

Eco-Friendly Pavement Design using Plastic Waste Modified Bitumen

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Abstract: Rapid urbanization and the growing use of plastics have resulted in a significant increase in plastic waste, leading to serious environmental concerns. Disposing of this non-biodegradable waste is a major challenge, as traditional methods like landfilling and incineration cause pollution and resource loss. To address this issue, an eco-friendly pavement design incorporating plastic waste is proposed. In this approach, waste plastics such as polyethylene, polypropylene, and polystyrene are shredded and used as a partial replacement for bitumen in flexible pavement construction. The addition of plastic waste improves the binding properties, increases the stability and durability of the pavement, and enhances resistance to water-induced damage. This method not only provides an effective solution for plastic waste management but also reduces the cost of road construction and conserves natural resources. Therefore, using plastic waste in pavement design offers a sustainable, economical, and environmentally responsible alternative for modern road infrastructure.

Keywords: Eco-friendly pavement, plastic waste, flexible pavement, bitumen modification, sustainable road construction, waste management, recycled plastics, environmental protection, durability, cost-effective pavement.

I. INTRODUCTION

The rapid growth of population, urbanization, and modernization has resulted in an enormous increase in the production and use of plastics worldwide. Although plastics are durable, lightweight, and versatile materials, their non-biodegradable nature makes their disposal a serious environmental problem. Large quantities of plastic waste accumulate in landfills and open areas, leading to soil and water pollution and posing threats to human and animal life. At the same time, the demand for durable and cost-effective road infrastructure is rising steadily, especially in developing countries.

To address both the environmental challenges of plastic waste and the need for sustainable construction materials, researchers and engineers have explored the use of waste plastics in road pavement construction. When processed and added to bituminous mixes, plastic waste improves the binding characteristics of bitumen and enhances pavement performance. It increases resistance to rutting, reduces moisture absorption, and extends the service life of roads. Moreover, it provides a valuable use for discarded plastics, thereby reducing environmental pollution and conserving natural resources.

The concept of eco-friendly pavement design using plastic waste combines waste management with infrastructure development, promoting sustainability in the construction industry. This innovative approach not only reduces the cost of pavement construction but also contributes to the development of greener and more resilient road networks.

II. MATERIALS AND METHODOLOGY

FINE AGGREGATE

The fine aggregate is employed to occupy the voids within the coarse aggregates and also to make the concrete mix workable. The fine aggregate utilized was natural river sand passing through a 10 mm sieve. The sand was free from clay or organic material and was well-graded.



In this research we used a fine aggregate as 25% of total mix.



Figure: 1

CORASE AGGREGATE

Coarse aggregate adds bulk and strength to the concrete. Crushed stone aggregate of size 15 mm and 20 mm was used in the mix. The aggregate was clean, angular, and dust-free and also free from organic impurities. Gradation and quality of the coarse aggregate have a direct impact on the workability and strength of high-strength concrete. In this mix, we used a coarse aggregate as 60% of total mix.



Figure:2

BITUMEN:

Bitumen is a black, sticky, petroleum-based material used as a binder in road construction. It holds the Aggregates together in flexible pavements and provides waterproofing, durability, and flexibility to the road surface. Bitumen softens when heated and becomes solid again when cooled, making it **easy** to mix with aggregates during paving. In this research , we used a bitumen as 6% or 8% or 9% of total mix.





Figure:3

WATER

Pure and drinking water was utilized for curing and mixing. The Water is used for the hydration of a cement and for proper chemical reaction. The water used was free from acids, free from oils, free from alkali, and free from organic contaminants. The water–cement ratio was also maintained under strict control to ensure the needed workability and strength.

FILLERS

Fillers are very fine materials added to construction mixes like **bitumen, asphalt, or concrete** to improve density and strength. They fill the tiny voids between larger particles, making the mix more stable and duration. In this research , we used a fillers as 4% of total mix.

