Design of Flexible Pavement by Using Waste Plastic

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***Abstract*—Plastic waste is a major component of solid waste and is abundantly available, often disposed of without proper treatment. The rapid increase in municipal plastic waste, especially in urban areas, affects environmental cleanliness and landscape beauty. Research has shown that waste plastic can be effectively used as a binder modifier in bitumen mixes for flexible pavements. This method improves resistance to high temperatures, minimizes cracking, reduces rainwater infiltration, and helps prevent pothole formation. Plastic roads also show better crushing strength, abrasion resistance, and lower water seepage. Such roads are especially suitable for India's hot and humid climate, where high temperatures and heavy rains often damage conventional pavements. Bituminous Concrete (BC), commonly used in road surfacing, airports, and parking areas, consists of bitumen and mineral aggregates compacted in layers. With increasing traffic loads and temperature variations, there is a need for improved pavement materials that are both strong and economical. Using waste polyethylene in road construction offers a practical solution while reducing environmental pollution caused by non-biodegradable plastic waste.**

***Index Terms*—Plastic waste, Solid waste management, Municipal waste, Bitumen mix, Flexible pavements, Plastic roads, High temperature resistance, Crack prevention, Rainwater infiltration, Pothole reduction, Abrasion resistance, Water seepage, Bituminous Concrete, Road surfacing, Waste polyethylene, Sustainable construction, Pavement improvement, Environmental pollution, non-biodegradable waste, Eco-friendly roads**

I. INTRODUCTION

Plastic is a synthetic material made of organic polymers with high molecular weight that can be molded into different shapes during manufacturing and remains solid in its final form. It is widely used in daily life because of its light weight, durability, low cost, and versatility. However, plastic is non-biodegradable and degrades very slowly, creating serious environmental problems. Large amounts of plastic waste are generated every day in the form of carry bags, bottles, cups, food wrappers, and packaging materials.

Plastics are mainly classified into two types: thermoplastics and thermosetting plastics. Thermoplastics soften when heated and can be reshaped after cooling. Examples include polyethylene (PE), polypropylene (PP), and polyethylene terephthalate (PET). Thermosetting plastics become hard permanently after heating and cannot be remolded. Thermoplastics are suitable for road construction because they melt at high temperatures and coat aggregates effectively.

The disposal of plastic waste has become a major challenge due to rapid urbanization and population growth. Improper disposal blocks drainage systems, causes water stagnation, pollutes land, and affects public health. Therefore, using waste plastic in road construction is an effective solution for waste management.

In this method, shredded plastic waste is mixed with hot aggregates or bitumen to produce plastic-modified bitumen. The melted plastic forms a coating on aggregates and improves the bonding strength of the mix. This increases the softening point of bitumen, reduces water absorption, and improves resistance to cracks, rutting, and potholes.

Plastic roads are more durable than conventional roads and require less maintenance. They perform well under heavy traffic loads, high temperatures, and rainfall conditions, making them suitable for countries like India. In addition, the use of waste plastic reduces the requirement of bitumen and lowers construction cost.

Thus, the use of waste plastic in road construction provides a sustainable, economical, and eco-friendly solution. It improves pavement performance while helping to solve the growing problem of plastic waste disposal.

II. OBJECTIVES

The main objectives of the present study are:
- To utilize waste plastic effectively in road construction.
- To coat aggregates with shredded plastic materials.
- To study the properties of plastic-modified bituminous mixes.
- To compare conventional and modified bituminous mixes.
- To improve pavement strength and durability.
- To reduce bitumen consumption and construction cost.
- To minimize environmental pollution caused by plastic waste.

III. LITERATURE REVIEW

1. Francis Hveem (1927/1942)
Francis Hveem developed the Hveem Stabilometer to determine optimum bitumen content scientifically. His method improved pavement mix design accuracy and became an important advancement in asphalt technology.

2. Justo et al. (2002)
Justo studied processed plastic bags as additives in asphalt concrete. The results showed improved strength and water resistance, though ductility decreased. This work supported the use of waste plastic in road construction.

3. S. Rajasekaran et al. (2009)
Rajasekaran investigated plastic-coated aggregates using the dry process. The study found higher Marshall Stability, lower binder requirement, and improved water resistance compared to conventional mixes.

4. Amit P. Gawande (2013)
Gawande analyzed the economics and performance of plastic roads. His study reported improved fatigue life, better creep resistance, and reduced long-term maintenance costs.

