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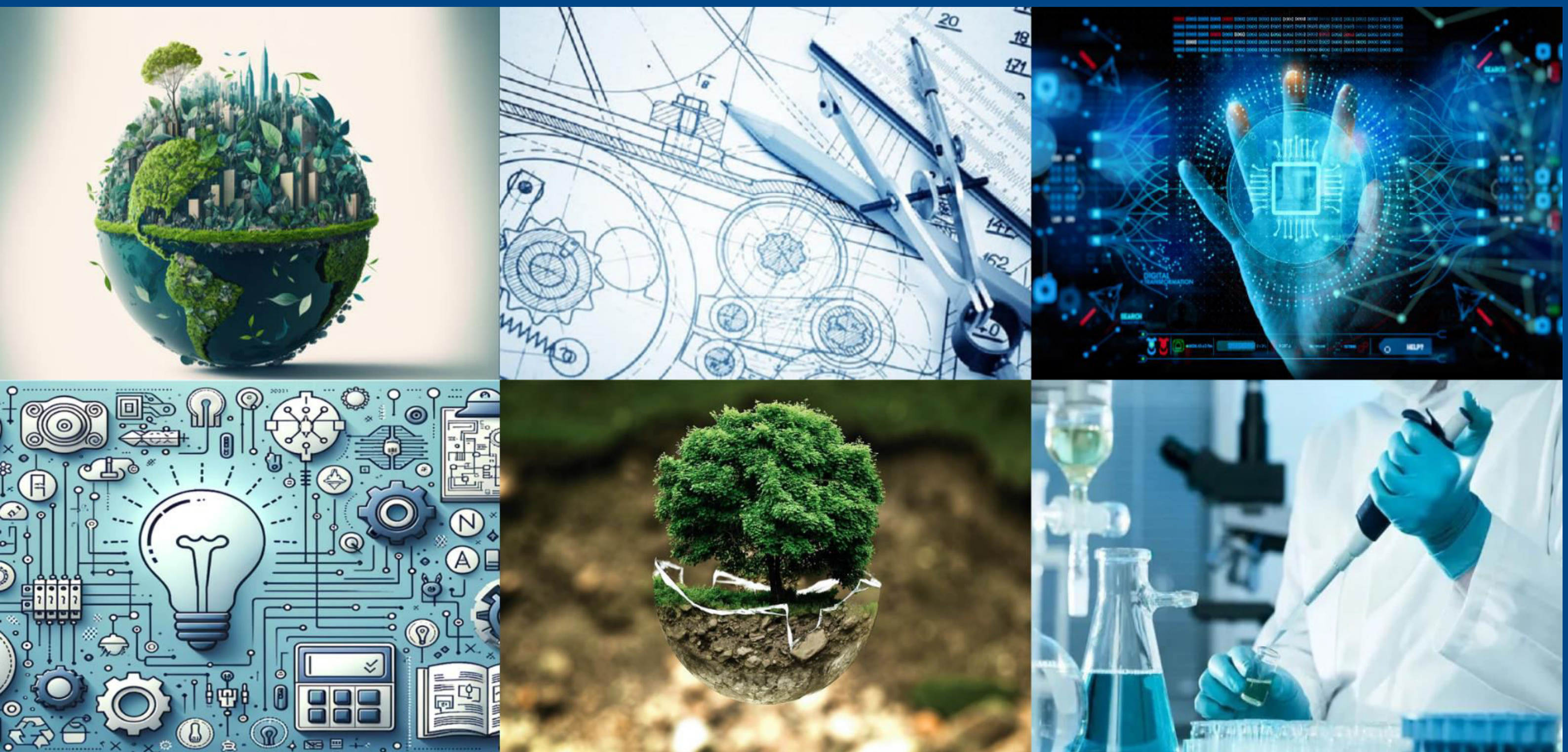

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Development of Durable Bituminous Roads Using Plastic Waste, Biomass (Mesquite) Ash and Crumb Rubber Powder