SHREDDED PLASTIC WASTE

Shredded plastic waste refers to discarded plastic materials that are cut into small pieces using shredding machines. These small plastic pieces are often used in road construction, especially in **bitumen modification**. In this research, we used a shredded plastic waste as 5% or 3% of total mix.



Figure:4



LAYERING DESIGN

LAYERING PROCEDURE:

Prepare materials – ensure fine aggregate through 10mm sieve .

Selecting a materials.

Layering a materials one by one according to the flexible pavement layers .

Heated the bitumen to 150-165°C.

Mix the shredded plastic , bitumen and fine aggregate .

Mix thoroughly until a uniform, workable mix is achieved.

Pour it on the base course of the layer.

Setting it on 24 hours.

PROCEDURE :

The layering procedure for constructing the flexible pavement begins with the preparation of all materials, ensuring that the fine aggregate passes through a 10 mm sieve for proper grading.

After selecting suitable materials, the construction starts with placing the **subgrade layer**, where 8 kg of native soil is spread evenly to achieve a 50 mm thickness and compacted to form a stable foundation.

Over this, the **sub-base layer** is laid by spreading and compacting a mixture of soil and aggregate weighing 8 kg to a thickness of 60 mm.

Next, the **base course** is constructed by placing 11 kg of coarse aggregate and compacting it to an 80 mm layer, providing structural strength to the pavement. For the surface course, bitumen is heated to 150–165°C, and 5 kg of shredded plastic is added to form a modified binder.

This plastic-coated bitumen is then mixed thoroughly with fine aggregate passing the 10 mm sieve until a uniform hot mix is obtained

The prepared hot mix is poured over the compacted base course and spread to form a 40 mm thick surface layer.

After proper laying and compaction, the completed surface is allowed to set for 24 hours, resulting in a durable and eco-friendly pavement section.

III. TESTS CONDUCTED

Introduction to Specific Gravity Test (Plastic-Modified Bitumen Mix)

Specific gravity is an important property used to evaluate the density and compactness of bitumen and bitumen-modified mixes. When plastic waste is blended with bitumen, its density changes, which affects the overall performance of pavement layers.

The **Specific Gravity Test** determines the ratio of the density of the material to the density of water at a standard temperature (usually 27°C). This test is commonly performed according to **IS 1202 (Method for Specific Gravity of Bituminous Materials)**.

Purpose of the Test

- To determine the density of the bitumen–plastic blend.
- To evaluate how plastic waste content affects the mix.
- To use the value in volumetric mix design (Marshall Mix Design).
- To assess workability, stability, and performance of the pavement.

Principle of the Test

- Specific gravity is calculated by measuring the:
- Weight of the sample in air
- Weight of the sample in water
- Temperature of water



- Then applying the formula:

$$\text{Specific Gravity (G)} = \frac{\text{Weight of sample in air}}{\text{Weight of sample in air} - \text{Weight of sample in water}}$$

A higher specific gravity indicates a denser and more compact material.

Calculation for Given Values

You have already calculated the specific gravity values for different plastic contents. Below is a clean presentation:

Interpretation

As the percentage of **plastic waste increases**, the **specific gravity increases** from **1.01 to 1.07**.

This indicates that the **density of the plastic-bitumen blend increases**, which may:

Improve binding characteristics

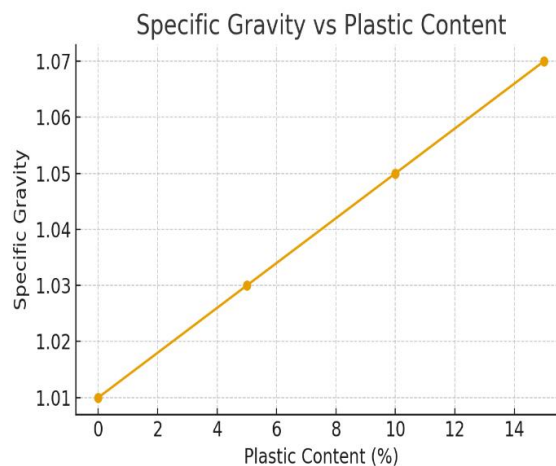
Increase compactness

Reduce voids in the mix

Enhance stability

IV. SPECIFIC GRAVITY TEST

Plastic Content (%)	Specific Gravity
0%	1.01
5%	1.03
15%	1.05
20%	1.07



Summary

The Specific Gravity Test is crucial for understanding the density behavior of plastic-modified bitumen. The increasing trend in your values shows that incorporating plastic waste improves the material density, which is beneficial for pavement strength and durability.