5. Vatsal Patel et al. (2014)
Patel studied polymer additives such as EVA and SBS in bitumen. The results showed improved resistance to temperature variations, reduced bleeding, and better pavement performance.

6. Anzar Hamid Mir (2015)
Mir focused on the visco-elastic behavior of plastic-modified bitumen. The study concluded that waste plastic improves stiffness at high temperatures while maintaining flexibility at lower temperatures.

7. Sasane Neha B. et al. (2015)
Sasane Neha compared HDPE and LDPE plastics in bituminous mixes. HDPE showed better strength and stability, with an optimum plastic content of about 12% by weight of bitumen.

8. Kurmadasu Chandramouli et al. (2016)
Chandramouli studied waste plastic in road construction and found improved resistance to deformation, pothole reduction, and better waterproofing properties. The dry process was recommended as effective and durable.

IV. METHODOLOGY

In this study, conventional bituminous mix is compared with plastic-modified bituminous mix. Shredded waste plastic of size 2.36 mm is used through the dry process by coating heated aggregates before mixing with VG-30 bitumen. Plastic is added in proportions of 6% to 8% by weight of bitumen. The performance of the modified mix is evaluated using Marshall Stability and Flow values.

Collection of Raw Materials
The materials used in the study are:
Bitumen – VG 30 grade
Waste plastic – shredded soft plastic (2.36 mm size)
Coarse aggregate – 10 mm to 12.5 mm
Fine aggregate – 5 mm

Base and subgrade material
Material Tests
Tests on Aggregates
The following tests are conducted on aggregates:
Abrasion Test
Impact Test

Water Absorption Test

1. Abrasion Test

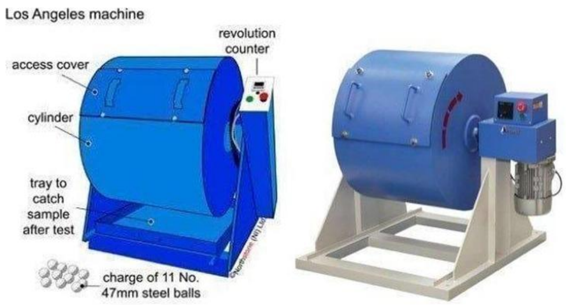

Fig 1: Los Angeles Abrasion Testing Machine

This test determines the hardness and wear resistance of aggregates using the Los Angeles Abrasion Machine. Lower abrasion value indicates better quality aggregates.

2. Impact Test

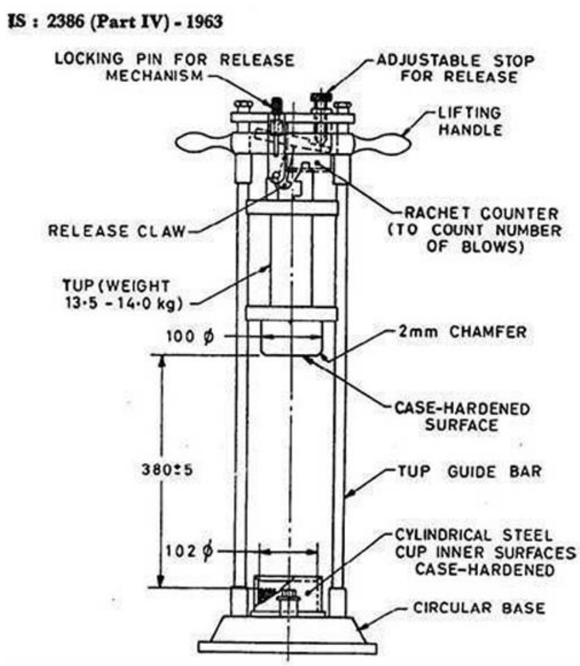

Fig 2: Impact Testing Machine

This test measures the toughness of aggregates against sudden impact loads. Lower impact value indicates stronger aggregates.

Water Absorption Test

This test determines the amount of water absorbed by aggregates. Low water absorption indicates durable aggregates.

Tests on Bitumen

3. Penetration Test

Fig 3: Penetration Test

This test determines the hardness or softness of bitumen by measuring the depth of penetration of a standard needle under specified conditions.

4. Flash and Fire Point Test

Fig 4:Flash and Fire Point Testing Machine

This test determines the temperature at which bitumen gives off vapours (flash point) and catches fire continuously (fire point). It is useful for safety during heating.

5. Ductility Test
This test measures the stretching property of bitumen before breaking. Higher ductility indicates better flexibility.

