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Utilization of Plastic Waste as an Additive in Bituminous Mixes for Flexible Road Construction

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Abstract: Plastic waste and its disposal pose a significant threat to the environment, contributing heavily to pollution and global warming. Among various types of waste, plastic is one of the most harmful to nature due to its non-biodegradable properties. While plastics are convenient and widely used, they are not environmentally friendly. Traditional road surfaces made with plain bitumen often face issues such as bleeding in high temperatures, cracking in colder climates, reduced load-bearing capacity, and damage from the increasing axial loads caused by modern infrastructure growth.

Incorporating plastic waste into road construction offers a dual benefit: enhancing pavement durability and addressing the growing problem of plastic waste management. The process involves shredding the plastic, coating it over aggregates, and then mixing it with hot bitumen. This composite mix is used in flexible pavement construction. The primary goal of the associated testing is to determine the optimal percentage of plastic waste that can partially replace bitumen while maintaining or improving the performance of the pavement.

Keywords: *Waste Plastics, Asphalt Binder, Coarse Aggregates, Polymer-Modified Roads, Plastic-Asphalt-Aggregate Blend.*

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I. INTRODUCTION

Plastic has become an integral part of modern life, leading to a major concern regarding its disposal. Since plastic is non-biodegradable, it contributes to environmental issues such as the greenhouse effect and global warming. Plastics are generally classified into two main types: thermo sets and thermoplastics. Thermo sets are known for their high strength and durability, as they harden permanently upon heating. Due to these properties, they are particularly suitable for use in construction-related applications.

Plastic waste, such as discarded bottles (Fig. 1), can be used to modify bitumen and aggregates, improving certain characteristics of these construction materials. However, the disposal of plastic waste (Fig. 2) poses significant challenges. Being non-biodegradable, plastic remains in the environment for long periods. Land filling plastic is hazardous, as toxic substances can leach into the soil and contaminate underground water sources, thereby polluting nearby water bodies.

Fig 1: Plastic Waste-Disposable Bottles.

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Fig 2: Various Material of Plastic Wastes

➢ *Scope of The Project*

- Identification and classification of different types of plastic waste that is appropriate for use in pavement construction.
- Conversion of plastic waste into a practical form—such as shredded or granulated plastic—for its effective integration with bitumen and aggregates.
- Conducting laboratory experiments to analyze and compare the physical and mechanical characteristics of plastic-enhanced bitumen with those of standard bitumen.
- Evaluating the performance of the resulting pavement, including factors like durability, load-bearing capacity, water resistance, and resistance to deformation under stress.
- Analyzing environmental implications, focusing on the advantages of utilizing plastic waste in road construction to mitigate pollution and reduce landfill dependency.
- Economic assessment to determine the practicality and cost-efficiency of adopting this technique for large-scale infrastructure projects.

➢ *Objectives*

- *Bitumen and Aggregate Mixtures*

✓ Durability and Longevity
✓ Strength and Stability:
✓ Flexibility and Workability

➢ *Advantages*

- Environmental Sustainability
- Enhanced Road Durability
- Increased Lifespan of Roads
- Cost-Effective
- Improved Binding Properties
- Reduction in Carbon Footprint

➢ *Disadvantages*

- Collection and Segregation Challenges
- Processing Requirements
- Health and Safety Concerns
- Inconsistent Quality
- Limited Awareness and Implementation
- Environmental Risks if Not Handled Properly

