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Optimizing Asphalt Mix with Plastic Coated Aggregate

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Abstract: The Process investigates the potential of using plastic-coated aggregates to enhance the performance of asphalt pavement. With growing concerns over plastic waste pollution and deteriorating road infrastructure, the study aims to develop a sustainable and durable solution by incorporating plastic waste into road construction materials. Specifically, the study focuses on coating aggregates with Polymethyl Methacrylate (PMMA) and modifying bitumen with Styrene Butadiene Rubber (SBR) and Polyphosphoric Acid (PPA). additionally, the study optimizes asphalt performance by modifying bitumen with Styrene Butadiene Rubber (SBR) and Polyphosphoric Acid (PPA). The research methodology involves a systematic approach where aggregates are coated with varying percentages of PMMA (4%, 6%, and 8%) and asphalt binder is enhanced with different concentrations of SBR (3%, 4%, and 5%) and PPA (2%, 3%, and 4%). Several tests, including the Marshall Stability Test, impact test, abrasion test, water absorption test, and softening point test, are conducted to assess the mechanical properties, durability, and resistance to environmental factors of the modified asphalt mix. The methodology includes preparation and testing of plastic-coated aggregates with varying percentages of PMMA, followed by modifying asphalt with different concentrations of SBR and PPA. Key performance tests such as the Marshall Stability Test, impact tests, and water absorption tests were conducted to evaluate the mechanical properties and durability of the modified asphalt mix. Results indicate that plastic-coated aggregates improve road strength, water resistance, and longevity, while bitumen modified with SBR and PPA enhances the asphalt's flexibility and resistance to rutting.
Keywords: Plastic-coated aggregates, Asphalt performance, Polymethyl Methacrylate (PMMA), Styrene Butadiene Rubber (SBR), Polyphosphoric Acid (PPA), Sustainable Road construction.

I. INTRODUCTION

A material that contains one or more organic polymers of large molecular weight, solid in its finished state and at some state while manufacturing or processing into finished articles, can be shaped by its flow, is called as ‘Plastic’. Plastics are durable and degrade very slowly; the chemical bonds that make plastic so durable make it equally resistant to natural processes of degradation. Plastics can be divided into two major categories: Thermoset and Thermoplastics. A thermoset solidifies or ‘‘sets’’ irreversibly when heated. They are useful for their durability and strength, and are therefore used primarily in automobiles and construction applications.

These plastics are polyethylene, polypropylene, polyamide, polyoxymethylene, terephthalate. A thermoplastic softens when exposed to heat and returns to original condition at room temperature. According to recent studies, plastics can stay unchanged for as long as 4500 years on earth with increase in the global population and the rising demand for food and other essentials, there has been a rise in the amount of waste being generated daily by each household. Plastic in different forms is found to be almost 5% in municipal solid, which is toxic in nature.

It is a common sight in both urban and rural areas to find empty plastic bags and other type of plastic packing material littering the roads as well as drains. Due to its biodegradability, it creates stagnation of water and associated hygiene problems. In order to contain this problem experiments have been carried out whether this waste plastic can be reused productively. The experimentation at several institutes indicated that the plastic, when added to hot aggregate will form a fine coat of plastic over the aggregate and such aggregate, when mixed with the binder is found to give higher strength, higher resistance to water and better performance over a period of time Use of plastics along with the bitumen in construction of roads not only increases its life and smoothness but also make it economically sound and environment friendly. Plastic waste is used as modifier of bitumen to improve some of bitumen properties roads that are constructed using plastic waste are known as Plastic Roads and are found to perform better compared to those constructed with conventional bitumen.

Further it has been found that such roads were not subjected to stripping when come in contact with water. Use of higher percentage of plastic waste reduces the need of bitumen by 10%, thereby saves approximately Rs.35000 to Rs.45000 per kilometre of a road stretch. The uses of plastic waste help in substantially improving the abrasion and slip resistance of flexible pavement and also allows to obtain values of splitting tensile strength tensile strength satisfied the specified limits while plastic waste content is beyond 30% by weight of mix. If the consistent mixing time and mixing temperature are not provided for bitumen-modifier mix, modified bitumen cannot exhibit good performance in situ, thus premature failures will occur. Therefore, there are certain recommended mixing time, mixing temperature and modifier content for all the polymers with trademark. This all should be taken in mind while mixing and laying of roads is to be done using plastic waste. Plastic road would be a boon for India. In hot and extremely humid climate durable and eco-friendly plastic roads are of greatest advantages. This will also help in reliving the earth from all type of plastic waste. (Siddhant Singh,2022).

II. METHODOLOGY

The proposed methodology outlines a structured process to evaluate the performance of plastic-coated aggregates and optimize the asphalt mix using polymers such as polymethyl methacrylate (PMMA), styrene-butadiene rubber (SBR), and polyphosphoric acid (PPA). It begins with a literature study to gather relevant research insights, followed by material selection to identify suitable aggregates and binders for the experiment. The methodology is divided into two major sections: preparation of plastic-coated aggregates and optimization of asphalt.

