EFFECT OF DAILY USE PLASTIC ON PERFORMANCE OF ASPHALT PAVEMENT

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Abstract - *The rapid growth in plastic consumption has resulted in severe environmental challenges due to improper disposal and non-biodegradability. This research investigates the utilization of daily use plastic waste in asphalt pavement and its impact on performance characteristics. Waste plastics such as polyethylene (PE), polypropylene (PP), and polystyrene (PS) are incorporated into bituminous mixes using dry and wet processes. Laboratory tests including Marshall Stability, flow value, indirect tensile strength, rutting resistance, and moisture susceptibility are analyzed. The results demonstrate significant improvement in mechanical properties and durability of asphalt pavements. The study establishes that plastic-modified bitumen provides an eco-friendly, cost-effective, and sustainable alternative to conventional pavements.*

Key Words: Waste Plastic, Asphalt Pavement, Bitumen Modification, Sustainable Roads, Marshall Stability.

1. INTRODUCTION

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1.1 Background

Plastic materials have become an essential part of modern society due to their wide range of applications, durability, low cost, and lightweight nature. They are extensively used in packaging, construction, transportation, electronics, and daily household activities. Among various types of plastics, polyethylene (PE), polypropylene (PP), and polyethylene terephthalate (PET) are most commonly used in everyday life. However, the increasing consumption of plastic products has led to a significant rise in plastic waste generation worldwide.

One of the most critical issues associated with plastic is its non-biodegradable nature. Unlike organic waste, plastics do not decompose easily and can persist in the environment for hundreds of years. As a result, plastic waste accumulates in landfills, rivers, oceans, and urban areas, causing severe environmental pollution. In developing countries like India, rapid urbanization, population growth, and changing lifestyles have further accelerated plastic consumption. It is estimated that India generates millions of tonnes of plastic waste annually, a large portion of which is either not collected or improperly disposed of Improper disposal of plastic waste leads to several environmental and health hazards. Plastic waste often blocks drainage systems, leading to waterlogging and urban flooding. It also contaminates soil and groundwater by releasing toxic chemicals over time. Additionally, open burning of plastic waste produces harmful gases such as carbon monoxide, dioxins, and furans, which are dangerous to human health and contribute to air pollution. Marine ecosystems are also adversely affected, as plastic waste enters water bodies and harms aquatic life.

At the same time, the transportation sector is continuously expanding, leading to an increased demand for durable and long-lasting road infrastructure. Flexible pavements, which use bitumen as a binding material, are widely used due to their ease of construction and cost-effectiveness. However, conventional bituminous pavements are prone to various types of failures such as rutting, cracking, potholes, and stripping, especially under heavy traffic loads and varying environmental conditions.

In recent years, the concept of incorporating waste materials into road construction has gained attention as a sustainable solution. The use of waste plastic in asphalt pavements is one such innovative approach. Shredded plastic can be blended with aggregates or bitumen to improve the overall performance of the pavement. This not only enhances the strength and durability of roads but also provides an effective method for managing plastic waste. Therefore, the utilization of daily-use plastic in asphalt pavements addresses both environmental concerns and infrastructure challenges simultaneously.

1.2 Problem Statement

Despite various initiatives and policies for waste management, plastic disposal remains a major challenge worldwide. Conventional methods such as landfilling and incineration are not sustainable in the long term. Landfilling requires large areas of land and leads to environmental issues such as soil contamination and groundwater pollution. Moreover, plastics remain intact in landfills for decades, creating long-term ecological problems. Incineration, on the other hand, reduces the volume of waste but releases harmful gases into the atmosphere, contributing to air pollution and health risks.

Recycling of plastic is another alternative; however, it is limited by factors such as improper segregation, contamination, lack of infrastructure, and economic constraints. A significant portion of plastic waste, especially thin carry bags and packaging materials, is not suitable for recycling and often ends up in open dumps or water bodies.

