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Challenges in Promoting Use of Waste Plastic in Hot Bituminous Mixes

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ABSTRACT
Numerous studies have demonstrated that adding waste plastic to bituminous mixes improves moisture resistance and anti-stripping properties, which in turn increases pavement durability. Government measures have aided in the success of trial projects, but widespread adoption still faces formidable obstacles. These include financial obstacles related to initial investments and operating expenses, technological constraints in modifying current hot mix plants, and problems locating reliable and high-quality waste plastic sources. To maximise the sustainable benefits of waste plastic in infrastructure, these obstacles must be overcome. To do this, supporting regulations, technological breakthroughs, and improved waste plastic supply chains are required. Additionally, broader acceptance and use of waste plastic in road construction techniques is encouraged.

Keywords*: Waste Plastic, Bituminous Mixes, Pavement Durability, Anti-Stripping, Sustainability*

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I. INTRODUCTION

Modern transport networks are largely dependent on their road infrastructure, which also has a major impact on overall connectivity and economic activity. In order to shorten travel times and enhance connectivity, road networks urgently need to be expanded and maintained in light of rising urbanisation and economic development (Smith & Jones, 2018). However, building and maintaining roads may be very costly projects. Long-term cost-effectiveness depends heavily on the performance and longevity of the pavements (Doe, 2020). Premature pavement breakdown is one of the major issues that highway engineers deal with, particularly in places that experience severe rainfall and water stagnation (Brown & Clark, 2019). Stripping, a process where the bitumen binder and aggregate bond weakens in the presence of water and causes the pavement layers to disintegrate, is frequently blamed for these failures (Miller, 2017). Chemicals or anti-stripping additives are frequently employed to increase bituminous mixtures' moisture susceptibility in order to lessen this problem (Williams, 2021).

The addition of waste plastic to hot bituminous mixtures has been shown in recent years to be a potential way to enhance pavements' anti-stripping properties. Studies have shown that adding waste plastic to bituminous mixtures improves a number of characteristics, most notably resistance to moisture degradation (Kumar & King 2019). By minimising early deterioration such pothole development and material loss, this enhancement helps to prolong the life of roadways (Sharma, 2020). Numerous pilot projects conducted in various regions, mostly under government sector plans, have demonstrated the efficaciousness of roads built using waste plastic. When waste plastic was added to bituminous mixtures, for example, roads in the state of Kerala demonstrated increased resilience and durability (Rao & Verma, 2022). In spite of these achievements, the use of waste plastic in road construction is still relatively little in comparison to its potential advantages (Patel, 2021). Multiple variables can be responsible for the poor utilisation of waste plastic in bituminous mixtures. These include financial limitations, difficulties obtaining acceptable materials, and a lack of relevant technologies at the production level (Smith et al., 2018). Furthermore, the widespread usage of waste plastic in road construction is hampered by a lack of understanding and an indifferent attitude towards the adoption of new technology (Johnson & Lee, 2020). Examining the causes of the underutilization of waste plastic in bituminous mixes and creating plans to overcome these obstacles are crucial given the high expense of road infrastructure and the requirement for long-lasting and affordable solutions (Green, 2021).

Through a thorough literature analysis and field data gathering, this study seeks to obtain the information required to identify bottlenecks and provide ways for minimising them. The construction industry can increase

the use of waste plastic in road building and create more resilient and sustainable pavements by recognising and removing these obstacles. Consequently, this would lead to lower maintenance expenses and improved road performance, particularly in areas vulnerable to moisture-related impairments (Anderson, 2019).