Introduction to Specific Gravity Test (Plastic-Modified Bitumen Mix)

Bulk Density Test – Introduction

Bulk density is defined as the **mass of the compacted bituminous mix per unit volume**. It represents how well the mix particles are packed together after compaction. This property is important in pavement design because it influences:

Strength and stability of the mix

Durability and resistance to deformation

Optimum compaction and air void content

The test is performed by measuring the **weight of the compacted specimen in air, saturated surface-dry (SSD) condition, and submerged in water**.

Using these measured values, bulk density is calculated.

BULK DENSITY TEST

Plastic Content (%)	Bulk Density (g/cm ³)
0%	2.10
5%	2.15
15%	2.18
20%	2.22

Formula Used

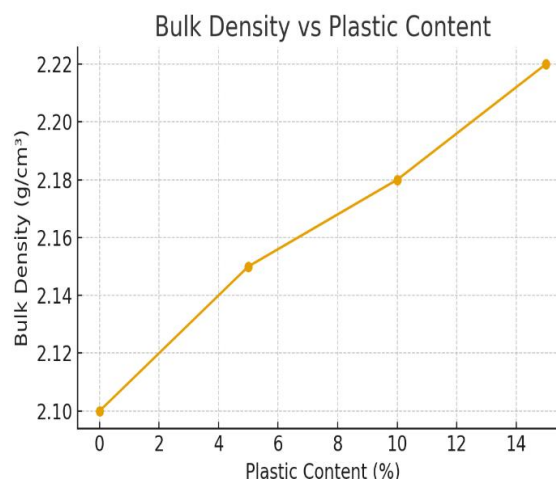
$$\text{Bulk Density (g/cm}^3\text{)} = \frac{W_a}{W_{ssd} - W_w}$$

Where:

W_a = Weight of specimen in air

W_{ssd} = Saturated surface dry weight

W_w = Weight of specimen in water



Summary

The Bulk Density Test plays an important role in assessing the compactness and packing efficiency of plastic-modified bitumen mixes. The results show a clear increasing trend in bulk density with higher plastic content, rising from 2.10 g/cm³ at 0% plastic to 2.22 g/cm³ at 20% plastic. This steady increase indicates that the addition of plastic waste



enhances the overall density and improves the compaction of the mix. Higher bulk density reflects fewer air voids, better interlocking of particles, and improved structural integrity. Therefore, incorporating plastic waste in the bitumen mix results in stronger, more durable, and better-performing pavement layers.

V. CONCLUSION

The experimental study on eco-friendly pavement design using plastic-waste-modified bitumen demonstrates that incorporating shredded plastic waste significantly enhances the engineering properties of bituminous mixes. The specific gravity and bulk density values increased consistently with higher plastic content, indicating better compaction, improved bonding, and enhanced structural integrity of the mix. This improvement suggests that plastic-coated aggregates develop stronger interlocking and reduced void spaces compared to conventional mixes.

The results confirm that using plastic waste (5–15%) not only improves the mechanical characteristics of pavement layers but also provides a sustainable solution for managing non-biodegradable waste. Plastic-modified bitumen enhances durability, reduces rutting, resists water absorption, and increases the service life of flexible pavements. Therefore, this method is technically beneficial, economically feasible, and environmentally responsible. Overall, the study concludes that plastic-waste-modified bitumen is a viable and eco-friendly alternative for modern road construction.

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