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ABSTRACT: The rapid increase in vehicular traffic, along with growing environmental concerns related to waste disposal, has created a need for sustainable and durable road construction materials. This study explores the development of high-performance bituminous roads by incorporating plastic waste (6%-8%), biomass (mesquite) ash, and crumb rubber powder as modifiers in conventional bitumen mixes. Plastic waste improves binding characteristics and enhances resistance to moisture damage, while crumb rubber powder increases elasticity, fatigue resistance, and overall pavement durability. Biomass (mesquite) ash, an agricultural by-product, acts as a filler material that enhances stiffness and reduces voids within the mix. The performance of the modified bituminous mix was evaluated using standard tests, including Marshall Stability, flow value, indirect tensile strength, and moisture susceptibility. The results show a significant improvement in strength, durability, and resistance to rutting and cracking when compared to conventional mixes. Furthermore, the use of waste materials promotes environmental sustainability by reducing landfill waste and encouraging resource recycling. Overall, this study demonstrates that the combined use of plastic waste, mesquite ash, and crumb rubber powder offers a cost-effective, eco-friendly, and efficient solution for constructing durable and bituminous roads.

KEYWORDS: Plastic waste, Mesquite ash, crumb Powder and bituminous.

I. INTRODUCTION

Road infrastructure is a key factor in the economic and social development of any country. In (ex: India) flexible pavements using bituminous materials are widely used due to their low initial cost and ease of construction. However, conventional bituminous roads often face problems such as rutting, cracking, pothole formation, and reduced service life under increasing traffic loads and changing climatic conditions. These issues result in frequent maintenance and higher overall costs.

At the same time, the accumulation of waste materials such as plastic waste, discarded tyres, and biomass residues has become a major environmental concern. Improper disposal of plastic leads to land and water pollution, while waste tyres occupy large landfill space and pose fire hazards. Mesquite (Prosopis Juli flora), an invasive plant species, spreads rapidly in agricultural lands, and its ash after burning creates disposal challenges.

(Studies by researchers such as Vasudevan Thiagarajan) have shown that plastic-modified bituminous roads perform better than conventional roads in terms of strength, durability, and resistance to environmental damage. Combining plastic waste, crumb rubber powder, and mesquite ash provides a “waste to wealth” approach that not only improves pavement performance but also reduces environmental pollutio

II. SCOPE OF THE STUDY

- This study focuses on the development to utilize plastic waste, crumb rubber powder, and mesquite ash in bituminous road construction.
- To evaluate improvements in rutting resistance, cracking resistance, and moisture resistance.
- Conducting laboratory tests such as Marshall Stability, flow value, and other standard tests.
- An important objective is to reduce environmental pollution caused by plastic, tyres, and biomass waste while determining the optimum percentage of plastic, rubber, and ash for best performance.

III. OBJECTIVES

- To promote an innovative "waste to wealth" approach in eco-friendly road construction.
- To improve pavement strength, stability, and durability using waste materials.
- To determine the optimum percentage of plastic, rubber, and biomass ash using standard mix design methods (e.g., Marshall Stability method).
- To study the economic feasibility and cost-effectiveness of modified bituminous pavements compared to conventional mixes.

IV. MATERIALS AND METHODOLOGY

4.1 MATERIALS

4.1.1 Bitumen

Bitumen is a hydrocarbon-based material that provides adhesion, waterproofing, and durability in pavement structures. Bitumen is classified based on its viscosity (resistance to flow). The commonly used grades in India (as per Indian Roads Congress specification) include **VG-30 (Viscosity Grade 30) bitume**n: with a viscosity of 2400–3600 poise at 60°C, is commonly used for roads carrying moderate to heavy traffic such as highways and urban roads. It offers a good balance of flexibility and strength, ensuring durability and resistance to cracking, and performs well under moderate climatic conditions**. VG-40 (Viscosity Grade 40) bitumen**: with a viscosity of 3200–4800 poise at 60°C, is suitable for heavy traffic and high-stress areas such as expressways, toll roads, and intersection.

4.1.2 Aggregate

Aggregates are the main structural component in bituminous (asphalt) roads, forming about 90–95% of the total mix by weight. They provide strength, stability, and durability to the pavement. Two types used in, coarse aggregate (up to 4.75 mm), fine aggregate (0.075 mm to 4.75 mm).

4.1.3 Collection of materials

The required materials were collected from various sources for the study. Plastic waste such as LDPE, HDPE, and polypropylene was gathered along with waste tyre crumb rubber and mesquite biomass ash.

