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The Impact of Footwear Waste on Modified Bitumen Mix

Nikhil B[1], Shabana Shibin KK[2], Nihal Thamarath[3], Hafiz Javad[4], Fathimath Binsiya[5]
Department of Civil Engineering, MEA Engineering College

Abstract: This study investigates the potential of utilizing footwear waste as a sustainable modifier in bitumen to enhance its properties for road construction. With millions of tons of footwear waste accumulating in landfills each year, this approach offers a dual benefit—environmental sustainability and improved road performance. Modified bitumen samples were prepared with varying proportions of footwear waste and tested for penetration, softening point, ductility, viscosity, and Marshall Stability. Results demonstrated improved elasticity, temperature resistance, and overall stability. The findings suggest that incorporating footwear waste can significantly enhance the performance of bitumen, offering a viable, eco-friendly alternative in road infrastructure.
Keywords: Bitumen, Footwear Waste, Modified Asphalt, Sustainability, Marshall Stability

I. INTRODUCTION

The rapid urbanization and industrialization have led to a significant rise in footwear waste, posing serious environmental challenges. Footwear, primarily composed of non-biodegradable materials like rubber and polyurethane, accumulates in landfills, contributing to pollution. Simultaneously, traditional bitumen used in road construction faces performance limitations under extreme conditions. This study explores the incorporation of footwear waste into bitumen as a modifier to enhance its properties and promote sustainable construction.

II. SPECIFIC OBJECTIVES

1) To assess the feasibility of using footwear waste as a sustainable modifier in bitumen for road construction.
2) To evaluate the impact of footwear waste on key bitumen properties including penetration, softening point, and ductility.
3) To determine the mechanical performance of modified bituminous mixes using Marshall Stability test.
4) To compare the performance of footwear waste-modified bitumen with conventional bitumen mixes.
5) To identify the optimum percentage of footwear waste that yields maximum performance improvement.

III.MATERIALS AND METHODS

A. *Materials*

The primary materials used in this study include VG30 bitumen, coarse and fine aggregates, and shredded footwear waste. Aggregates were locally sourced, satisfying the gradation requirements as per MORTH specifications. Bitumen of VG30 grade was selected for its suitability in moderate to high-temperature regions. Footwear waste, consisting mainly of rubber and synthetic polymers, was collected from local municipal waste centres, cleaned, and shredded to the required size.

B. *Mix Proportion*

Modified bitumen mixes were prepared by replacing bitumen with footwear waste at 2%, 3%, 5%, and 7% by weight. Each modified blend was mixed with aggregates to form test specimens following standard Marshall method procedures. below table shows the mix proportion (TABLE 1)

TABLE I MIX PROPORTION

SL. No	1	2	3	4
% of bitumen replaced by footwear waste	2	3	5	7
Weight of footwear	1.2	1.8	3	4.2

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C. Experimental Procedure

1) *Basic Tests:* Aggregates were tested for crushing value, impact value, and abrasion resistance. Bitumen was evaluated for penetration, softening point, and ductility. And listed below (TABLE 2)

TABLE IIIII
BASIC PROPERTIES OF MATERIALS

SL. No	Property	Value
1	Crushing value	30.63%
2	Impact value	30%
3	Abrasion value	47.6%
4	Penetration value	54.6
5	Softening point	49.7C
6	Ductility	83 cm

2) Preparation of Modified Bitumen: Shredded footwear waste was added to hot bitumen and mixed thoroughly. The blend was used to prepare Marshall samples.
3) Marshall Stability Test: Compacted specimens were subjected to standard Marshall testing at 60°C to evaluate stability and flow.
4) Density and Voids Analysis: Bulk specific gravity and air voids were calculated for each sample to assess compaction and durability.
5) Determination of Optimum Modifier Content: Results from stability, flow, VMA, VFB, and air voids were analyzed to identify the best performing modifier percentage.

IV. RESULTS AND DISCUSSION

The addition of 3% footwear waste yielded the highest Marshall Stability (90.12 kN). Flow values decreased with increased modifier content, indicating improved stiffness. VMA and VFB values remained within acceptable limits, ensuring durability. Air voids and density analysis confirmed that modified mixes met required specifications, with 3% waste offering the best balance of strength, flexibility, and durability. Table 3 shows test results.

