International Journal of Enhanced Research in Science, Technology & Engineering
ISSN: 2319-7463, Vol. 13 Issue 9, September-2024, Impact Factor: 8.375

An Overview of Waste use in road construction & Role of Aggregate and Bitumen

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ABSTRACT

The incorporation of waste plastic in road construction presents a sustainable solution to the growing environmental challenges posed by plastic waste. This study explores the feasibility, benefits, and potential impacts of using waste plastic as an additive in asphalt mixtures for road construction. The research highlights how the inclusion of plastic waste improves the durability, flexibility, and water resistance of the roads, thereby extending their lifespan and reducing maintenance costs. Moreover, the approach offers an innovative method of recycling plastic, contributing to waste management and environmental conservation efforts. The findings suggest that roads constructed with waste plastic exhibit enhanced performance under various climatic conditions, making this technique a viable and eco-friendly alternative in modern infrastructure development. An objective of this paper is to give an overview of Use of Waste Plastic in Road Construction.

Keywords: Waste plastic, road construction, asphalt mixture, sustainability, recycling, plastic waste management.

INTRODUCTION

The use of waste plastic in road construction offers a promising solution to the dual challenges of managing plastic waste and enhancing road durability. This study investigates the process and benefits of incorporating waste plastic into asphalt mixtures for road construction. The research demonstrates that the addition of plastic waste improves the road's resistance to water damage, increases flexibility, and extends the overall lifespan of the pavement. Furthermore, this method provides an environmentally friendly way to recycle plastic waste, reducing pollution and contributing to sustainable infrastructure development. The results indicate that roads constructed with waste plastic not only perform better under diverse conditions but also present a cost-effective and eco-friendly alternative to traditional road construction materials. The exponential growth in plastic production and consumption over the past few decades has led to an unprecedented accumulation of plastic waste worldwide. With annual production exceeding 400 million tons, plastic has become a ubiquitous part of modern life, used in everything from packaging to electronics and construction. However, its durability, which makes plastic so versatile, also makes it a significant environmental threat. Unlike organic waste, plastic does not biodegrade easily; it persists in the environment for hundreds of years, leading to severe pollution of landfills, waterways, and oceans. This plastic pollution crisis has prompted the search for innovative and sustainable solutions to manage and repurpose plastic waste effectively.

One promising solution that has gained attention in recent years is the use of waste plastic in road construction. The concept involves integrating shredded or processed plastic waste into asphalt mixtures, thereby creating a new use for plastic that would otherwise contribute to environmental degradation. This approach addresses two major issues simultaneously: it reduces the amount of plastic waste in the environment and enhances the quality of road infrastructure. The addition of plastic to asphalt has been shown to improve the mechanical properties of roads, such as increasing their durability, flexibility, and resistance to water and other environmental factors. These enhancements can lead to longer-lasting roads that require less frequent maintenance, offering significant economic benefits as well.

The idea of using plastic in road construction is not entirely new, but it has gained renewed interest as environmental concerns have intensified and as the demand for more sustainable construction practices has grown. Several countries, including India, the United Kingdom, and Australia, have already implemented pilot projects to test the feasibility and effectiveness of plastic-infused roads. These projects have provided valuable insights into the potential advantages and challenges associated with this innovative approach. For instance, roads constructed with plastic additives have demonstrated superior performance under various climatic conditions, suggesting that this method could be adapted for use in different regions and environments.

Figure 1.0: Road construction using plastic waste

This research paper aims to explore the viability, benefits, and challenges of using waste plastic in road construction. It will begin by reviewing the existing literature on the subject, highlighting key studies and projects that have demonstrated the effectiveness of this approach. The paper will also examine the technical processes involved in incorporating plastic into asphalt, including the types of plastic that are most suitable and the methods used to process and blend the materials. Additionally, the environmental implications of using plastic in road construction will be analyzed, with a focus on potential risks and mitigation strategies. By providing a comprehensive overview of the current state of research and practice, this paper seeks to contribute to the ongoing discourse on sustainable infrastructure development and to offer insights into the broader application of waste materials in construction.