4.1.3.1 Plastic waste

In this process, waste plastics such as polyethylene bags, bottles, and packaging materials are cleaned, shredded, and mixed with hot aggregates before adding bitumen. Plastic waste is added in the range of 6–10% of bitumen, with 8% as optimum. It must be clean, shredded, and free from PVC. At temperatures around 160°C, plastic melts and coats aggregates, improving strength, durability, and water resistance of bituminous roads. This method is also eco-friendly, as it reduces plastic waste pollution, and cost-effective due to lower bitumen consumption and reduced maintenance costs.

4.1.4 waste tyre crumb rubber

Crumb rubber from waste tyres is added to bitumen typically in the range of 8–15% to produce CRMB. It must be clean, well-graded, and free from impurities. Its use significantly improves strength, elasticity, rutting resistance, and durability of bituminous roads, making pavements more sustainable and long-lasting. Using code books (IRC: SP:53, IRC:37, MoRTH Section 500 and IS 15462).

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Figure 1: crumb rubber powder

4.1.5 Mesquite biomass ash

Obtained by burning mesquite (Prosopis Juli flora) biomass. Rich in silica and mineral content, making it suitable as a filler material in bituminous mixes. Acts as a partial replacement for conventional mineral filler (like stone dust or lime). Mesquite biomass ash is used as a partial filler replacement in bituminous roads as per IRC:37 and MoRTH Section 500. It is added in the range of 4–8% of filler (optimum 5–6%). It must pass the 75-micron sieve and be free from impurities as per IS standards.

Figure 2: Mesquite ash powder

4.2 METHODOLOGY

4.2.1 Preparation of modified binder and Mixing process

The modified binder is prepared by adding shredded plastic waste (6–8%) to hot aggregates at about 160–170°C, where it melts and coats the aggregates. Hot bitumen (155–160°C) is then added, followed by crumb rubber powder to improve elasticity and strength. Mesquite ash is used as a filler to enhance density and stability. The entire mi x is blended uniformly at controlled temperature to ensure proper coating.

4.2.2 Casting and Testing

The bituminous mix is placed in Marshall moulds, compacted, cooled, and removed as test specimens, after which the specimens are heated in a water bath at 60°C and tested for stability and flow, and the results are used to determine strength, durability, and optimum mix performance.

V. RESULT AND DISCUSSION

5.1 Test results of bitumen sample

a) Penetration test

The penetration test measures the consistency (hardness) of bitumen.
A standard needle is allowed to penetrate the sample.
VG-30 penetration range:50-70 (0.1mm)
VG-40 penetration range:30-50 (0.1mm)

b) Softening test

Determines the temperature at which bitumen softens.
Conducted using the Ring and Ball apparatus.
Formula: Softening point = (T1+T2)/2

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Table 2(a): Test result of penetration test and softening result

s.no	Bitumen + Aggregate + Plastic + Crumb rubber powder + Mesquite ash	Plastic +crump rubber powder+ Mesquite ash content %	Penetration value test (mm)	Softening test (°C)
1.	Without plastic, crump rubber powder and mesquite ash	0	37.55mm	57.67 °C
2	With plastic, crump rubber powder and mesquite ash	2%	37.25 mm	58.67 °C
		4%	35.78 mm	58.78 °C
		6%	34.89 mm	61 °C
		8%	32.58 mm	62.78 °C

Figure 3: Bituminous softening test

5.2 Test result for aggregate sample

a) Los Angeles abrasion test

It determines the resistance to wear, impact, and grinding.

Conducted using the Los Angeles abrasion machine (rotating drum with steel balls). Aggregate sample is placed along with standard steel balls.

Using formula, LA Abrasion value (%) = (W1 – W2) / W1 X 100

b) Water absorption test

It determines the porosity and moisture holding capacity of aggregates.

Finally, dried in an oven at 100–110°C and weighed again (dry weight).

Using formula: Water Absorption (%) = (Wssd – Wdry) / Wdry X 100

c) Flakiness index test

It measures the percentage of flaky particles (thickness < 0.6 × mean size).

A particle is considered flaky if its least dimension (thickness) is small compared to its size.

Using formula: Flakiness index (%) = (Wf / W) X 100

d) Elongation index test

It measures the percentage of elongated particles in a sample.
A particle is considered elongated if its length > 1.8 times the mean size of that fraction.

