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Experimental Study on Modified Asphalt Pavement by Using Waste Materials

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Abstract: ***India, being one of the fastest urbanizing countries, faces a significant challenge in managing tyre waste, which increases by 15-20% annually due to the rising number of vehicles. This study aims to enhance road construction efficiency and reduce costs by incorporating various waste materials such as scrap tyres, waste engine oil, and coal fly ash into asphalt mixtures. Bitumen is modified by adding crumb rubber at levels of 5%, 10%, and 15%, which enhances its binding strength, elasticity, stability, and flow characteristics. Additionally, coal fly ash is introduced as a filler (at 3%, 6%, and 9% by weight of aggregates) to improve the workability and durability of the mix. To address cracking and extend pavement life, waste engine oil is used as an additive, contributing to improved self-healing capacity, aging resistance, and fatigue performance. The modified asphalt mix is evaluated using the Marshall Stability method and the results are compared between conventional and modified asphalt mixes to determine overall improvements in performances.***

Keywords: Modified Asphalt Pavement, Bitumen Modification, Crumb Rubber, Waste Tyres, Waste Engine Oil, Coal Fly Ash, Marshall, Stability Test, Asphalt Mix Performance, Sustainable Road Construction, Pavement Durability, Waste Material Utilization.

I. INTRODUCTION

Pavements are critical components of transportation infrastructure, designed to provide a smooth, durable, and safe surface for vehicular and pedestrian traffic.

They are typically constructed in multiple layers, with each layer serving a specific function in distributing loads to the underlying subgrade. Among the various types of pavements, flexible pavements are the most widely used due to their cost-effectiveness, ease of construction, and ability to withstand varying traffic and environmental conditions.

The primary binding material in flexible pavements is bitumen, a viscoelastic material derived from the distillation of crude oil. Bitumen acts as a binder that holds the aggregate particles together, providing strength, durability, and resistance to deformation. However, over time, bitumen undergoes a natural process called ageing, which leads to the deterioration of its physical and chemical properties. This ageing process results in the hardening of bitumen, making it more brittle and prone to cracking, rutting, and other forms of pavement distress.

The ageing of bitumen is a significant concern in pavement engineering, as it reduces the service life of roads and increases maintenance costs. To address this issue, researchers and engineers have explored various methods to rejuvenate aged bitumen, including the use of waste materials such as Waste Engine Oil (WEO), Crumb Rubber and Fly Ash. All of these are by products from some industries has shown potential as a sustainable and cost-effective rejuvenator for aged bitumen.

II. SCOPE OF THE PROJECT

1) Enhanced performance: The crumb rubber gives the additional binding strength, increases elastic property, stability and flow of bitumen mix. The coal fly ash improves workability and durability of asphalt mix. Waste engine oil improves age resistance and fatigue life of bituminous mix.

2) Waste Material Utilization: beneficial reuse of waste materials like fly ash, crumb rubber (from tires) and waste engine oil, reducing landfill burden and conserving natural resources.

3) Reduced Carbon Footprint: By incorporating recycled materials, the need for virgin asphalt and aggregates is reduced, potentially lowering the carbon footprint associated with pavement construction.

4) Cost Effectiveness: helps for long-term savings and reduced replacement costs as the potential for extended pavement life and by delaying the need for pavement replacement and repair.

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A. Waste Engine Oil



Fig. 1.1 Waste engine oil (WEO)

The improper disposal of WEO (Fig. 1.1) poses significant environmental and health risks. When WEO is dumped into landfills or water bodies, it can contaminate soil and water resources, leading to long-term ecological damage. One of the most severe environmental impacts of WEO is eutrophication, a process in which oil layers on water surfaces block sunlight, disrupting oxygen supply and harming aquatic life. Additionally, the combustion of WEO releases harmful airborne pollutants, including particulate matter, sulphur dioxide, and nitrogen oxides, which can enter the human respiratory system and cause serious health problems.
To mitigate these environmental and health risks, there is a growing need to develop sustainable methods for recycling and reusing WEO. One promising approach is the use of WEO as a rejuvenator for aged bitumen in road construction. This not only provides a sustainable solution for WEO disposal but also enhances the performance of aged bitumen, extending the service life of pavements.