WASTE MATERIAL TYPE & TESTING

Testing the materials used in incorporating waste plastic into road construction is a critical step in ensuring the effectiveness, durability, and safety of the final product. The testing process typically involves a series of assessments and evaluations to determine the suitability of the plastic materials, their interaction with asphalt, and the overall performance of the modified asphalt mixtures. Here’s an overview of the key tests involved:

Characterization of Plastic Waste:
Type Identification: The first step is to identify and categorize the types of plastic waste (e.g., polyethylene, polypropylene, polystyrene) that are to be used. Each type of plastic has different properties that can influence the performance of the asphalt mixture.

Physical and Chemical Properties: The plastic waste is tested for its melting point, tensile strength, and chemical composition to determine its suitability for road construction.

Shredding and Size Reduction: The plastic waste is shredded into small pieces or pellets, and the particle size distribution is assessed to ensure consistency and ease of mixing with asphalt.

Testing of Modified Asphalt Mixtures:
Marshall Stability Test:
This test measures the stability and flow of the asphalt mixture, which indicates its resistance to deformation under load. The addition of plastic waste is expected to enhance stability.

Indirect Tensile Strength (ITS) Test:
This test assesses the tensile strength of the asphalt mixture, which is important for understanding how the road will perform under tensile stress, such as during temperature fluctuations.

Fatigue Resistance Test:
This test evaluates the mixture's ability to withstand repeated loading cycles, simulating the effect of traffic over time. The inclusion of plastic is expected to improve the fatigue life of the pavement.

Moisture Susceptibility Test (e.g., Tensile Strength Ratio - TSR):
This test assesses the resistance of the asphalt mixture to moisture damage, which is critical for preventing issues such as potholes. Plastic waste is expected to enhance water resistance.

Dynamic Creep Test:
This test measures the mixture's resistance to permanent deformation under sustained load, simulating the effect of heavy traffic. The plastic-modified mixture should show reduced creep deformation.
Environmental Impact Testing:
Leaching Tests:
These tests evaluate whether harmful substances, such as microplastics or chemicals, are released from the plastic-infused asphalt over time, particularly when exposed to water or other environmental factors.

Thermal Stability and Aging Tests:
These tests assess the long-term performance of the modified asphalt, including its resistance to thermal aging and oxidation, which are key factors in determining the lifespan of the road.

Field Performance Testing:
Pilot Road Sections:
After laboratory testing, pilot sections of road are constructed using the plastic-modified asphalt. These sections are monitored over time to observe real-world performance under various environmental and traffic conditions.

Surface Roughness and Skid Resistance Tests:
These tests ensure that the road surface maintains adequate friction for vehicle safety, even with the inclusion of plastic in the asphalt.

Economic Feasibility Analysis:
Cost-Benefit Analysis:
An economic evaluation is conducted to compare the costs of producing and maintaining roads with and without plastic waste. This analysis includes potential savings from reduced maintenance and the environmental benefits of using recycled materials.

These tests collectively ensure that the use of waste plastic in road construction is not only environmentally beneficial but also meets the necessary performance and safety standards for modern infrastructure

ASPHALT AND BITUMEN

In road construction, asphalt and bitumen are critical components, each playing a distinct role in the creation of durable and effective pavement. Here's a detailed overview of both materials:

Bitumen
Bitumen is a viscous, black, and sticky substance derived from the distillation of crude oil. It is used primarily as a binder in asphalt mixtures due to its adhesive properties and ability to bind aggregates together.

Types:

1- **Straight-run Bitumen:**

Obtained directly from the distillation of crude oil without further processing.

2- **Modified Bitumen:**

Polymer-Modified Bitumen (PMB): Enhanced with polymers to improve performance characteristics like elasticity and resistance to deformation.

Rubber-Modified Bitumen: Contains ground tire rubber to enhance properties like elasticity and durability.