Simultaneously, the performance of conventional asphalt pavements is deteriorating due to increasing traffic volume, higher axle loads, and extreme climatic variations. Roads frequently experience structural and functional failures such as rutting (permanent deformation under repeated loading), fatigue cracking, thermal cracking, and moisture-induced damage. These failures reduce the service life of pavements and increase maintenance and rehabilitation costs. Poor road conditions also lead to increased vehicle operating costs, fuel consumption, and safety hazards for road users.

A major limitation of conventional bitumen is its temperature susceptibility. At high temperatures, bitumen becomes soft and leads to rutting and deformation, whereas at low temperatures, it becomes brittle and results in cracking. Additionally, the presence of water weakens the adhesion between bitumen and aggregates, causing stripping and pothole formation.

Therefore, there is an urgent need to develop innovative, sustainable, and cost-effective solutions that can improve the performance of asphalt pavements while addressing environmental concerns. The use of waste plastic in road construction offers a promising alternative, as it can enhance the mechanical properties of bitumen, improve pavement durability, and simultaneously provide an efficient method for plastic waste utilization. However, a detailed investigation is required to evaluate its effectiveness, determine the optimum plastic content, and assess its long term performance under different conditions.

1.3 Objective

- To study the effect of plastic waste on asphalt performance
- To determine optimum plastic content
- To evaluate improvements in strength and durability
- To promote sustainable road construction practices

2. LITERATURE REVIEW

Extensive research has been conducted globally on the utilization of waste plastic in asphalt pavement. Various studies have demonstrated that incorporating plastic waste into bituminous mixes significantly enhances pavement performance and durability. Several researchers have reported that waste plastic improves the binding characteristics of bitumen by increasing its viscosity and adhesion properties. This results in better coating of aggregates and reduced stripping due to moisture. Additionally, the incorporation of plastic has been found to increase Marshall Stability by approximately 20–40%, indicating improved load bearing capacity of the pavement. Plastic-modified asphalt mixtures also exhibit enhanced resistance to rutting, fatigue cracking, and temperature variations, making them more durable under heavy traffic and adverse climatic conditions. Furthermore, guidelines such as IRC:SP:98 2013 and IRC 37:2018 support the use of waste materials in road construction, promoting sustainable infrastructure development.

Review of Previous Studies

1. Vasudevan et al. (2017): Vasudevan and co-researchers conducted pioneering work on the use of waste plastic in flexible pavements. Their study demonstrated that coating aggregates with shredded plastic improves the binding between aggregates and bitumen. The results showed a significant increase in Marshall Stability and a reduction in water absorption. The study concluded that plastic roads have better resistance to deformation and are more durable compared to conventional roads.

2. Al-Hadidy and Yi-Qiu (2019): This study focused on the performance of polyethylene modified asphalt mixtures. The researchers observed that the addition of plastic improves the viscoelastic behavior of bitumen, making it less susceptible to temperature variations. The modified mix exhibited improved rutting resistance at high temperatures and better flexibility at low temperatures, thereby reducing cracking.

3. Sahu and Pradhan (2023): Sahu and Pradhan investigated the feasibility of using waste plastic in road construction. Their findings indicated that plastic-modified bitumen enhances the strength and stability of asphalt mixtures. The study also highlighted environmental benefits, as the use of plastic waste reduces landfill burden and promotes recycling. They recommended the adoption of plastic roads in urban areas with heavy traffic.

4. Kumar and Garg (2024): Kumar and Garg studied the effect of different percentages of plastic on bituminous mixes. Their experimental results showed that Marshall Stability increases with plastic content up to an optimum level (around 6–8%), beyond which it starts decreasing. They also reported improved resistance to moisture damage and better durability of the pavement.

5. Gupta et al. (2021): Gupta and co-authors conducted a comprehensive study on plastic modified asphalt and found that the addition of plastic significantly enhances mechanical properties such as tensile strength and stiffness. The study also confirmed improved fatigue life and reduced rutting under repeated loading. The researchers concluded that plastic waste can be effectively utilized in road construction for sustainable development.

