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Utilization of Plastic Waste in Bituminous Mix for Durable and Sustainable Road Construction

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Abstract: *The accelerated generation of plastic waste has emerged as one of the most serious environmental concerns of the contemporary era. Conventional methods like landfilling and incineration are responsible for causing enormous environmental degradation and pollution. In order to overcome this, the current study investigates the efficient use of plastic waste in bituminous road construction as a green and sustainable option. Plastic wastes like polyethylene (PE), polypropylene (PP), and polystyrene (PS) are utilized as modifiers in the bituminous mixture to enhance the performance of the pavement. Modified bitumen with improved binding strength, enhanced stability, and enhanced resistance to water damage and rutting is a result of this method. This technique not only decreases plastic waste but also minimizes the use of traditional bitumen, thus making road construction less costly and environment-friendly. In addition, plastic waste addition imparts improved load-carrying capacity, increased Marshall Stability values, and increased resistance to deformation due to heavy traffic. Field observations and laboratory tests have proved that plastic-modified bitumen roads record higher service life and reduced maintenance. The concept promotes waste-to-wealth practices and meets the global objectives of sustainable infrastructure as well as environmental conservation. Accordingly, use of plastic waste in bituminous mixes is a promising and sustainable option for contemporary road construction techniques.*

Keywords: plastic waste

I. INTRODUCTION

Construction of roads is an important factor in the nation's economic development but is also responsible for natural resource depletion and pollution of the environment. Parallelly, the large-scale application of plastic materials in daily life has resulted in a dangerous surge in plastic waste generation. Since plastics are non-biodegradable, they stay in the environment for many centuries and cause serious damage to soil and marine ecosystems. Hence, discovering a suitable and sustainable means for plastic waste disposal and recycling has been the priority of the whole world. The idea of utilizing plastic waste in bituminous road construction has come forth as an innovative and real solution for these issues. In combination with bitumen, plastic waste serves as a modifier of the mechanical and rheological characteristics of the road. The plastic-coated aggregate method further enhances the strength and performance of roads under changing climatic and traffic conditions.The objective of this project is to research the application of waste plastics in bituminous mixes, analyze their impact on the physical characteristics of bitumen and pavement performance, and compare the environmental and economic advantages of this technology. By utilizing waste to produce a useful building material, this process favors the concepts of sustainable development and circular economy and offers strong, resilient, and long-lasting road infrastructure.

II. OBJECTIVE

1. Minimizing environmental pollution by proper recycling of non-biodegradable plastic waste in road construction.
2. Studying the characteristics of plastic-modified bitumen, including penetration, ductility, softening point, and stability.

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3. Enhancing the performance and durability of bituminous roads by increasing their strength, flexibility, and resistance to water damage and rutting.
4. To compare the performance of traditional bituminous mixes and plastic-modified mixes by carrying out laboratory tests like the Marshall Stability test.
5. To find the economic viability of employing plastic waste in road construction by quantifying cost savings in materials and maintenance.
6. To facilitate sustainable and environmentally friendly road construction practices that are consistent with waste management and circular economy principles.

III. METHODOLOGY

- Literature Review
- Material collection
- Mix design
- Casting and curing
- Testing
- Result and conclusion

IV. MATERIALS USED

1. Bitumen
Type: VG-30 Grade Bitumen
Source: Obtained from a standard refinery as per IS: 73–2013.
Properties:
Penetration Value = 70 dmm
Softening Point = 47 °C
Description: VG-30 bitumen is suitable for regions with moderate to heavy traffic and tropical climatic conditions. It acts as a binding material, providing adhesion between aggregates and flexibility to the pavement structure. Function: Serves as the primary binder and ensures cohesion in the bituminous mix.

2. Plastic Waste
Type: Shredded Low-Density Polyethylene (LDPE), High-Density Polyethylene (HDPE), and Polypropylene (PP) Size: Less than 2.36 mm (passing through 2.36 mm sieve) Source: Collected from post-consumer plastic waste such as carry bags, bottles, and packaging materials, which are cleaned and shredded.Plastic Content Used: 4%, 6%, 8%, and 10% by weight of bitumen Description: These thermoplastic materials soften upon heating and uniformly coat the hot aggregates, enhancing bonding and improving pavement strength. Function: Used as a modifier in the bituminous mix to enhance stability, reduce rutting, and improve resistance to water damage and aging.

