Impact of Waste HDPE on Bitumen Properties

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Abstract -The rapid increase in plastic consumption, particularly High-Density Polyethylene (HDPE), has resulted in mounting environmental concerns due to its non-biodegradable nature. In parallel, the search for improved materials in road construction has led to growing interest in polymer-modified bitumen. This research investigates the influence of waste HDPE on the fundamental properties of bitumen with the aim of enhancing pavement performance while promoting sustainable waste management practices. Waste HDPE was blended with bitumen in proportions 3%, 6%, 9% and the modified samples were subjected to a series of conventional tests, including penetration, softening point and ductility assessments. The findings reveal that HDPE modification significantly alters the rheological behavior of bitumen, yielding a binder with increased stiffness, higher softening point, and reduced temperature susceptibility. These modifications suggest enhanced resistance to rutting and deformation under heavy traffic loads. The study underscores the dual benefit of utilizing plastic waste in road construction, mitigating environmental pollution and improving the longevity of flexible pavements.

***Key Words*:**high density polyethylene, modified bitumen, pavement, bitumen properties, waste plastic, conventional tests.

1.INTRODUCTION:

Plastic waste has become one of the most pressing environmental challenges of the 21st century. Among the various types of plastics, High-Density Polyethylene (HDPE) is widely used in packaging, containers, and household products due to its durability and chemical resistance. However, its extensive use has also contributed to the growing volume of non-biodegradable waste, which poses long-term risks to land and marine ecosystems. At the same time, the construction industry, particularly the sector focused on flexible pavement, is in constant search of innovative materials that can improve the performance and lifespan of roads.

In recent years, the construction industry has increasingly turned its focus toward sustainable practices, especially in road infrastructure, where the use of waste-derived materials has gained considerable attention. One material that has shown notable promise as a bitumen modifier is waste High-Density Polyethylene (HDPE). Widely used in everyday products such as plastic containers, bottles, and packaging, HDPE is durable and chemically resistant but these same characteristics also make it highly persistent in the environment. Its resistance to degradation has contributed significantly to the global plastic waste crisis, prompting the need for innovative reuse strategies.

Incorporating waste HDPE into bitumen offers a compelling dual benefit. It provides an effective solution for diverting plastic waste from landfills and incineration, while also enhancing the performance characteristics of asphalt. When processed correctly and blended with bitumen, HDPE can improve the material's resistance to high-temperature deformation and low-temperature cracking. These improvements stem from changes in the binder's viscoelastic behavior, resulting in pavements that are more durable and resilient under varying environmental and traffic conditions.

Beyond performance, HDPE-modified bitumen displays reduced sensitivity to temperature fluctuations, improved resistance to aging, and superior load-bearing capacity. These traits make it particularly suitable for road networks exposed to heavy traffic and harsh climates. Moreover, the extended lifespan of such pavements translates into lower maintenance requirements and long-term cost savings. From an economic and environmental perspective, the reuse of waste HDPE in asphalt production aligns well with circular economy principles. It reduces the dependency on virgin materials, cuts down manufacturing costs, and helps curb the environmental impact of road construction. By integrating waste into infrastructure, this approach supports broader goals of pollution reduction and sustainable development.

The application of HDPE-modified bitumen thus represents more than just a technical advancement it reflects a shift toward more responsible and future-ready engineering solutions. As the demand for durable, eco-friendly transportation infrastructure continues to grow, embracing such materials could play a vital role in shaping the roads of tomorrow. This study focuses on the incorporation of waste HDPE into bitumen and investigates its effect on key physical properties such as penetration, softening point and ductility. By analyzing the performance of HDPE modified bitumen, the research aims to contribute to sustainable infrastructure development while simultaneously offering a solution for plastic waste management.

2. MATERIALS AND TESTS:

2.1 Materials:

a)Bitumen: Bitumen is a dense, black, and semi-solid hydrocarbon product obtained during the distillation of crude oil. It is extensively used as a binder in flexible pavement construction due to its adhesive and waterproofing properties. While bitumen performs well under standard conditions, it is highly sensitive to temperature variations. At elevated temperatures, it becomes soft and susceptible to permanent deformation, whereas at lower temperatures, it may crack due to brittleness. These performance limitations have led to the development of bitumen modification techniques aimed at improving its behavior under varying environmental and traffic conditions.The bitumen used in study is of 60/70 penetration grade.

b) High density polyethylene (HDPE):

High-Density Polyethylene (HDPE) is a widely used thermoplastic polymer valued for its strength, stiffness, and chemical resistance. It is commonly found in consumer products such as plastic bottles, food containers, and packaging films. Due to its resistance to biodegradation, HDPE waste accumulates in landfills and poses serious environmental challenges. Recycling HDPE into construction materials offers a promising solution by reducing waste and conserving resources.When HDPE is blended with bitumen, it influences the binder's physical properties, enhancing its stiffness and resistance to temperature-induced damage. This modification can improve the pavement’s ability to withstand heavy traffic loads and adverse weather, ultimately leading to longer-lasting road surfaces. Moreover, the incorporation of waste HDPE into bituminous mixtures contributes to sustainable construction practices by repurposing plastic waste for infrastructural applications. For this study the source of HDPE was waste used cement bags collected directly from construction sites.