3. MATERIALS AND PROPERTIES

3.1 Bitumen

- Grade: VG-30
- Tests conducted: Penetration, ductility, softening point, viscosity

3.2 Aggregates

- Crushed stone aggregates
- Properties: • Impact value: < 30%
- Crushing value: < 25%
- Water absorption: < 2%

3.3 Waste Plastic

- Types: Carry bags, PET bottles, packaging films
- Size: 2–4 mm shredded
- Melting range: 110–160°C

4. METHODOLOGY

4.1 Dry Process

- Aggregates heated to 170°C
- Plastic added and coated uniformly
- Bitumen added at 160°C

4.2 Wet Process

- Plastic melted into bitumen
- Mixed thoroughly before adding aggregates

4.3 Experimental Plan

Plastic content varied as:

- 0%, 4%, 6%, 8%, 10%

5. EXPERIMENTAL RESULTS

The experimental results show that adding waste plastic improves the performance of asphalt mixes. The Marshall Stability increases with plastic content, indicating better strength and load bearing capacity, up to an optimum level (around 6–8%). Beyond this, the strength may slightly decrease due to reduced workability. The flow value shows a moderate increase, suggesting improved flexibility of the mix, which helps in resisting cracking. The rutting resistance is significantly enhanced, meaning the pavement can better withstand high temperatures and heavy traffic without deformation. Additionally, indirect tensile strength (ITS) improves, indicating better resistance to fatigue and cracking. The moisture susceptibility also reduces, showing improved resistance to water damage and stripping. Overall, the results confirm that plastic modified asphalt performs better than conventional mixes when used in optimum proportions.

Table -1: Marshall Stability Test Results

Percentage (%) of Plastic in Bitumen	Stability (KN)	Flow (mm)
0		3.9
5		3.4
10	13.5	3.1
15	13.1	2.8
20		2.7

Table -2: Rutting Resistance Test Result

Percentage (%) of Plastic in Bitumen	Rut Depth (mm after 10,000 cycles)
0	7.6
5	5.2
10	4.3
15	4.5
20	5.8

Table -3: Fatigue Performance Test Result

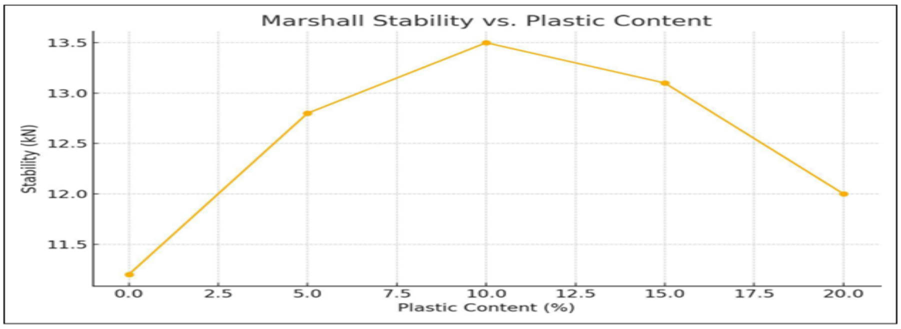
Percentage (%) of Plastic in Bitumen	Fatigue Life (No. of Load Cycles)
0	8,200
5	10,500
10	12,700
15	11,200
20	9,500

Table -4: Water Sensitivity Test Result

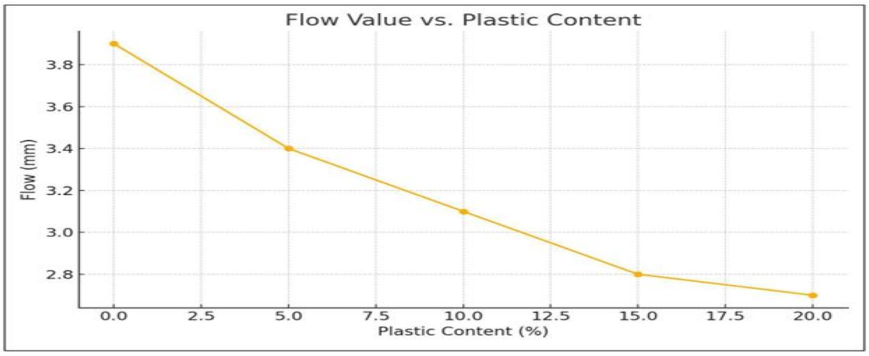
Percentage (%) of Plastic in Bitumen	Fatigue Life (No. of Load Cycles)
0	78.4
5	84.5
10	88.2
15	85.7
20	81.0