B. Coal Fly Ash



Fig. 1.2 Coal fly ash (FA)

It is a major industrial waste that, if improperly managed, can cause air, soil, and water pollution and pose health risks. Toxic elements such as arsenic, mercury, lead, and cadmium present in fly ash can leach into the ground, reducing soil fertility and polluting groundwater resources. This contamination can make water unsafe for both agricultural and domestic use. Another major issue is air pollution. Fly ash (Fig. 1.2) particles are extremely fine and can easily become airborne, especially when stored in open ash ponds or landfills. Inhalation of these particles can cause respiratory problems such as asthma, bronchitis, and silicosis, and long-term exposure increases the risk of lung cancer and cardiovascular diseases.
The utilization of fly ash in construction materials, asphalt mixes, and cement production is gaining importance to mitigate these impacts. This approach not only reduces the environmental burden of disposal but also promotes sustainable development.

C. Crumb Rubber



Fig. 1.3 Crumb rubber (CR)

Crumb rubber (Fig. 1.3) is recycled rubber produced from automotive and truck scrap tires. During the recycling process, steel and tire cord (fluff) are removed, leaving tire rubber with a granular consistency. Due to increase in vehicular amount of tyre waste originated in range of 15-20% each year and it causes a great problem while disposing them into the environment.

Therefore, utilizing waste rubber in roads pavements imparts to the properties of roads and to the environment as well. The cost of natural construction materials is increasing day by day, so it becomes necessary to find alternatives to replace the natural resources which may lead to improved quality of roads and reduced constructional costs. Rubber tyres have been proved user friendly to the people in many ways but are not eco-friendly. So, it becomes a matter of utmost importance to reuse waste rubber in any means possible. Reusing it as a partial replacement of road materials like bitumen can be an environmentally friendly approach.

III. OBJECTIVES

1) To explore the effective use of waste materials in road construction.
2) To study the effect of crumb rubber, waste engine oil and fly ash in increasing the stability of modified asphalt mix.
3) To study the effect of waste engine oil in increasing the rheological properties of modified asphalt binder.
4) To compare the strength of bitumen and additives of modified asphalt mix with conventional asphalt mix.

IV. COMPONENTS OF ROAD CONSTRUCTION MATERIALS

1) BINDER : Bitumen Grade VG 30
2) MODIFIER : Crumb Rubber
3) AGGREGATE MIX : Coarse Aggregate
4) FILLER : Coal Fly Ash
5) ADDITIVES : Waste Engine Oil

V. EXPERIMENTAL WORKS

Following test were conducted to investigate the material properties used in asphalt mix.

A. Tests On Aggregate

Tests which are generally carried out for judging the desirable properties and suitability of stone aggregates are listed below

Table 4.1 Physical properties of Coarse Aggregate

Property tested	Tests method	Morth specification	Results
Aggregate impact test	IS:2386 (Part 4)	20-24%	27.45 %
Los Angeles abrasion value test	IS:2386 (Part 4)	30% max	28.08 %
Specific gravity test	IS:2386 (Part 4)	2.5-3.0	2.7
Water absorption test	IS:2386 (Part 4)	2% max	.8 %
Aggregate crushing test	IS:2386 (Part 4)	45% max	28.91 %

B. Tests On Bitumen

Bitumen is available in a variety of types and grades. To judge these binders' various physical tests have been specified by agencies like Bureau of Indian Standards (BIS), American Society for Testing and Materials (ASTM) and the British Standards Institution. Various tests that are generally carried out to evaluate the properties of bitumen binders are ductility test, Softening point and Penetration test.

Table 4.2 Physical properties of Bitumen

Property tested	Tests method	Permissible limit	Results
Ductility test	IS:1208	40 cm (min)	47.2 mm
Softening point	IS:1205	35-70 °C	55 °C
Penetration test	IS:1203	50-70 mm	86.33 mm

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VI. TEST RESULT AND DISCUSSSION

All the respective samples are collected and various tests were conducted in laboratory. The result obtained from the test are tabulated and discussed as follows:

Table 5.1 Physical Properties of Bitumen with Crumb Rubber and with Waste Engine Oil