3. Coarse Aggregates
Type: Crushed Granite Aggregates
Specification: Conforming to IRC: 111 and IS: 2386 (Part I–IV)
Coarse Aggregates: Retained on 4.75 mm sieve Fine Aggregates: Passing 4.75 mm sieve
Properties: Hard, angular, durable, and free from dust, clay, and organic impurities.Function: Provide the main structural skeleton of the pavement and distribute the traffic load effectively.

4. Fly ash
Type: Stone Dust / Lime / Cement (as per availability) Purpose: To fill the voids in the mix and improve inter-particle bonding and density.

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MIX DESIGN

An appropriate design mix for employing bitumen, plastic waste, coarse aggregate, and fly ash for sustainable construction of roads is the incorporation of shredded plastic waste as a modifier into the bituminous mix via the dry process. Shred the clean plastic waste to a size through which it can pass a 2.36 mm sieve. Dry the coarse and fine aggregates to around 160–165°C, and then uniformly spread the hot aggregates with 6–8% plastic waste on the weight of bitumen—i.e., for each 100 kg mix, employ some 5 kg bitumen and 300–400 g plastic waste. Follow this by adding fly ash (approximately 4–6% of the mix) as a mineral filler, which improves workability and sustainability. After being coated, add the pre-heated bitumen and thoroughly mix to distribute evenly. Roll compact at approximately 150–155°C and subject to laboratory tests (e.g., Marshall Stability and flow) to optimize the ratios for maximum engineering properties. This design not only enhances the strength, durability, and watertightness of pavements but also gives plastic waste a useful road construction material, contributing to environmental sustainability

LITERATURE REVIEW:

[1] Sharma, R., and Choudhary, S. (2018) explored the performance of plastic waste-modified bituminous mixes with low-density polyethylene (LDPE) as the additive. The research identified that plastic waste addition enhanced the softening point and reduced the penetration value of bitumen, which indicated the improvement in stiffness and temperature susceptibility resistance. Marshall Stability tests indicated a sharp increase in load-carrying capacity to an optimum level of 8% plastic content on the weight basis of bitumen, after which performance decreased. The authors suggested the use of LDPE-modified bitumen for flexible pavement construction in hot climatic conditions to enhance the rutting resistance and service life.

[2] Rajasekaran, S., Vasudevan, R., and Rajkumar, K. (2019) investigated the dry process of blending shredded plastic waste with bituminous mixes. Aggregates were first coated with molten plastic and then blended with bitumen. The findings were found to have enhanced bonding between bitumen and aggregates, lower voids, and higher values of stability when compared to traditional mixes. The plastic-coated aggregate method gave improved water-induced damage resistance and reduced pothole formation. The research concluded that waste plastic can be utilized effectively in road construction without modifying the current mixing and laying process.

[3] Singh, D., and Gupta, P. (2020) conducted a comparative analysis on traditional bituminous mix and plastic-extended mix with polyethylene and polypropylene waste. The binder showed an increased softening point and lower ductility, which enhanced high-temperature properties but slightly compromised flexibility at low temperatures. Marshall Stability value improved by approximately 25–30%, whereas flow value reduced, reflecting a harder mix. The researchers suggested the utilization of mixed plastic waste as much as 10% by weight of bitumen for the best outcome.

[4] Nayak, P., and Mohanty, R. (2021) examined the rheological and durability characteristics of bitumen modified with varying percentages of plastic waste. Laboratory testing confirmed that the modified binder demonstrated better resistance to rutting and stripping, along with enhanced aging properties. Moisture susceptibility tests (Tensile Strength Ratio) showed improvement of up to 15% compared to conventional mix. The research underscored that incorporating plastic waste not only improves the mechanical performance of pavements but also offers an eco-friendly approach to plastic waste management.