II. LITERATURE REVIEW

- **Dr. R. Vasudevan (2007)**, His findings show that combining polymers with bitumen results in a more effective binder. This modified blend shows an increase in softening point, a reduction in penetration value, and maintains sufficient ductility, making it more suitable than regular bitumen.
- **Nagarajan (2014)**, The study concludes that crushed stone offers improved resistance to mechanical stresses such as impact, abrasion, and crushing, when compared to traditional granite aggregates. It can be mixed directly with asphalt for various tests, excluding water absorption analysis.
- **Ramadhansyah et al. (2014)**, Researchers emphasized the development of pavement materials with enhanced structural and mechanical properties. Traditional pervious concrete (PC) pavements often fall short in strength due to high porosity, making it difficult to achieve desired durability with standard material mixes.
- **Thulasirajan (2011)**, Investigated the effects of coconut fibers on flexible pavement properties by adjusting fiber content, binder percentage, and fiber length. The study indicated that incorporating coconut fibers can significantly enhance resistance to traffic-induced stress.
- **Sunil J. Kulkarni (2015)**, Discussed the extensive use of plastics in both household and industrial sectors, and pointed out that improper disposal remains a major issue. The research proposed that plastic waste could serve as a raw material for alternative products like ethanol.
- **Prof. C.E.G. Justo (2015)**, Stated that integrating 8% of processed plastic (by weight) into bitumen can lead to a reduction in bitumen use by approximately 0.4% in the mix, translating to a savings of about 9.6 kg per cubic meter of bituminous concrete.
- **Ms. Apurva Chavan (2013)**, Highlighted the multiple benefits of utilizing plastic waste in road construction, such as lowering bitumen usage by around 10%, boosting pavement performance, eliminating the need for anti-stripping agents, and reducing environmental hazards through effective plastic reuse.

III. METHODOLOGY

The methodology employed in this study encompasses a thorough approach to assessing the potential advantages of integrating waste plastic into bituminous mixes for road pavements. The following steps outline the detailed methodology:

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25apr2083

A. Use of Materials

➢ *Aggregate*

Used in the construction of base layers for roads and other infrastructure projects, as well as in the production of bitumen. Tests perform on aggregate in laboratory as (fig. 3) sieve analysis, specific gravity testing, and potentially other tests to assess its particle size distribution, durability, and suitability for specific applications like concrete mixes or pavement base layers. Aggregate properties play a vital role in pavement performance, and various tests are outlined in construction standards to assess them. These include evaluations of mechanical strength, impact resistance, particle shape and texture, clay contamination, surface hardness, long-term durability, geometric form, and the material's ability to adhere to bituminous binders.

Fig 3: Test Perform on Aggregates (Size-10mm)

- *Experimental Results:*

Table 1: Test Results with Modified Aggregate

Test	Normal aggregate	5% Plastic Added Aggregate	6% Plastic Added Aggregate	7% Plastic Added Aggregate
Specific gravity & Water absorption	0.6	0.5	0.45	0.45
Crushing Value Test	21.45	19.86	19.04	18.12