2.2 Tests:

a)Penetration test: (IS 1203-1978)

The penetration test is a standard procedure used to assess the hardness or consistency of bitumen by measuring the depth to which a standard needle penetrates the sample under specific conditions. In this test, a needle is allowed to vertically penetrate a bitumen sample for five seconds under a load of 100 grams at a temperature of 25°C. The depth of penetration is expressed in tenths of a millimeter. A lower penetration value indicates a harder grade of bitumen, while a higher value suggests a softer binder. This test helps determine the suitability of bitumen for various climatic and traffic conditions, as the consistency directly influences the pavement's ability to resist deformation under load.

Fig 1: Penetration test

b)Ductility test:(IS 1208-2023)

The ductility test measures the bitumen’s ability to stretch without breaking, which reflects its flexibility and adhesive characteristics. In this test, a standard-sized sample of bitumen is molded and then stretched at a uniform speed and temperature 25°C in a ductility testing machine. The distance the bitumen can be elongated before it breaks is recorded in centimeters. A higher ductility value indicates that the bitumen can better withstand thermal and traffic-induced stresses without cracking, making it especially important in colder regions where flexibility is critical.

Fig 2:Ductility test

c)Softening point test:(IS 1205-2022)

The softening point test is used to determine the temperature at which bitumen transitions from a solid to a semi-liquid state. This property is crucial for evaluating how the material will behave under elevated temperatures. The test involves heating bitumen samples in a controlled environment using the Ring and Ball method. Steel balls are placed on top of bitumen disks within brass rings, and the temperature is gradually increased. The softening point is recorded as the temperature at which the softened bitumen allows the ball to fall through a specified distance. Bitumen with a higher softening point is generally preferred in warmer climates, as it offers better resistance to rutting and flow.

Fig 3:Softening point test

d)Flash and fire point test:(IS 1209-2021)

The flash and fire point test determines the temperature at which bitumen emits vapors that can momentarily ignite (flash point) and the temperature at which it sustains continuous combustion (fire point). These properties are essential for ensuring safe handling and storage of the material. The test is carried out by gradually heating a sample of bitumen in an open cup and passing a test flame over its surface at regular intervals. The flash point is the lowest temperature at which a flame causes a brief ignition, while the fire point is when the material sustains burning for several seconds. High flash and fire points indicate better thermal stability and safety during heating and application processes.

Fig 4:Flash and fire point test

2.3 Sample preparation:

- Bitumen of 60/70 penetration grade was used and for HDPE waste cement bags which was collected directly from construction sites were used.
- The collected cement bags were then shredded.
- After hat the bitumen sample was heated till it gets in its liquid state and then the shredded HDPE material was added at the required proportion.
- The proportion used was 3%,6% and 9% by weight of bitumen.

Fig 5:Shredded HDPE sample

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 04 | April - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

Fig 6:Sample preparation

3.RESULTS:

All the tests were conducted as he Indian Standard and the results of all the conducted test on modified bitumen are as mentioned in table below.

a)Penetration test results:

HDPE %	SAMPLE	RESULTS (dmm)			AVERAGE RESULT (dmm)
0	Sample 1	58	63	65	62
3	Sample 2	48	53	55	52
6	Sample 3	38	41	44	41
9	Sample 4	28	31	34	31

Table -1: Penetration test results

b)Ductility test results:

HDPE %	SAMPLE	RESULTS (cm)			AVERAGE RESULT (cm)
0	Sample 1	66	69	72	69
3	Sample 2	54	58	62	58
6	Sample 3	42	45	48	45
9	Sample 4	26	28	30	28

Table -2: Ductility test results

c)Softening point test results:

HDPE %	SAMPLE	RESULTS (degree celsius)			AVERAGE RESULT (degree celsius)
0	Sample 1	48	52	56	52
3	Sample 2	55	57	59	57
6	Sample 3	59	61	63	61
9	Sample 4	65	69	70	68

Table -3: Softening point test results

d)Flash and fire point test:

HDPE %	SAMPLE	FLASH POINT RESULTS (degree celsius)			AVERAGE RESULT (degree celsius)
0	Sample 1	90	94	95	95
3	Sample 2	113	115	117	115
6	Sample 3	151	153	155	153
9	Sample 4	175	177	179	177

Table -4: Flash point test results

HDPE %	SAMPLE	FIRE POINT RESULTS (degree celsius)			AVERAGE RESULT (degree celsius)
0	Sample 1	109	113	114	112
3	Sample 2	131	135	136	134
6	Sample 3	165	170	169	168
9	Sample 4	221	223	225	223

Table -5: Fire point test results

4. CONCLUSIONS

The incorporation of waste HDPE into bitumen resulted in noticeable improvements in critical performance parameters, particularly an increase in binder stiffness. These changes suggest enhanced resistance to deformation, making the material better suited for pavements subjected to high temperatures and heavy vehicle loads. One of the most significant outcomes was the improved thermal stability of the modified bitumen, which directly contributes to greater durability and reduced maintenance needs. Beyond technical advantages, this approach addresses environmental concerns by providing a practical use for discarded plastics. Converting HDPE waste into a valuable component for bitumen modification supports both sustainable waste management and the broader goals of a circular economy in the construction sector.

ACKNOWLEDGEMENT

None

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