Utilization of Recycled Plastic Waste in Bituminous Road Construction: A Sustainable Pavement Approach

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ABSTRACT: The sudden accumulation of plastic wastes is a major environmental hazard since the material is not biodegradable. Modified bitumen road construction offers a green solution to plastic waste disposal. This study examines the properties of bituminous concrete when Low-Density Polyethylene plastic waste is incorporated at 5%, 7.5%, and 10% by bitumen weight. Tests for Marshall Stability and flow were performed according to MoRTH specifications. Results indicated that the use of 7.5% plastic waste enhanced stability, durability and water resistance of the pavement. This research concludes that plastic waste inclusion in road construction offers a sustainable and environmentally friendly option to the traditional bituminous mix.

KEYWORDS: Plastic Waste, Sustainable Roads, LDPE, Modified Bitumen, Marshall Stability, Environmental Engineering.

1 INTRODUCTION

India generates over 9.46 million tonnes of plastic waste annually and CPCB reports reveal that a large portion of this waste does not get collected and is disposed of improperly. Since plastic waste is non-biodegradable, it stays in the environment for hundreds of years, causing soil pollution, water pollution, clogging of drains, and toxic impacts on ecosystems and human health. Traditional disposal practices like landfilling and incineration give rise to other issues such as land shortages, poisonous emissions of gases, and groundwater pollution. Hence, there is an urgent necessity to discover cost-saving and environmentally friendly engineering measures for plastic waste management.

One of the viable options is the use of plastic waste as a pavement material, with shredded plastic mixed with natural binding agents such as bitumen to produce plastic-modified bitumen. Low-Density Polyethylene (LDPE) plastic waste possesses good binding characteristics and enhances viscosity, stability, and bituminous mix durability. When plastic is heated and applied as a coating on aggregate surfaces, it produces an excellent adhesive film, which enhances road strength and resistance against rutting, moisture damage, and deformation.

Besides, plastic-modified bitumen roads are found to:

- Withstand greater traffic loads
- Show greater service life
- Need less maintenance
- Provide cost benefits over traditional roads
- Hence, the application of plastic waste in road construction has two advantages:
- Effective waste management and environmental conservation, and
- Better pavement performance and endurance.

1.1 Objective of the Study

This research seeks to assess the mechanical and physical characteristics of LDPE plastic waste-modified bituminous concrete mixes with varying percentages. The performance was measured using Marshall Stability, Flow Value, Water Absorption, and Softening Point tests, in a bid to identify the appropriate percentage of plastic waste that improves pavement quality and ensures sustainability.

2 MATERIALS AND METHODS

2.1 Material Utilized

2.1.1 Bitumen (VG-30)

Viscosity Grade (VG-30) bitumen was employed as the binding agent. VG-30 is routinely utilized in flexible pavement construction since it provides appropriate viscosity and stability under Indian tropical climatic conditions. It is generally prescribed for highways with heavy traffic loading. The penetration value and ductility of the bitumen made it well-suited for compatibility with plastic waste modification.

2.1.2 LDPE Plastic Waste

Low-Density PolyEthylene (LDPE) plastic carry bags were obtained from city waste dumping yards. The plastic brought was well washed, dried, and torn into finer strips of about 2–4 mm in length. LDPE was utilized because it has a low melting point of 110–130°C and offers a high binding capacity, enabling uniform coating over hot aggregates.

2.1.3 Fine Aggregate

Locally sourced river sand meeting Zone II as per IS: 383-2016 was utilized. The sand was organic impurity free and possessed good gradation to improve inter-particle bond.

2.1.4 Coarse Aggregate

Angular crushed aggregate of 20 mm size was utilized. Angular aggregates impart higher strength through interlocking. Aggregates were impacted, abrasion value tested and crushing strength tested according to IS standards for selection suitability for pavement construction.

Material	Properties	Source
Bitumen (VG-30)	Penetration grade	Local supplier
LDPE Plastic Waste	Shredded (2–4 mm size)	Municipal waste facility
Fine Aggregate	River sand	Quarry
Coarse Aggregate	Crushed stone 20 mm	Quarry

2.2 Mix Proportions

Plastic waste was incorporated as a weight percentage of the total bitumen weight, and the aggregate content was kept constant. Dry Mix Process was the technique employed, wherein hot aggregates are initially coated with molten plastic, followed by the incorporation of bitumen.