6. GRAPHICAL ANALYSIS

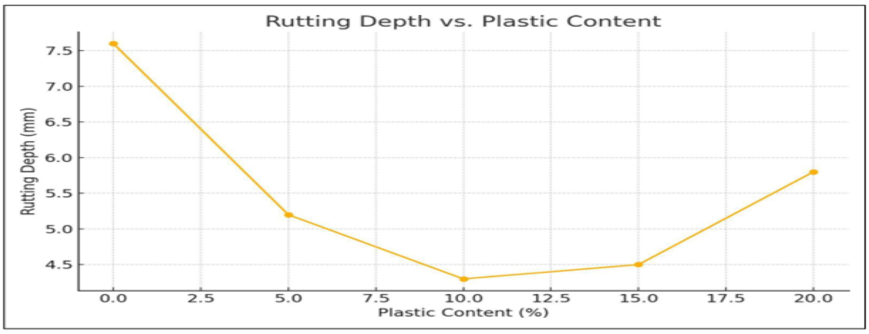
Graph-1: Chart for Stability Vs Plastic Content



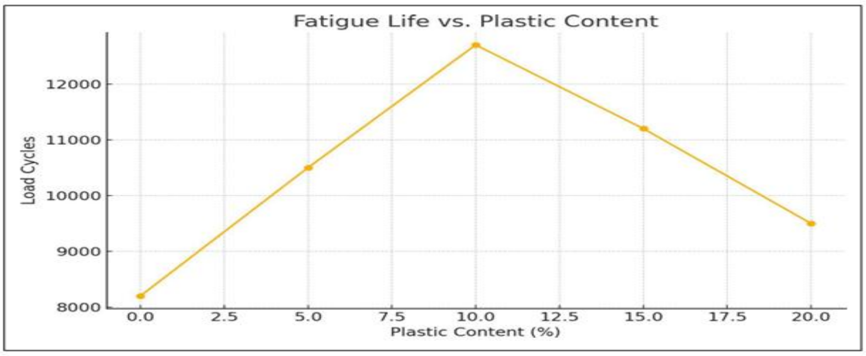
Graph -2: Flow Value Vs Plastic Content



Graph -3: Rutting Depth Vs Plastic Content



Graph - 4: Load Cycles Vs Plastic Content



7. DISCUSSION

7.1 Strength Characteristics

- Stability increases due to better binding
- Optimum plastic content: 10%

7.2 Durability

- Reduced voids and permeability
- Higher resistance to water damage

7.3 Rutting Resistance

- Plastic increases stiffness
- Reduces deformation under heavy loads

7.4 Environmental Impact

- Reduces plastic waste
- Minimizes landfill usage
- Promotes circular economy

8. ADVANTAGES

- Improved pavement life (30–50%)
- Cost-effective solution
- Reduced maintenance
- Better resistance to temperature variations

9. LIMITATIONS

- Emission concerns during heating
- Requires proper plastic segregation
- Limited field performance data

10. APPLICATIONS

- Urban roads
- Highways
- Rural roads
- Airport pavements

11. FUTURE SCOPE

- Use of nano-modified plastics
- Combination with rubber and fibers
- Smart roads with recycled materials
- Long-term performance monitoring

12. CONCLUSION

The study confirms that daily-use plastic waste significantly improves asphalt pavement performance. The enhancement in stability, tensile strength, and durability proves that plastic modified bitumen is a viable solution for modern infrastructure. Adoption of this technology will lead to sustainable development and efficient waste management.

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