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A Sustainable Approach for Pothole Repair Using Plastic Waste

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Abstract: India's expansive road network, vital to its economic growth and connectivity, suffers from recurring pothole issues that disrupt traffic, damage vehicles, and pose significant safety risks—especially during the monsoon season. Simultaneously, the country faces an escalating plastic waste crisis, with millions of tons of non-biodegradable waste generated annually. This study presents a sustainable solution by integrating shredded plastic waste into VG-30 bitumen for pothole repair, aiming to address both infrastructure degradation and environmental concerns. Laboratory tests reveal that a 9% addition of plastic waste yields optimal results, enhancing mechanical properties such as Marshall Stability, flow, and thermal resistance, while maintaining workability. The approach not only offers a cost-effective and durable pothole repair technique but also promotes circular economy principles by repurposing plastic waste. The research provides actionable insights and practical recommendations for implementing this method on a larger scale, particularly in developing nations like India.
Keywords: Pothole Repair, Plastic Waste, Bitumen Modification, Sustainable Pavement, VG-30 Bitumen, Marshall Stability, Cost-effective Maintenance, and Environmental Sustainability.

I. INTRODUCTION

India's road infrastructure, one of the most extensive in the world, is a vital enabler of the country's socio-economic development, supporting the movement of goods and people across urban and rural areas. Despite its scale and strategic significance, this network is marred by the frequent occurrence of potholes—depressions in the road surface that significantly degrade transport efficiency and public safety. Their emergence is attributed to several compounding factors, such as inadequate drainage, material failures, overloading, and weather-induced stresses, particularly during the monsoon season when water ingress and pavement degradation accelerate rapidly.

Potholes are not merely an inconvenience; they are a critical challenge that influences road safety, vehicle maintenance costs, logistics delays, and overall quality of life. According to national traffic statistics, thousands of road accident fatalities in India have been directly linked to potholes, underscoring the severity of this infrastructural issue. Compounding this problem is the environmental hazard posed by plastic waste. India generates millions of tonnes of plastic waste annually, a large portion of which remains unmanaged and ends up polluting land and water systems.

In response to these dual challenges, researchers and practitioners have explored the integration of plastic waste into road construction materials. This method presents a promising approach to enhance the mechanical performance of bituminous mixes while simultaneously offering an environmentally sustainable waste management strategy. Recent advancements indicate that incorporating shredded plastics into bitumen can significantly improve pavement durability, thermal resistance, and overall life span, particularly in high-traffic and climate-vulnerable zones.

This research focuses on evaluating the feasibility of using plastic-modified bituminous mixes for pothole patching—an application that has not been extensively studied compared to full pavement construction. The study investigates the mechanical behavior, workability, and durability of VG-30 bitumen when blended with various percentages of shredded plastic waste. The objective is to develop a practical, cost-effective, and eco-friendly solution for pothole repair, contributing to both infrastructure resilience and sustainable waste reuse.

II. LITERATURE REVIEW

The reviewed literature collectively emphasizes the viability of utilizing plastic waste in bituminous mixtures as an innovative and sustainable approach to pothole repair. From the work of Goyal et al. (2025), which validates cold plastic-modified mixes for minor road damage, to Zhang et al. (2024), who explored advanced bio-binder formulations with LDPE additives, the trend is clear—plastic-enhanced materials improve mechanical performance and environmental outcomes.

Gosavi et al. (2022) further reinforce this with evidence of improved pavement strength and moisture resistance using plastic-coated aggregates, while Gurudeep and Nitin (2023) highlight the broader need for material innovation and proactive maintenance strategies. Complementing these findings, Dhirde et al. (2020) demonstrate the cost-effectiveness and durability of bituminous plastic, reinforcing its potential for long-term municipal use. Collectively, these studies advocate a paradigm shift from conventional patching methods toward eco-friendly, high-performance alternatives that support circular economy goals and road infrastructure resilience.

III.RESEARCH METHODOLOGY

In this study, a systematic experimental approach was adopted

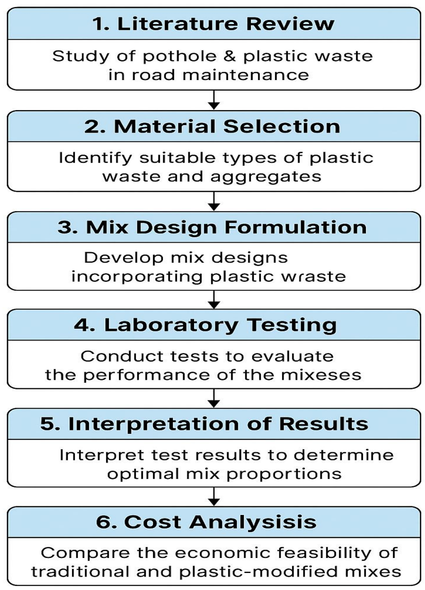

Figure: Flowchart for research methodology

1) Literature Review: Study of Pothole & Plastic Waste in road maintenance.
2) Material Selection: Identify suitable types of plastic waste and aggregates.
3) Mix Design Formulation: Develop mix designs incorporating plastic waste.
4) Laboratory Testing: Conduct tests to evaluate the performance of the mixes.
5) Interpretation of result: Interpret test results to determine optimal mix proportions.
6) Cost Analysis: Compare the economic feasibility of traditional and plastic-modified mixes.
7) Result & Conclusions: Summarize findings and suggest practical applications.