Using formula: Flakiness index (%) = (We / W) X 100

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Table 2(b): Test results of Aggregate test

STONE AGGREAGATE	PLSTIC CONTENT (%)	AGGREGATE IMPACT VALUE	LOS ANGELES ABRASION TEST	WATER ABSORPTION TEST	FLAKINESS ON INDEX TEST	ELONGATION ON INDEX TEST
WITHOUT PLASTIC, CRUMB RUBBER POWDER AND MESQUITE ASH	0%	23.12%	29.21%	1.1%	10.18%	9.33%
WITH PLASTIC, CRUMB RUBBER POWDER AND MESQUITE ASH	2%	22.19%	27.52%	1.05%	10.12%	9.35%
	4%	22.09%	26.43%	1.15%	10.03%	9.30%
	6%	21.78%	25.20%	1.19%	9.98%	9.47%
	8%	21.58%	25.12%	1.3%	9.75%	9.15%

Figure 4: Flakiness index test

5.3 Test result of Crumb rubber powder
a) Crumb rubber powder sieve test

Determine gradation (particle size distribution) of crumb rubber powder. Conducted as per standards like ASTM D564

Sample is oven-dried before testing. The sample is placed on the top sieve and mechanically shaken (10–15 minutes).

Formula: Percentage Retained = (weight retained on sieve / Total weight of sample) x 100

Table 3(c): Test results of Crumb rubber powder sieve test

S.NO	SIEVE	RETAINED %	CUMALATIVE RETAINED %	PASSING%
1	1 mm	6	6%	94%
2	0.6 mm	18	24%	76%
3	0.3 mm	40	64%	36%
4	0.15 mm	22	86%	14%
5	Pan	14	100%	0%

b) Crumb rubber powder specific gravity test

Used to determine the specific gravity (relative density) of crumb rubber powder.

Air bubbles must be removed during testing (by gentle shaking or vacuum).

Using formula: specific gravity (G) = (W2 – W1)/ ((W2 – W1) – (W3 – W4)

Table 3(d): Test results of Crumb rubber powder specific gravity test

S.NO	DESCRIPTION	WEIGHT (g)
1	Empty weight of pycnometer (W1)	600g
2	weight of pycnometer + Crumb rubber powder (W2)	700g
3	weight of pycnometer + Crumb rubber powder + kerosene (W3)	1120g
4	weight of pycnometer + kerosene (W4)	1050g
5	SPECIFIC GRAVITY (G) = (W2 – W1)/ ((W2 – W1) – (W3 – W4)	1.11

5.4 Test results for mesquite ash

a) Mesquite ash specific gravity test

Determines relative density of mesquite ash compared to water.

Mesquite ash is a lightweight pozzolanic material, so its specific gravity is lower than cement.

Test is useful for bituminous mix design and concrete mix proportioning.

Formula: specific gravity (G) = (W2 – W1)/ ((W2 – W1) – (W3 – W4)

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Table 4(e): Test results of mesquite ash specific gravity test

S.NO	DESCRIPTION	WEIGHT (g)
1	Empty weight of pycnometer (W1)	650g
2	weight of pycnometer + Mesquite ash (W2)	850g
3	weight of pycnometer + Mesquite ash + water (W3)	1250g
4	Weight of pycnometer + r (W4)	1150g
5	SPECIFIC GRAVITY (G) = (W2 – W1)/ ((W2 – W1) – (W3 – W4)	2.0

Figure 6: Mesquite ash specific gravity test

5.5 MARSHALL STABILITY TEST

Prepare bituminous mix with different bitumen contents.

Place mix in Marshall mould and compact (75 blows each side).

Remove specimen and allow it to cool Immerse specimen in water bath at 60°C for 30–40 minutes. Place specimen in testing machine Apply load at a constant rate (50 mm/min).

Table 5(f): Test results of Marshall stability

BITUMEN + AGGREGATE+ PLASTIC+ CRUMB RUBBER POWDER + MESQUITE ASH	PLASTIC CONTENT	MARSHALL STABILITY
WITHOUT PLASTIC, CRUMB RUBBER POWDER AND MESQUITE ASH	0%	1145.56

