6%	108 gm	36 gm
3	7%	102 gm	42 gm
4	8%	96 gm	48 gm

4.3.2 Stability and Flow Values

Normal Mould (only bitumen and aggregate):

Table – 4: Stability and Flow Values of Normal Mould

Mould	Bitumen (%)	Stability (kg)	Flow (mm)
1	5.0	1250.4	3.35
2	5.5	1382.6	3.50
3	6.0	1524.8	3.65
4	6.5	1680.2	3.80

Plastic Modified Mould (bitumen partially replaced):
Table – 5: Partially replacing Bitumen only with plastics

Mould	Plastic (%)	Stability (kg)	Permissible Stability (kg)	Flow (mm)	Permissible Flow (mm)
1	5	1250.4	1500	3.35	4.0
2	6	1382.6	1500	3.50	4.0
3	7	1524.8	1500	3.65	4.0
4	8	1680.2	1500	3.80	4.0

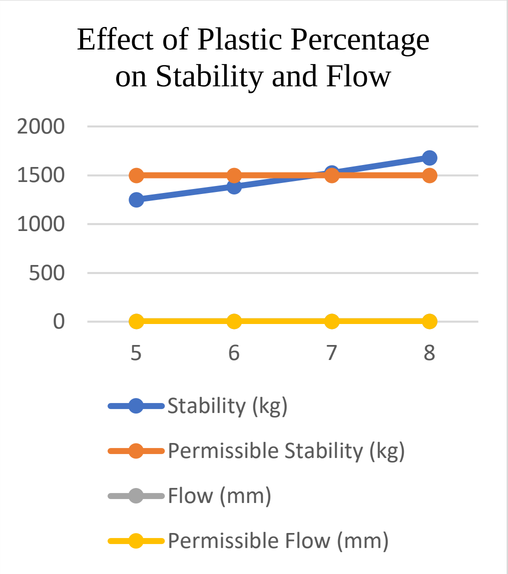

Chart – 1: Partially replacing Bitumen only with plastics

5. CONCLUSION

From the study conducted, it is clearly observed that plastic waste, when used properly in road construction, can significantly improve the quality and strength of bituminous mix. The tests carried out on aggregates and bitumen showed satisfactory results and confirmed their suitability for road work. By partially replacing bitumen with plastic waste, the Marshall Stability values improved, indicating better performance and durability of roads.

The overall result proves that plastic not only enhances the properties of the road surface but also provides an eco-friendly solution for managing plastic waste, which is one of the major environmental concerns today. Using plastic in road construction can reduce the amount of waste dumped in landfills or burnt, and also reduce the cost of road construction to some extent.

Thus, this project shows a positive approach towards sustainable development, creating strong roads while protecting the environment. It can be considered a step forward towards cleaner and greener infrastructure development in India.

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