[5] Patil, S., and Kulkarni, A. (2022) assessed the economic as well as environmental advantages of incorporating plastic waste in flexible pavement construction. Based on the analysis, it was found that there was a decrease in the overall requirement of bitumen by about 8% and thus a reduction in construction costs as well. Plastic-modified bitumen roads showed improved service life with lower maintenance needs. The research found that such technology enables sustainable infrastructure development through the recycling of waste into a useful construction material and the application of circular economy values.

TEST CONDUCTED SOFTENING POINT TEST

Plastic%	Softening point (°C)
0%	47
4%	50
6%	53
8%	56
10%	55

The test results show that as the plastic content in the bituminous mix increases, so does the softening point of the mix. With no plastic, the softening point is recorded at 47°C. When 4% plastic is used, the softening point is raised to 50°C. For 6% plastic content, the reading goes up to 53°C, and with 8% plastic, the softening point increases to 56°C. But when plastic content goes up to 10%, the softening point reduces by a small margin to 55°C. This development proposes that the incorporation of plastic tends to improve the thermal stability of the bituminous mix to 8%, after which the improvement is constant or slightly dips, showing an optimum zone for plastic modification

DUCTILITY TEST

Plastic%	**Ductility(cm)**
0%	82
4%	78
6%	75
8%	68
10%	62

The test results indicate that the ductility of the bituminous mix decreases with the increase in the amount of plastic added. When no plastic was added (0%), there was a ductility of 82 cm. When the content of plastic was raised to 6%, the ductility fell to 75 cm. Increasing the plastic content further to 8% gave a ductility of 68 cm, and with 10% plastic content, the ductility was the minimum at 62 cm. This shows that the addition of plastic lowers the ductility of the bituminous mix so that it becomes stiffer.

ROTATIONAL VISCOSITY

Plastic %	**Viscosity**
0%	390
4%	420
6%	440
8%	465
10%	480

The outcome is that the bituminous mix viscosity rises as plastic is added. The viscosity was 390 at 135 °C when there was no plastic (0%). When plastic levels rose to 6%, the viscosity went up to 440 With 8% plastic, the viscosity increased further to 465 and with 10% plastic, the viscosity was at its maximum of 480. This pattern indicates that the addition of plastic increases the viscosity of the bitumen and makes it thicker and more resistant to flow at high temperature.

V. RESULT

Test	0% plastic	4%	6%	8%	10%
Softening point	47	50	53	56	55
Ductility(cm)	82	78	75	68	62
Viscosity(cSt)	390	420	440	465	480

Softening point was found to rise from 47°C to 56°C with increasing plastic content up to 8%, indicating greater thermal stability.

The ductility reduced from 82 cm to 62 cm upon the addition of plastic, suggesting that the mix stiffens and is less elastic.

The viscosity went up gradually from 390 to 480 to ensure that the bitumen thickens and is more resistant to deformation upon addition of plastic.

VI. CONCLUSION

The addition of plastic waste in bituminous mixtures considerably increases the softening point and viscosity, enhancing the temperature susceptibility and mix durability. The ductility is reduced with higher plastic content, demonstrating the decrease in elasticity but an increase in stiffness — a good attribute for high-temperature performance. The optimum content of plastic is determined to be approximately 8%, where the softening point and viscosity are at beneficial levels without reducing ductility too much .Plastic waste addition makes the bituminous mix tougher against rutting, deformation, and temperature change, leading to increased pavement life .This study proves that using plastic waste in road construction not only enhances the engineering properties of bitumen but also offers a sustainable plastic waste management solution

REFERENCES

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[3] Singh, D., and Gupta, P. (2020) carried out a comparative study on conventional bituminous mix and plastic-modified mix using polyethylene and polypropylene waste.

[4] Nayak, P., and Mohanty, R. (2021) examined the rheological and durability characteristics of bitumen modified with varying percentages of plastic waste.

[5] Patil, S., and Kulkarni, A. (2022) evaluated the economic and environmental benefits of using plastic waste in flexible pavement construction.

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