IV.MATERIALS & TESTS

A comprehensive overview of the materials employed and the methodology followed in investigating the use of plastic waste as a sustainable additive in pothole repair. The objective is to evaluate how plastic waste can be efficiently used as an additive in bituminous mixes for sustainable and cost-effective road maintenance solutions.

The materials used in this study include VG-30 grade bitumen, conventional aggregates (coarse and fine), and selected shredded plastic waste types—namely High-Density Polyethylene (HDPE), Low-Density Polyethylene (LDPE), and Polypropylene (PP). These plastics were cleaned, dried, and mechanically shredded to a uniform size suitable for blending. Bituminous mixes were prepared by incorporating varying proportions of plastic waste (ranging from 3% to 12% by weight of bitumen) using the dry process technique. To evaluate the mechanical and durability characteristics of the modified mixes, a series of laboratory tests were conducted as per relevant IS and MoRTH standards. These included the Marshall Stability Test to assess strength and flow properties,. The results were compared with conventional bituminous mixes to identify the optimal plastic content offering maximum performance and sustainability.

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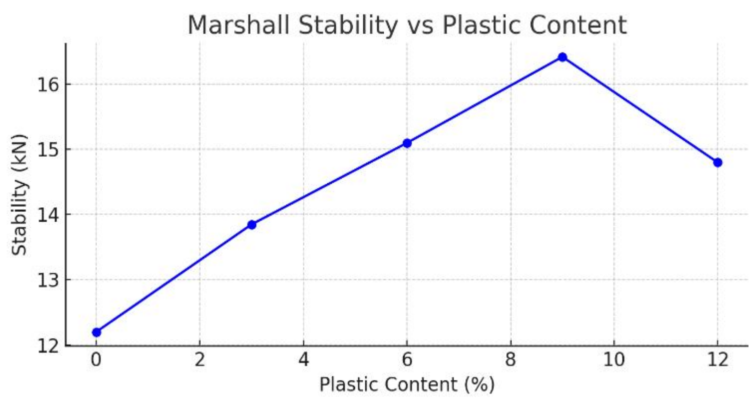
TABLE I
TEST RESULTS

Plastic Waste Content (%)	Penetration (mm)	Softening Point (°C)	Ductility (cm)	Marshall Stability (kN)	Flow (mm)	Bulk Density (g/cc)	Air Voids (%)	VMA (%)	VFB (%)
0	72	45	90	12.20	3.60	2.31	4.80	14.60	67.10
3	65	48	80	13.85	3.40	2.34	4.50	14.20	68.31
6	58	51	68	15.10	3.20	2.36	4.20	13.90	69.78
9	50	54	55	16.42	3.10	2.38	3.90	13.60	71.32
12	45	56	42	14.80	3.30	2.35	4.40	14.10	68.80

Various properties of bitumen and bituminous mixes vary with different percentages of plastic waste:

1) Penetration decreases with more plastic: indicating increased hardness.
2) Softening Point rises: showing better temperature resistance.
3) Ductility reduces: less flexibility but better stiffness.
4) Marshall Stability peaks at 9% plastic: maximum load resistance.
5) Flow Value stays within ideal range: sufficient workability.
6) Bulk Density increases till 9%: suggests optimal compaction.
7) Air Voids reduce: indicating improved compactness.
8) VMA decreases slightly: denoting better aggregate packing.
9) VFB increases: shows enhanced bitumen effectiveness.



Graph: Results showing Marshall Stability Vs Plastic Content

Marshall Stability: The highest Marshall Stability value of 16.42 kN was achieved at 9% plastic content, indicating maximum resistance to deformation.

V. CONCLUSIONS

This study presents a sustainable and performance-oriented approach to pothole repair by utilizing VG-30 grade bitumen modified with shredded plastic waste. The experimental investigation confirms that VG-30 bitumen inherently meets the required specifications for penetration, softening point, ductility, flash point, and viscosity, making it suitable for flexible pavements exposed to moderate to high traffic loads and variable climatic conditions.

Upon modification with plastic waste, significant improvements in the mechanical performance of the bitumen were observed. The addition of plastic increased the stiffness and temperature susceptibility of the bitumen, as evidenced by reduced penetration and ductility values and elevated softening points. These enhancements contribute to greater resistance to rutting and thermal deformation.