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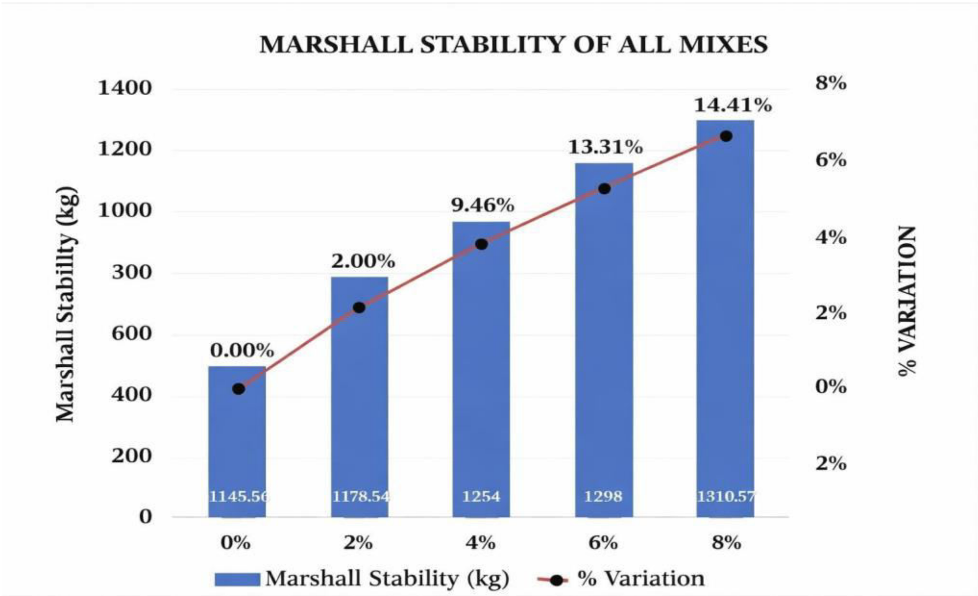
WITH PLASTIC, CRUMB RUBBER POWDER AND MESQUITE ASH	2%	1178.54
	4%	1254
	6%	1298
	8%	1310.57

MARSHALL STABILITY IN KG AND % VARIATION

VI. CONCLUSIONS

➢ Pro This study shows that adding plastic waste, spoils Juli flora ash and crumb rubber powder increases the Marshall Stability of bituminous mix.



➢ From the results, the highest Marshall Stability is obtained at 8% replacement, which shows better strength compared to other mixes.

➢ Hence, 8% addition gives the best performance among the tested samples. These materials also improve durability and flexibility, and help in effective waste management. Therefore, this method is economical and eco-friendly for road construction

REFERENCES

1. L. R. Kadiyali (2013). Highway Engineering. Khanna Publishers, New Delhi.
2. S. K. Khanna & C. E. G. Justo (2017). Highway Engineering. Nem Chand & Bros, Roorkee.
3. Yang H. Huang (2004). Pavement Analysis and Design. Pearson Education, USA.
4. Indian Roads Congress (2013). IRC: SP:98 – Guidelines for the Use of Waste Plastic in Hot Bituminous Mixes (Dry Process). New Delhi.
5. Indian Roads Congress (2018). IRC:37 – Guidelines for the Design of Flexible Pavements. New Delhi.
6. Ministry of Road Transport and Highways (2013). Specifications for Road and Bridge Works (MORTH). New Delhi.
7. Bureau of Indian Standards (1963). IS 2386 (Part I–VIII): Methods of Test for Aggregates for Concrete. New Delhi.

 DOI:10.15680/IJMRSET.2026.0905011

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8. Bureau of Indian Standards (1978). IS 1203: Methods for Testing Tar and Bituminous Materials – Penetration Test. New Delhi.
9. Shell plc (2015). The Shell Bitumen Handbook (6th Edition). Thomas Telford Publishing.
10. Utilization of Biomass (Mesquite) Ash in Road Construction (Various Authors). SATISH, C. - LEIF, B.: Lightweight Aggregate Concrete Lightweight Aggregate Concrete Science Technology and Application. Noyes Publications, 2002, 450 p.
11. BRYAN - DENNIS, S. P.: Occurrence and uses of Natural Lightweight Aggregate in the Western United States. Lightweight aggregate in Western United States, 1989, pp.193.
12. OWENS, P. L.: Lightweight aggregates for structural concrete. Structural Lightweight Aggregate Concrete. Chapman and Hall, London, 1993, pp.1-18.
13. HOSSAIN, K. M. A.: Properties of Volcanic Pumice Based Cement and Lightweight Concrete. Cement and Concrete Research, Vol. 34, Iss. 2, 2004, pp. 283-291.
14. IS 6042: Indian Standard, recommended guidelines for Light weight concrete.

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