Plastic waste was added as a percentage of bitumen weight:

- Mix A → 0% (Control)
- Mix B → 5% Plastic + Bitumen
- Mix C → 7.5% Plastic + Bitumen
- Mix D → 10% Plastic + Bitumen

Mix ID	Bitumen Replacement with Plastic	Description
Mix A	0%	Conventional mix (Control)
Mix B	5%	Bitumen + 5% LDPE Plastic
Mix C	7.5%	Bitumen + 7.5% LDPE Plastic
Mix D	10%	Bitumen + 10% LDPE Plastic

TABLE 1. Mix Proportions

3 TESTS CONDUCTED

S.NO	TEST	STANDARD CODE USED
1	Marshall Stability	ASTM D6927
2	Flow Value	ASTM D6927
3	Water Absorption	IS 2386
4	Softening Point	IS 1205

TABLE 2. Tests Conducted

3.1 PURPOSE OF CONDUCTING THE TESTS

TEST	PURPOSE
MARSHALL STABILITY TEST	To determine maximum load-carrying capacity
FLOW VALUE TEST	To assess the deformation of mix before failure
WATER ABSORPTION TEST	To evaluate the mix's water-resistance
SOFTENING POINT TEST	To check temperature susceptibility

TABLE 3. Purpose of conducting the tests

4 RESULTS AND DISCUSSION

Mix ID	Plastic %	Marshall Stability (kN)	Flow (mm)	Softening Point (°C)
A	0%	9.8	3.8	48
B	5%	11.2	3.6	52
C	**7.5%**	**13.4**	**3.2**	**56**
D	10%	12.1	3.0	59

TABLE 4. Marshall Stability and Flow Test Results

4.2 Discussion of Results

- Increasing value of Marshall Stability is obtained with the incorporation of plastic up to 7.5%, showing better load-carrying capacity of the pavement.
- Mix C (7.5% plastic) produced the highest stability of 13.4 kN, which is ~36.7% greater than the control mix.
- Flow Value reduces with more plastic content, i.e., the mix becomes more stiff and deforming-resistant.
- Softening Point rises with increased plastic addition, representing improved resistance to rutting under tropical conditions.

4.3 Important Performance Interpretation

Property	Improvement Cause	Result
Strength	Strong bonding between melted LDPE and aggregates	Roads withstand higher traffic loads
Durability	Plastic acts as moisture barrier	Reduced pothole formation
Thermal Resistance	Increased softening point	Suitable for Indian hot climate road networks

TABLE 5. Performance Interpretation

4.4 Final Observation

The 7.5% Plastic Waste mix (Mix C) is discovered to be the best because it:

- Attains highest stability
- Exhibits lowest deformation
- Gives best resistance to heat
- Reduces the environmental waste disposal problem

Therefore, 7.5% LDPE modified bitumen is highly recommended for flexible pavement construction works, particularly in hot climate and heavy-traffic areas.

5. CONCLUSION

This research proves that the use of LDPE plastic waste as a modifier in bituminous mixes can enhance flexible pavement performance to a great extent while concurrently resolving environmental issues. Out of the different mixes tested, the mix incorporating 7.5% LDPE plastic waste showed better results with regard to Marshall Stability, flow, and softening point, reflecting a greater load-carrying capacity, enhanced resistance to rutting, and enhanced temperature stability compared to the control mix.

The increased resistance of the plastic-modified bituminous mixture is due to the significant binding action between aggregates and melted plastic, which limits moisture entry and reduces pavement failure in terms of potholes, cracks, and surface deformation. Apart from performance enhancement, this process represents a viable process for recycling municipal waste plastic and decreases landfill pressure and possible soil and water contamination.

Due to its cost-effectiveness, sustainability, and engineering advantages, the use of plastic-modified bitumen is advisable for application in national highway schemes as well as rural road networks, especially in government schemes like Swachh Bharat Mission, Pradhan Mantri Gram Sadak Yojana and Green Road Development Schemes. The large-scale adoption of this method has the potential to encourage environmental protection, increase pavement life and assist in sustainable infrastructure development in India.

Additional research can investigate:

- The performance of other plastic types (HDPE, PP)
- Field testing under different traffic and climatic conditions
- Long-term maintenance cost comparison and behavior analysis

6. REFERENCES

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