In the first section, plastic-coated aggregates are prepared by coating them with varying percentages of PMMA (4%, 6%, and 8%). These coated samples are then evaluated to determine the optimal PMMA percentage that provides the best performance. The second section focuses on asphalt optimization, where the percentages of SBR (3%, 4%, and 5%) and PPA (2%, 3%, and 4%) are varied to identify their optimal combination. Once the optimum percentages of SBR and PPA are determined, the asphalt mix is evaluated based on this combination.

The final stage involves conducting the Marshall Stability Test, a standard method to assess the strength and stability of asphalt mixes. The results from these tests help in concluding the performance comparison between conventional asphalt and modified mixes. This stepwise methodology ensures a thorough analysis of both the coated aggregates and the modified asphalt for enhanced performance in road construction applications.

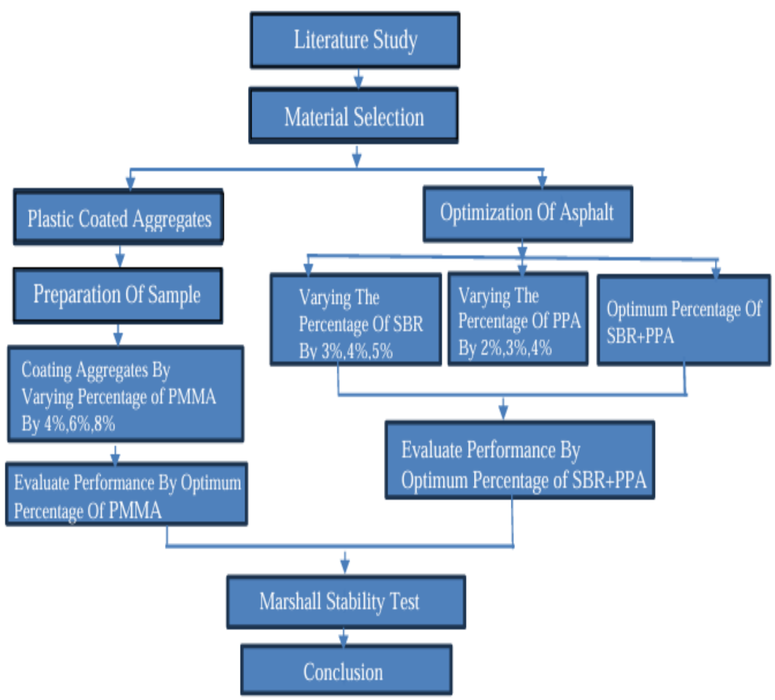

Fig.1 Flowchart Showing Procedure of Project Work

III. RESULTS

A. *Analysis of Bitumen Test Results with Polymer Modifications (SBR and PPA)*

1) *Ductility Test Results*

This section discusses the influence of varying percentages of Styrene-Butadiene Rubber (SBR) and Polyphosphoric Acid (PPA) on the ductility, softening point, and penetration values of bitumen

Fig 2 Ductility Test

TABLE I
DUCTILITY TEST FOR SBR MODIFICATION

SBR Content (%)	Ductility (cm)
0%	68
3%	39
4%	20
5%	15

TABLE IIi
DUCTILITY TEST FOR PPA MODIFICATION

SBR Content (%)	Ductility (cm)
0%	68
2%	13
3%	11
4%	9.5

2) *Softening Point Test Results*

The softening point values obtained from the tests with SBR and PPA modifications are as follows:

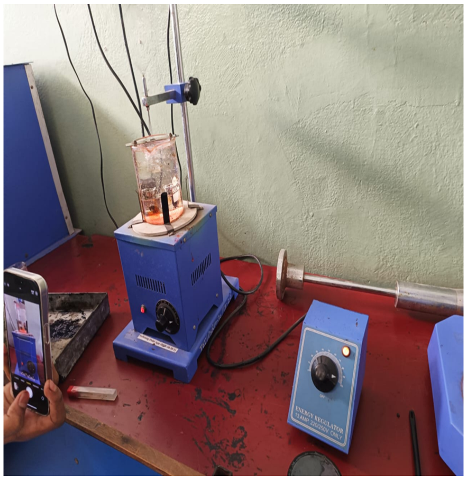

Fig 2 Softening Point Test

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TABLE III
SOFTENING POINT TEST FOR SBR MODIFICATION

SBR Content	Softening Point
3%	65 to 70
4%	75 to 80
5%	85 to 90

TABLE IV
SOFTENING POINT TEST FOR PPA MODIFICATION

PPA Content	Softening Point
2%	70 to 75
3%	80 to 85
4%	90 to 95

3) Standard Penetration Test Results

The penetration values obtained from the tests with PPA modifications are as follows:

Fig 3 Standard Penetration Test

TABLE V
STANDARD PENETRATION TEST FOR PPA MODIFICATION

PPA Content	Softening Point
0%	44.0
2%	78.83
3%	89.66
4%	50..0

B. Result Analysis for the Aggregate Impact Value Test

1) Procedure: The aggregate sample was prepared, compacted in layers, subjected to 15 hammer blows, and sieved through a 36 mm IS sieve to calculate the impact value.
2) Material Behaviour: Results indicated the ability of polymer-coated aggregates to withstand dynamic forces, demonstrating suitability for road surfaces.
3) Significance: Lower impact values correlate with better resistance to fragmentation, confirming the effectiveness of polymer coatings.