No.	Specimen	Softening point °C	Ductility	Penetration
1	B + 5% CR	60 °C	44.5 cm	84 mm
2	B + 10% CR	62 °C	44 cm	80 mm
3	B + 15 % CR	66 °C	43.5 cm	75 mm
4	B + 2% WEO	53 °C	58.5 cm	117.33 mm
5	B + 4% WEO	50 °C	79 cm	224.33 mm
6	B + 6 % WEO	45 °C	98.6 cm	329.33 mm

Table 5.2 Physical Properties of Modified Bitumen

No.	Mix combinations	Softening point °C	Ductility	Penetration
1	B + 2% WEO + 5% CR	58 °C	53 cm	98 mm
2	B + 2% WEO + 10 % CR	62 °C	50 cm	89 mm
3	B + 2% WEO + 15% CR	64 °C	46 cm	78 mm
4	B + 4% WEO + 10 % CR	58 °C	60 cm	105 mm

From the results, it was observed that the addition of crumb rubber increases the softening point and decreases penetration, indicating that the bitumen becomes stiffer and more resistant to high temperatures. However, ductility slightly decreases with increasing crumb rubber content. In contrast, the addition of waste engine oil reduces the softening point and increases penetration and ductility, showing that WEO acts as a softening and rejuvenating agent that improves the flexibility of bitumen. The combined modification of bitumen with both CR and WEO helps in balancing stiffness and flexibility. Among the combinations studied, the mix B + 2% WEO + 10% CR shows balanced properties with adequate softening point, moderate penetration, and satisfactory ductility.

Therefore, the use of crumb rubber and waste engine oil as modifiers in bitumen can improve pavement performance while also promoting sustainable waste management by utilizing waste materials in road construction.

A. Marshall Stability Test

Table 5.3 Results of Dense Bituminous Mix with Modified Bitumen and Varying Percentages of Fly Ash

No.	Parameter	Results			
		Normal bitumen	MB+3%FA	MB+6%FA	MB+9%FA
1	Stability (KN)	8.9	11.03	12.5	11.6
2	Air voids (%)	6.47	5.66	5.26	6.07
3	Voids filled with bitumen, VFB (%)	66.21	69.32	70.94	67.71
4	Flow value (mm)	3.42	3.08	2.92	3.17
5	Density (g/cc)	2.36	2.37	2.38	2.36

The results of the Marshall Stability Test show that the modified bitumen (MB) mixes perform better than conventional bitumen. The conventional mix has a stability of 8.9 KN, while the mixes with MB + 3% FA, MB + 6% FA, and MB + 5% FA show higher stability values of 11.03 KN, 12.5 KN, and 11.6 KN respectively. This indicates an improvement of 23.9%, 40.4%, and 30.3% compared to conventional bitumen.

The air voids decrease in the modified mixes, showing better compaction. The VFB values increase, indicating improved binding between aggregates and bitumen. The flow values slightly decrease, which means better resistance to deformation. Density also shows a small increase, indicating improved aggregate packing.

Overall, the results indicate that the addition of WEO and CR with FA improves the performance of the bituminous mix compared to conventional bitumen. Among the tested mixes, B + 2% WEO + 10% CR + 6% FA shows the best performance with the highest stability value.

VII.CONCLUSION

This study investigated the potential use of Waste Engine Oil (WEO), Crumb Rubber (CR), and Fly Ash (FA) as modifiers in asphalt pavement. The results indicate that these waste materials can significantly improve the mechanical and rheological properties of asphalt while also offering a sustainable solution for waste management. WEO acts as a rejuvenator that improves binder flexibility and resistance to aging, CR enhances elasticity, stability, and fatigue resistance, and Fly Ash functions as a mineral filler that improves density, strength, and workability of the asphalt mix.

The Marshall Stability Test played a key role in evaluating the performance of the modified asphalt mixtures. Through this test, important parameters such as stability, flow value, and durability characteristics of the asphalt mixes were determined. The stability value indicates the load-carrying capacity of the mixture, while the flow value represents the deformation behaviour under load. By analysing these parameters, the Marshall method helped identify the optimum proportions of WEO, CR, and FA that provide a balanced combination of strength, flexibility, and durability for pavement applications.