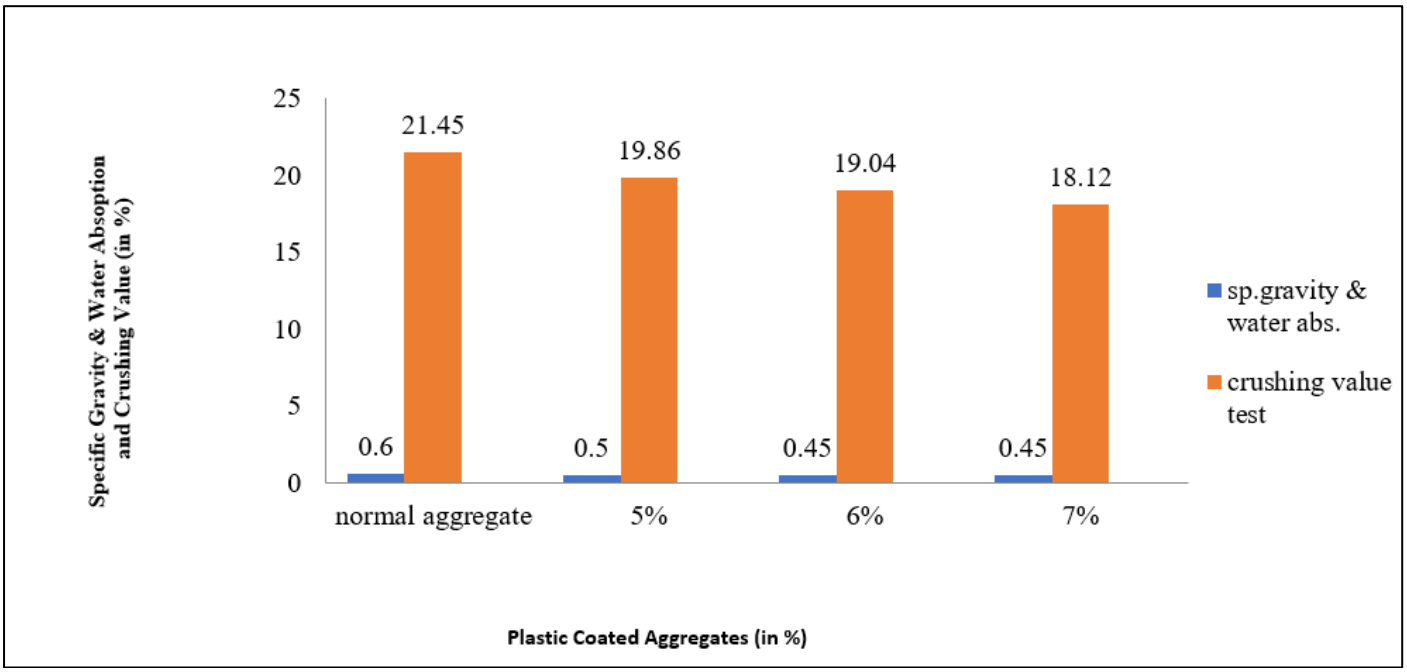

Fig 4: Specific Gravity & Water Absorption and Crushing Value vs Plastic Coated Aggregates

➢ *Bitumen*

Bitumen is commonly used as a binder in road construction. It can be obtained as a residue from the refining process or from naturally occurring asphalt deposits. Bitumen, often referred to as **asphalt**, contains a significant amount of solid mineral matter. This black, sticky, and thick substance is an organic byproduct derived from the decomposition of natural organic materials.

For this study, bitumen grades 60/70 and 80/100 were used, with VG-70 bitumen being specifically tested in the laboratory (Fig. 5). One of the key qualities of bitumen that has made it a popular construction material is its exceptional binding ability. It softens when heated, making it ideal for use in pavement construction.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25apr2083

- *Experimental Results:*

Table 2: Test Results with Modified Bitumen

Test	Normal Bitumen	5% Plastic Added Bitumen	6% Plastic Added Bitumen	7% Plastic Added Bitumen
Ductility (cm)	86	42	34	23

Fig 5: Test Perform on Bitumen (VG-70)