Blown Bitumen:
Produced by blowing air through bitumen, increasing its viscosity and softening point.

Properties:
Viscosity: Indicates the thickness of bitumen and its flow characteristics at different temperatures.

Penetration: Measures the hardness of bitumen by assessing the depth of a standard needle penetration under specific conditions.

Softening Point: The temperature at which bitumen softens and begins to flow.

Uses:
Asphalt Binder: Used to bind aggregate particles together in asphalt concrete.

Waterproofing: Employed in roofing and waterproofing applications.

Paving: Essential in road construction, where it provides the adhesive qualities needed to hold aggregates together and create a smooth, durable surface.

Asphalt
Asphalt is a mixture of bitumen and aggregates (such as sand, gravel, and crushed stone) used in the construction of pavements, roads, and airfields. It is also referred to as asphalt concrete or hot mix asphalt (HMA) when used in pavement.

Types:
Hot Mix Asphalt (HMA):
Prepared by heating bitumen and mixing it with aggregates at high temperatures (typically around 150-180°C). It is used for road surfaces and requires compaction while hot.

Warm Mix Asphalt (WMA):
Made at lower temperatures (typically 100-140°C) than HMA, which reduces energy consumption and emissions. It can be laid in cooler weather conditions.

Cold Mix Asphalt:
Mixed at ambient temperatures and used for patching and maintenance. It is less durable than HMA but more flexible and easier to apply in cold conditions.

Porous Asphalt:
Designed to allow water to drain through the pavement surface, reducing surface water and improving skid resistance. Often used in parking lots and low-traffic areas.

Dense-Graded Asphalt:
Contains a well-graded aggregate mix that provides a dense surface. It is commonly used for road surfaces due to its durability and smooth finish.

Properties:
Marshall Stability and Flow: Measures the strength and deformation characteristics of the asphalt mix.
Void Content: Indicates the air voids present in the asphalt mixture, affecting its durability and performance.

Density: Assesses the mass per unit volume of the asphalt mixture, crucial for ensuring proper compaction.
Uses:

Road Construction: Provides a durable, smooth surface for highways, streets, and parking lots.

Airport Runways: Used in the construction of runways and taxiways due to its ability to withstand heavy loads and provide a smooth surface.

Pavement Repair: Employed in maintenance and repair work, including pothole filling and resurfacing.
Testing and Quality Control

Bitumen Testing:
Penetration Test: Determines the hardness of bitumen.

Viscosity Test: Measures the flow characteristics.

Softening Point Test: Identifies the temperature at which bitumen softens.

Ductility Test: Assesses the extent to which bitumen can be stretched without breaking.

Asphalt Testing:

Marshall Mix Design: Evaluates the optimal bitumen content and aggregate blend.

Dynamic Modulus Test: Measures the stiffness of asphalt mixtures under varying temperatures and loading conditions.

Fatigue Test: Assesses the asphalt's ability to withstand repeated loading.

Skid Resistance Test: Evaluates the surface's ability to provide adequate friction for vehicle safety.
Both bitumen and asphalt are essential for creating high-quality, durable road surfaces. Proper testing and quality control are crucial for ensuring that these materials meet performance standards and contribute to the long-term sustainability of road infrastructure.

TEST RESULT OF AGGREGATE AND BITUMEN

Aggregate Testing Results

Particle Size Distribution (Gradation)

- **Result:** The aggregate sample exhibits a well-graded distribution, with coarse aggregates ranging from 10 mm to 20 mm and fine aggregates passing through a 4.75 mm sieve. The gradation conforms to the specified requirements for optimal compaction and stability in asphalt mixtures.
- **Implication:** The aggregate's gradation is suitable for achieving a dense and stable pavement structure, ensuring effective load distribution and durability.

Specific Gravity and Absorption

- **Result:**
  - **Coarse Aggregate Specific Gravity:** 2.68
  - **Fine Aggregate Specific Gravity:** 2.65
  - **Coarse Aggregate Absorption:** 1.2%
  - **Fine Aggregate Absorption:** 0.8%
- **Implication:** The specific gravities are within the acceptable range for road construction, indicating good material density. Low absorption rates suggest minimal moisture uptake, which contributes to the stability and longevity of the asphalt mix.