The Marshall Stability and Flow Test results reveal that the optimal performance was achieved at 9% plastic content by weight of bitumen. At this concentration, the modified mix exhibited:

1) Highest Marshall Stability (16.42 kN),
2) Optimal flow value (3.1 mm),
3) Maximum bulk density (2.38 g/cc),
4) Reduced air voids (3.9%),
5) Improved VFB (71.32%).

These parameters indicate superior structural integrity, compaction, and durability, all critical for long-lasting pavement life. However, further increase in plastic content beyond 9% resulted in diminished performance, marked by decreased stability and increased void ratios, potentially compromising mix workability and durability.

In conclusion, the research validates the use of 9% shredded plastic waste as the optimum modifier in VG-30 bitumen for road applications. This not only enhances the physical and mechanical characteristics of bituminous mixes but also contributes to environmental sustainability by diverting plastic waste from landfills. The findings support the broader implementation of plastic-modified bitumen in flexible pavement construction, aligning infrastructure development with ecological responsibility.

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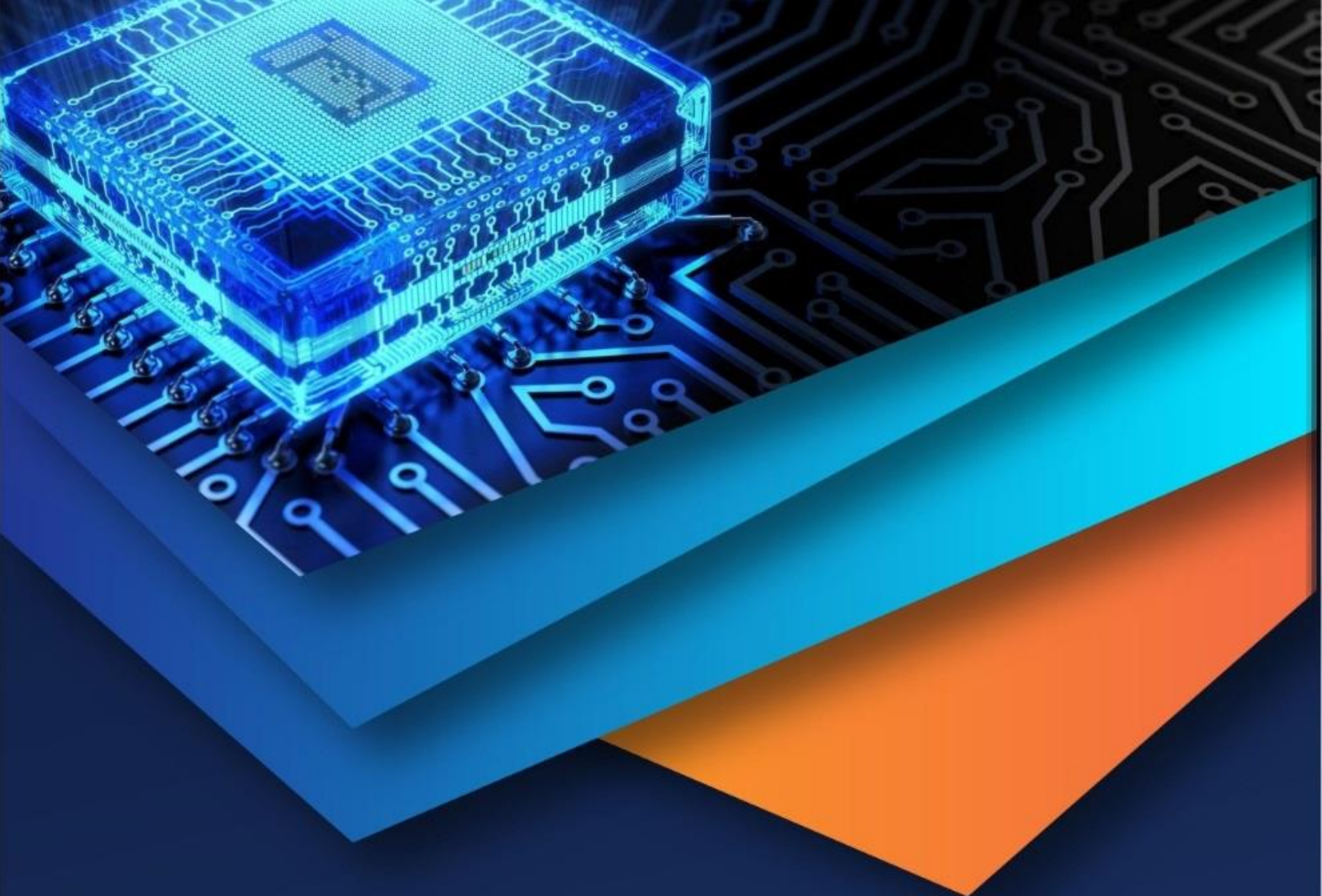

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