TABLE IVII
MARSHALL TEST RESULTS ON MODIFIED BITUMEN SPECIMEN

SL. No	**1**	**2**	**3**	**4**
% of bitumen replaced by footwear waste	2	3	5	7
Weight of footwear	1.2	1.8	3	4.2
Weight in air, W(g)	1232	1234	1241	1260
Weight in water W_w(g)	725	730	739	746
Bulk specific gravity of specimen	2.429	2.448	2.472	2.451
Theoretical specific gravity of specimen	2.509	2.528	2.552	2.531
V_v(%)	3.187	3.164	3.134	3.160
V_b	10.5	11	10.8	11.2
VMA	13.68	14.16	13.93	14.36
VFB	76.71	77.66	77.50	77.99
Stability in KN	82.16	90.12	80.17	73.77
Flow value (mm)	3.5	2.9	2.6	2.6

Fig. 1 represents the variation in flow value with respect to modifier content change and Fig. 2 represents the variation in stability value with respect to modifier content change

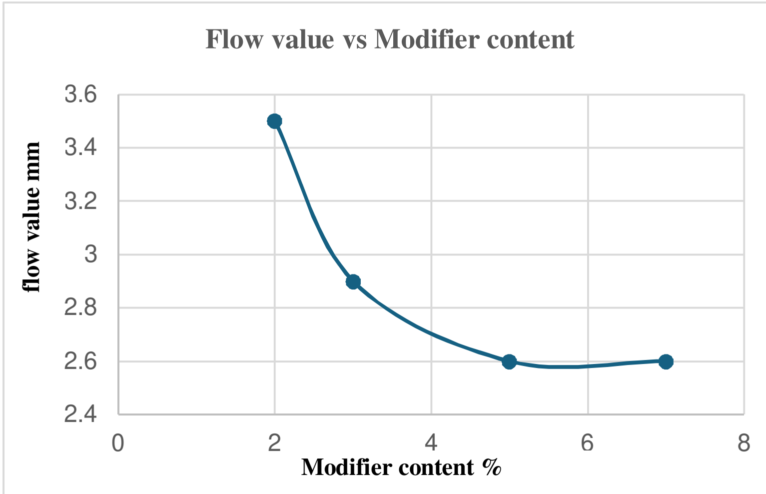

Fig. 1 A graph representing the variation in flow value with respect to modifier content change

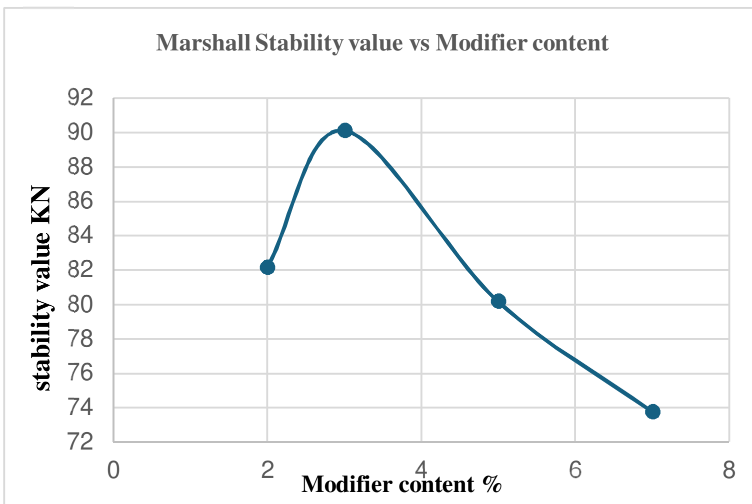

Fig. 2 A graph representing the variation in stability value with respect to modifier content change

The analysis of results provides a detailed evaluation of the impact of footwear waste modification on the performance characteristics of bituminous mixtures. Various parameters, including Marshall Stability, Flow Value, Voids in Mineral Aggregates, Voids Filled with Bitumen etc..The results show that stability initially increases as the footwear waste content increases up to 3%, reaching the highest stability value at this point. Beyond 3%, the stability begins to decrease, indicating a reduction in the load-bearing capacity of the mix.Also the flow value decreases significantly up to 3%, suggesting an improvement in the mix's resistance to deformation. However, beyond 3%, the decrease in flow value slows down, implying that higher footwear waste content may lead to increased stiffness, potentially affecting pavement flexibility.

V. CONCLUSIONS

This study explores the utilization of footwear waste as a sustainable modifier in bitumen, offering an environmentally beneficial approach to road construction. By replacing a portion of bitumen with shredded footwear waste, the research evaluates the mechanical and structural properties of modified bituminous mixes and assesses their feasibility for pavement applications. The Marshall Stability analysis demonstrated that stability values increase with the addition of up to 3% footwear waste, reaching the highest value of 90.12 kN.

The analysis of voids in the modified mix, including air voids, voids in mineral aggregates, and voids filled with bitumen, revealed a significant influence of footwear waste content. The air voids (Vv) initially decreased, suggesting improved compaction and density, particularly at 3% to 5% modification levels. However, beyond 5%, excessive voids led to a reduction in durability. The voids in mineral aggregates (VMA) and voids filled with bitumen (VFB) showed acceptable variations within the permissible range, ensuring sufficient bitumen retention and overall mix stability. Density measurements indicated a gradual increase up to 5% footwear waste content, suggesting improved material bonding. However, beyond this level, a reduction in density was observed, which could negatively impact long-term pavement performance. In future more Field trials and long-term durability tests are essential to validate laboratory findings and assess the practicality of using footwear waste in large-scale road construction projects.

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