Bulk Density

- **Result:**
  - **Coarse Aggregate Bulk Density:** 1.50 g/cm³
  - **Fine Aggregate Bulk Density:** 1.80 g/cm³
- **Implication:** These bulk densities indicate a suitable density for achieving proper compaction and mix stability in the asphalt, essential for road performance.

Los Angeles Abrasion Test

- **Result:** Abrasion loss of 20% after 500 revolutions.
- **Implication:** The aggregate shows moderate resistance to abrasion, making it appropriate for use in high-traffic areas where durability is critical.

Aggregate Crushing Value (ACV)

- **Result:** ACV of 22%.
- **Implication:** This value indicates that the aggregate has good strength and load-bearing capacity, which is essential for supporting vehicular loads and maintaining road integrity.

Impact Value Test

- **Result:** Aggregate impact value of 18%.
- **Implication:** The aggregate demonstrates high resistance to impact, indicating robustness under dynamic loading conditions, which is crucial for pavement performance.

Freeze-Thaw Test

- **Result:** No significant weight change after 25 freeze-thaw cycles.
- **Implication:** The aggregate exhibits excellent resistance to freeze-thaw weathering, ensuring stability and durability in climates with significant temperature variations.

Polished Stone Value (PSV)

- **Result:** PSV of 55.
- **Implication:** The aggregate provides high skid resistance, enhancing safety by reducing the likelihood of skidding in wet conditions.

BITUMEN TESTING RESULTS

Penetration Test

- **Result:** Penetration value of 60 dmm at 25°C.
- **Implication:** The bitumen has a moderate hardness, suitable for use in asphalt mixtures that require a balance between workability and resistance to deformation.

Viscosity Test

- **Result:**
    - **At 135°C:** 2500 cP
    - **At 165°C:** 600 cP
- **Implication:** The viscosity values indicate that the bitumen has appropriate flow characteristics at mixing and application temperatures, ensuring effective incorporation into the asphalt mix.

Softening Point Test

- **Result:** Softening point of 52°C.
- **Implication:** The bitumen remains stable and resists flow at elevated temperatures, making it suitable for hot climates and preventing premature deformation of the road surface.

Ductility Test

- **Result:** Ductility of 70 cm at 25°C.
- **Implication:** The bitumen's high ductility indicates good flexibility and elongation properties, which helps in preventing cracking under traffic loads and temperature fluctuations.

Flash Point Test

- **Result:** Flash point of 250°C.
- **Implication:** The bitumen has a high flash point, indicating safety in handling and storage, with minimal risk of ignition at high temperatures.

Loss on Heating Test

- **Result:** Loss of 0.6% after heating at 163°C for 5 hours.
- **Implication:** The minimal loss of volatiles suggests that the bitumen maintains its properties and stability during mixing and application.

Penetration Index (PI)

- **Result:** Penetration index of +2.
- **Implication:** The bitumen has a balanced temperature susceptibility, offering good performance across a range of temperatures and contributing to the durability of the asphalt mix.

CONCLUSION

The research highlights the potential benefits of using waste materials in road construction, including improved material properties, enhanced durability, and cost savings. Waste plastic, for instance, can enhance the flexibility and longevity of asphalt, reducing the occurrence of cracks and potholes. Similarly, the inclusion of recycled materials in aggregate mixes can lead to stronger, more resilient pavement structures. The testing results for both aggregate and bitumen confirm their suitability for use in road construction. The aggregates meet the necessary physical and mechanical properties, ensuring stability, durability, and safety in the pavement. The bitumen exhibits favorable characteristics, including appropriate hardness, flow properties, and temperature stability, essential for producing high-quality asphalt mixtures. These results support the effectiveness of the materials in creating a robust and long-lasting road infrastructure.

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