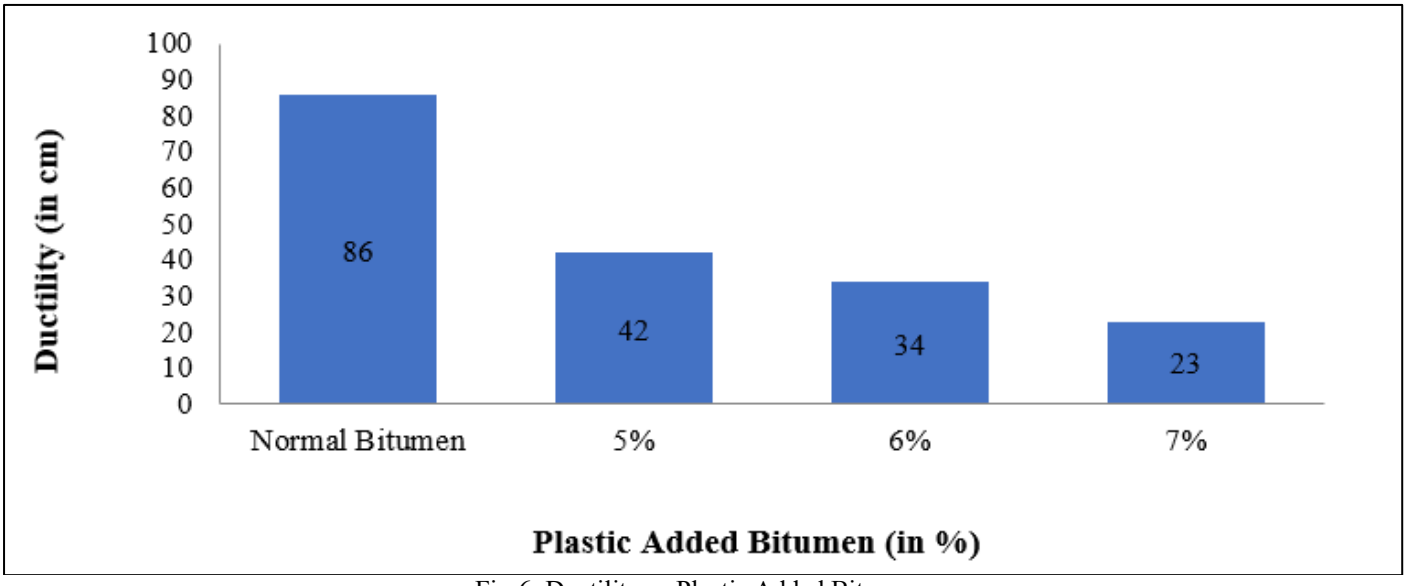

Fig 6: Ductility vs Plastic Added Bitumen

➢ *Plastic Material*

Plastics are generally classified based on the chemical structure of their polymer backbone and side chains. Major categories include acrylics, polyesters, silicones, polyurethanes, and halogenated polymers.

Plastic waste refers to unwanted or discarded plastic items that pose a threat to the environment when not managed properly. These materials are synthetic polymers derived from petroleum-based compounds. While their long-lasting nature makes them highly versatile, it also creates significant environmental challenges when disposal is mishandled.

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Fig 7: Waste Plastic Bottles & Disposal Glasses

The methodology employed in this study encompasses a thorough approach to assessing the potential advantages of integrating waste plastic into bituminous mixes for road pavements. The following steps outline the detailed methodology:

- Segregation - Plastic waste sourced from various outlets undergoes meticulous segregation to isolate it from other waste materials.
- Cleaning Stage – The separated plastic waste is thoroughly washed and dried to eliminate impurities, dirt, and moisture content.
- Shredding Stage – After cleaning, the plastic is cut or shredded into small, consistent fragments to ensure uniform mixing with bitumen.
- Collection Stage – Plastic particles that remain on a 2.36 mm IS sieve are carefully gathered for further treatment and use in the bituminous mix.

B. Testing of Materials

Various tests are performing in laboratory on both aggregate and bitumen to comprehensively characterize their properties. These tests include:

➢ *Test for Aggregate*

- Specific Gravity & Water Absorption Test
- Aggregate Crushing Value Test
- Flakiness & Elongation Index

➢ *Test for Bitumen*

- Ductility Test

C. Cubes Casting

➢ *Aggregate + Bitumen*

The cube casting procedure for bitumen and aggregate mixtures in a compressive test follows a structured methodology to evaluate strength and durability. a step-by-step breakdown:

- *Material Preparation*

✓ Collect bitumen, aggregates, and any additional stabilizers.
✓ Heat aggregates to around 170°C for proper bonding.
✓ Heat bitumen separately to 160-170°C and mix it with aggregates.

- *Mixing & Molding*

✓ Blend the bitumen-aggregate mixture thoroughly.
✓ Pour the mix into standard cube molds (typically 70mm x 70mm x 70mm).
✓ Compact the mix using a vibrating table or manual tamping.

- *Curing Process*

✓ Allow the cubes to cool and set for 24 hours.
✓ Cure the specimens under controlled conditions for 7days.

- *Compressive Strength Testing*

✓ Place the cube in a compression testing machine (CTM).
✓ Apply gradual load until failure occurs.
✓ Record the maximum load applied to the specimen.

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Fig 8: Cube Casting on Bitumen-Aggregate Mixture

- *Experimental Results:*

Table 3: Proportion of Aggregate & Bitumen

No.	1	2	3
Wt of Aggregate in Kg	6	6	6
Ratio of Bitumen in %	2	3	4
Wt. of Bitumen in gm	120	180	240
No. of Cubes	6	6	6

➢ *Aggregate + Bitumen + Plastic Waste*

The cube casting procedure for plastic-bitumen-aggregate mixtures in a compressive test follows a structured methodology to evaluate strength and durability. step-by-step breakdown:

- *Material Preparation*

✓ Collect plastic waste, bitumen, and aggregates.
✓ Clean and shred plastic into small pieces (typically 2.34 - 4.75mm).
✓ Heat aggregates to around 170°C and coat them with shredded plastic.
✓ Heat bitumen separately to 160-170°C & mix with plastic-coated aggregates.