TABLE VI
RESULT ANALYSIS FOR THE AGGREGATE IMPACT VALUE TEST

Parameter	0%	4%	6%	8%
Total weight of dry sample (W1)	350	350	350	350

Weight of material passing 2.36 mm sieve (W2)	39	27	22	19
Impact Value (%) (W2/W1) × 100	11.14 %	7.71%	6.28 %	5.42 %

C. Result Analysis for the Los Angeles Abrasion Test

1) Procedure: Aggregates were oven-dried at 105°C-110°C to achieve constant weight. Test samples and steel balls were placed in the Los Angeles abrasion machine and rotated at 20-33 rpm for 500 revolutions. After the test, samples were sieved through a 1.70 mm IS sieve, and the weight of the portion retained was recorded
2) Material Behaviour: Aggregates with lower abrasion values are more resistant to wear, making them suitable for construction, especially in high-traffic areas.
3) Significance: This test is crucial for selecting aggregates that ensure durability and long-term

TABLE VI
RESULT ANALYSIS FOR THE LOS ANGELES ABRASION TEST

Parameter	0%	4%	6%	8%
Total weight of dry sample (W1)	5000	5000	5000	5000
Weight of material retained on 1.70 mm sieve (W2)	2650	3050	3221	3428
Abrasion Value (%) W1-W2/W1 × 100	47 %	39%	35%	32%

D. Result Analysis for Aggregate Crushing Test

1) Procedure: Dry samples of aggregates were prepared and subjected to compressive loading. Fines passing through the 2.36 mm IS sieve were measured to calculate the crushing value.
2) Material Behaviour: Plastic-coated aggregates consistently showed lower crushing values, indicating improved resistance to compressive loads.
3) Significance: Lower crushing values correlate with stronger aggregates suitable for high-load applications in construction.

TABLE VI
RESULT ANALYSIS FOR AGGREGATE CRUSHING TEST TEST

Observation	0%	4%	6%	8%
Total weight of dry sample (W1) (gm)	2700	2700	2540	2450

Weight of fines passing 2.36 mm sieve (W2) (gm)	520	387	350	320
Crushing Value (%) (W2/W1)*100 (gm)	19.26 %	14.33 %	13.77 %	13%

E. Marshal Stability Test

Asphalt Mix Prepared with the Optimum Percentage found by tests on aggregates and bitumen which were

1) 8% PMMA Coated Aggregates.
2) 2% & 3% of SBR and PPA Modified Bitumen.

The Marshall Stability Test was performed on the specimen created Of the Asphalt mix.

TABLE VII
MARSHALL STABILITY TEST RESULTS

Sr.no.	Bitumen Content in %	Aggregate %	Diameter of Specimen (mm)	Height of specimen (mm)	Wt. of specimen in Air (gm)	Wt. of specimen in Water(gm)	Wt. of specimen in Surface Satureted Dry(gm)	Bulk volume (cc)	Bulk Density (Gmb) (cc)	Bulk Specific gravity (Gsb)	Therotical Specific gravity (Gmm)	Efective Specific gravity (Gse)	Marshall Stability (KN)			Flow (mm)	Air voids (Vv)	Voids of Mineral Agg. (VMA)	Voids Filled with Bitumen (VFB)
													Load	Corr. Factor	Corrected load				
1	4.5	95.5	100	59.5	1213	698	1230	532	2.280	2.707	2.431	2.510	220	0.96	12.174	3.5	6.21	19.561	68.262
2			100	61	1208	702	1228	526	2.297			2.510	215	0.96	11.898	2.8	5.53	18.979	70.866
1	5	95	100	56	1205	678.5	1226.5	548	2.199	2.707	2.415	2.502	290	0.89	14.878	3.2	8.95	22.831	60.808
2			100	60	1208	700.1	1235	534.9	2.258			2.502	298	0.96	16.491	3.4	6.49	20.744	68.734

IV. CONCLUSIONS

This study confirms that incorporating plastic-coated aggregates and modifying bitumen with polymer additives significantly enhances asphalt performance. The aggregate impact value decreased from 11.14% (0% PMMA) to 5.42% (8% PMMA), abrasion value reduced from 47% to 32%, and crushing value dropped from 19.26% to 13%, indicating improved durability.

Bitumen modification with Styrene Butadiene Rubber (SBR) and Polyphosphoric Acid (PPA) further enhanced properties. The softening point increased from 65-70°C (3% SBR) to 85-90°C (5% SBR) and from 70-75°C (2% PPA) to 90-95°C (4% PPA), improving thermal stability. Meanwhile, ductility decreased from 68 cm (0% SBR) to 15 cm (5% SBR) and from 68 cm (0% PPA) to 9.5 cm (4% PPA), enhancing stiffness.

V. ACKNOWLEDGMENT

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