6. Marshall Stability Test
This test determines the maximum load carrying capacity and deformation value of the bituminous mix. Specimens are prepared, compacted, heated in water bath at 60°C, and tested under loading. Stability and Flow values are recorded.

7. Mix Design
Bituminous mix design is carried out using the Marshall Method to determine optimum binder content and achieve required stability, flow, density, and air voids.

8. Mixing of Bitumen and Plastic
Shredded plastic is mixed with hot aggregates through the dry process. Then heated bitumen is added to prepare the plastic-modified mix. This improves strength, durability, and water resistance.

Procedure
1. The pavement model is prepared in layers:
2. Subgrade layer prepared and compacted.
3. Base layer laid with coarse aggregates.
4. Plastic-modified bitumen mix prepared.
5. Surface layer spread and compacted.

Casting and Handling
The pavement specimen is prepared using a steel mould of size 300 mm × 300 mm × 50 mm. Layers are compacted properly and finished smoothly for testing.

V. RESULTS AND DISCUSSION

This chapter presents the results of laboratory tests conducted on aggregates, bitumen, and plastic-modified bituminous mix. The obtained values are compared with standard specifications to evaluate the suitability of materials for flexible pavement construction.

- Tests on Aggregates

1. Crushing Test
Aggregate crushing test was conducted on plain and plastic-coated aggregates. The crushing value of plain aggregate ranged from 5.84% to 5.97%, whereas plastic-coated aggregate showed lower values of 5.08% to 5.16%. Lower crushing value indicates higher strength; therefore, plastic-coated aggregates exhibited better load-bearing capacity.

2.Abrasion Test
Los Angeles abrasion test results indicated abrasion values of 34.51% to 37.09% for plain aggregates, while plastic-coated aggregates showed lower values of 29.8% to 31.37%. This confirms that plastic coating improves resistance to wear and increases durability.

3. Water Absorption Test
The average water absorption of plain aggregate was 0.209%, while plastic-coated aggregate showed a lower average value of 0.145%. Reduced water absorption indicates improved resistance to moisture damage and better durability.

- Tests on Bitumen

1. Penetration Test
The average penetration value of VG-30 bitumen was 68.83 mm, whereas plastic-blended bitumen showed a lower value of 64.73 mm. This indicates that the modified bitumen is harder and more resistant to deformation.

2. Flash and Fire Point Test
For conventional VG-30 bitumen, flash and fire points were observed at 331°C and 369°C respectively. Plastic-modified bitumen showed higher values of 386°C and 423°C, indicating improved thermal stability and safer handling during heating.

3. Ductility Test
The average ductility value of plain bitumen was 177.4 cm, while plastic-modified bitumen recorded 194.4 cm. This indicates better flexibility and durability of the modified binder.

4. Marshall Stability Test
Marshall Stability test was conducted on conventional and plastic-modified bituminous mixes. The conventional mix showed a stability value of 12.5 kN. With the addition of waste plastic, the stability values increased significantly:

- 6% Plastic – 14 kN
- 8% Plastic – 17 kN
- 10% Plastic – 15 kN

The maximum stability was achieved at 8% plastic content, indicating the optimum percentage of plastic addition. Beyond this level, performance slightly decreased.

VI. DISCUSSION

The results clearly indicate that waste plastic improves the engineering properties of both aggregates and bitumen. Plastic-coated aggregates showed better strength, abrasion resistance, and lower water absorption. Plastic-modified bitumen exhibited improved hardness, thermal resistance, and ductility. Marshall Stability results confirmed that 8% plastic content is optimum for achieving maximum strength and durability.

VII. CONCLUSION

The use of waste plastic in bituminous pavement significantly enhances pavement performance while reducing environmental pollution. Therefore, plastic-modified roads provide a sustainable, economical, and durable solution for modern road construction.

- The study confirms that waste plastic can be effectively used in flexible pavement construction.
- It helps solve plastic waste disposal problems and improves road durability.
- Plastic-coated aggregates show higher strength, lower water absorption, and better wear resistance.
- Bitumen modified with 6–8% plastic shows improved binding properties.
- The pavement has better resistance to rutting, cracking, and heavy loads.
- Higher softening point and good ductility improve performance in different climates.
- Plastic roads have longer life and lower maintenance cost.
- It is an eco-friendly method for managing non-biodegradable plastic waste.
- Minor property changes remain within acceptable limits.
- Overall, plastic-modified pavement is a sustainable and economical solution for road construction.

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