- *Mixing & Molding*

✓ Blend the plastic-bitumen-aggregate mixture thoroughly.
✓ Pour the mix into standard cube molds (typically 70mm x 70mm x 70mm).
✓ Compact the mix using a vibrating table or manual tamping.

- *Curing Process*

✓ Allow the cubes to cool and set for 24 hours.
✓ Cure the specimens under controlled conditions for 7 days.
✓ Compressive Strength Testing
✓ Place the cube in a compression testing machine (CTM).
✓ Apply gradual load until failure occurs.
✓ Record the maximum load applied to the specimen.

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Fig 9: Cube Casting on Plastic-Bitumen-Aggregate Mixture

- *Experimental Results:*

Table 4: Proportion of Aggregate + Bitumen + Plastic Waste

No.	1	2	3
Wt of Aggregate in Kg	6	6	6
Ratio of Bitumen in %	2	3	4
Wt. of Bitumen in gm	120	180	240
Plastic Waste in % (by weight of bitumen)	5	6	7
Wt. of Plastic in gm (by weight of bitumen)	6	10.8	16.8
No. of Cubes	6	6	6

- *To Check a Compressive Strength*

Checking the compressive strength of bituminous concrete involves both laboratory and potential field testing methodologies. The most reliable results come from controlled laboratory tests on sample specimens. Shown in fig. 10.

Fig 10: Compressive Strength Check on Cube of Plastic-Bitumen-Aggregate Mixture

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- *Experimental Results on Wet & Dry Process:*

Table 5: Check Wet & Dry Process on Plastic, Bitumen & Aggregate

Bitumen content (%)	Plastic waste content (% - by wt of bitumen)	Wet Process		Dry Process	
		Peak Load (KN)	Compressive Strength (N/mm^2)	Peak Load (KN)	Compressive Strength (N/mm^2)
2	5	40.56	2.16	31.40	2.10
	6	41.34	3.54	32.15	2.65
	7	42.87	4.22	33.55	3.24
3	5	41.24	2.32	32	2.42
	6	42.04	3.74	32.80	3.11
	7	42.92	4.41	34.14	3.94
4	5	42.34	2.46	32.06	2.86
	6	43.76	3.96	33.23	3.46
	7	44.28	4.88	34.87	4.34

- *Comparison of the Results (This Research Paper Results and Other Research Paper Results)*

Table 6: Other Research Paper Result on Plastic, Bitumen & Aggregate

Bitumen content (%)	Plastic waste content (% - by wt of bitumen)	Wet Process		Dry Process	
		Peak Load (KN)	Compressive Strength (N/mm^2)	Peak Load (KN)	Compressive Strength (N/mm^2)
4.5	7	42.87	4.15	35.18	3.22
	8	43.52	4.72	36.36	3.48
	9	45.63	5.12	37.44	4.57
5.5	7	43.10	4.23	35.41	3.46
	8	44.16	4.85	36.41	3.76
	9	45.94	5.45	37.94	4.82
6.5	7	43.54	4.86	35.88	3.67
	8	44.53	5.32	36.97	4.13
	9	46.04	6.13	38.20	5.15

In above two results are weight and proportions to the near about same (table 5 & 6). The bitumen and plastic content (%) are use on less than proportion of (table 6) through such as result having quantity of ratio as compressive strength is near about same but the proportion is different. Hence, the results are different weight and proportion to be not useful the road construction

IV. CONCLUSION

➢ *From the Results the Following Conclusion has been Made:*

- The ductility of bitumen tends to decrease as the proportion of plastic waste increases, primarily due to the interlocking effect between the plastic and bitumen.
- As the plastic content in the coated aggregate rises, the aggregate's crushing value declines. However, this is accompanied by an improvement in overall stability.
- The compressive strength of bitumen mix increases by increasing percentage of bitumen as well as plastic.

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