The findings suggest that asphalt mixtures modified with these waste materials can improve pavement performance and extend service life while reducing environmental impacts and material costs. However, factors such as optimum dosage, storage stability, and large-scale field performance still require further investigation. Overall, incorporating WEO, CR, and FA in asphalt mixtures, together with performance evaluation using the Marshall Stability Test, provides a promising and sustainable approach for modern road construction and supports circular economy practices in civil engineering.

VIII. ACKNOWLEDGMENT

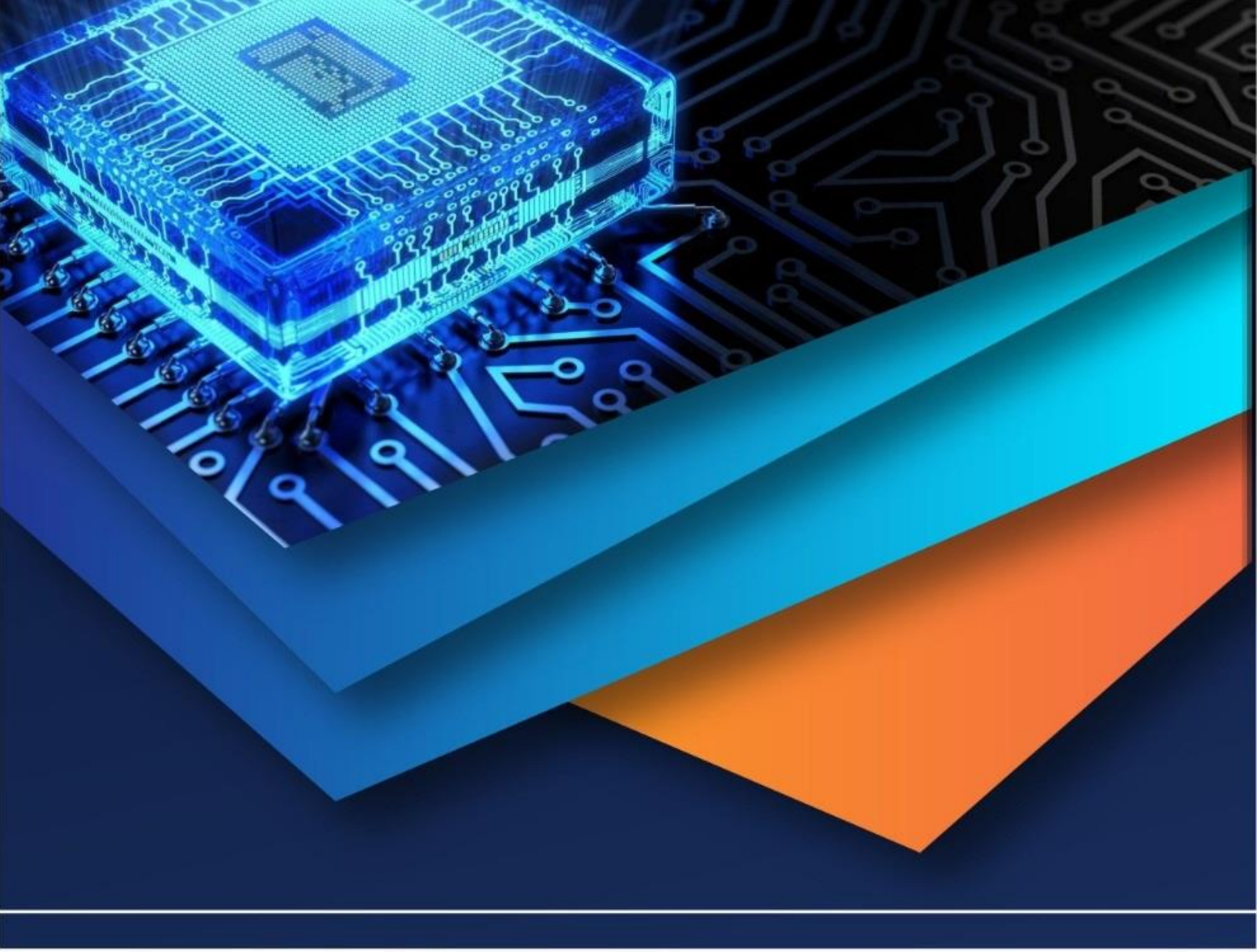
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