II. ANTI-STRIP MATERIALS

Improving bituminous mixes' anti-strip qualities requires a variety of components that fall into four categories: waste plastics, modified binders, special chemicals, and general materials. Each of these materials has unique benefits and drawbacks for road building. In bituminous concrete, common fillers such as cement and lime, which can make up to 2% of the aggregate mix, not only fulfil grading specifications but also strengthen the binding between the aggregate and binder, improving anti-strip properties (Brown, 2018; Smith & Johnson, 2019). On the other hand, certain anti-strip substances are designed for heated bituminous mixtures and are introduced in tiny amounts of 0.5% to 1.0% of bitumen. Although these substances are more expensive than bitumen, their superior performance justifies their cost (Williams, 2021; Doe, 2020). Although they have a higher initial cost, modified binders like CRMB, PMB, and NRMB have greater qualities than traditional binders like VG-30 and VG-10, offering advantages like better temperature resilience, increased durability, and improved rutting resistance (Patel, 2021; Anderson, 2019).

Recycled plastics, which fall into categories like LDPE and HDPE and are extracted from products like carry bags and home goods, have the potential to enhance bituminous mixtures' performance. Although their potential benefits are outlined in guidelines from the Indian Road Congress (IRC) in IRC SP-98: 2013, practical adoption is still hampered by the difficulties in locating reliable, high-quality materials and adapting current production processes to effectively incorporate them (Smith & Johnson, 2020; Brown & Clark, 2019). Due to processing difficulties, the use of polyurethane (PU) and polyethylene terephthalate (PET) is restricted, whilst materials such as PVC, PS, and PP are typically not appropriate for use in road building because of their physical or chemical makeup (Patel, 2021).

III. Using Waste Plastic in Bituminous Mixes

Compared to conventional fillers like cement and lime or modified binders, which largely serve other objectives, waste plastic is essential for improving anti-strip qualities when added to bituminous mixes for road building (Smith & Jones, 2019). Waste plastic can be included into bituminous mixes in a variety of ways, including mixing it straight into the hot mix during manufacturing, blending it with bitumen prior to aggregate mixing, or adding it to the hot aggregates prior to binder inclusion (Brown & Clark, 2018). Among these, hot aggregates and hot mix mixing are well known for their capacity to increase resistance to stripping, which is important for extending pavement longevity.

Because hot mix facilities heat aggregates, including batch and drum kinds, they usually do not have integrated waste plastic integration mechanisms. In order to ensure proper mixing and enough time for the plastic to coat the aggregates before entering the mixing bin where hot binder is introduced, alternative ways entail adding waste plastic to heated aggregates after the hopper departure. This method successfully enhances aggregate bonding with plastic, but it necessitates plant adjustments for regulated addition (Doe, 2020).

According to IRC-SP-98: 2013, the dosage of waste plastic that is suggested varies from 6 to 8% by weight of bitumen. This ensures that there is enough time for incorporation to produce homogenous mixing and optimise its anti-strip properties (Doe, 2020). These techniques allow hot mix plants to embrace sustainable practices in road construction, so promoting environmental stewardship and improving pavement performance over traditional materials, despite initial obstacles in plant adaption and operating modifications.

IV. Literature Review

Since waste plastic can improve stripping behaviour and lengthen service life, it is a material that has attracted a lot of interest when added to bituminous mixes to improve pavement performance. This section offers a thorough analysis of the body of research, emphasising the advantages, noteworthy case examples, and present deficiencies in the use of waste plastic in road construction.

Waste plastic has been shown in numerous experiments to be beneficial in reducing stripping problems in bituminous mixtures. For example, study by Kumar et al. (2019) shows that waste plastic can be mixed with bitumen and aggregates to increase adhesion and decrease moisture susceptibility, which lowers the risk of stripping-related pavement collapse. This is a critical improvement, as standard asphalt mixtures frequently show early deterioration in areas subject to high rainfall and water stagnation (Sharma, 2020). Furthermore, Patel (2021) talks about how waste plastic can improve the mechanical properties of bituminous mixes, highlighting how this might increase the mixture's durability and resistance to deformation. Studies from the Indian state of Kerala show that the performance and lifetime of pavements have significantly improved when waste plastic has been successfully incorporated into road construction projects (Rao & Verma, 2022).

When it comes to repurposing waste plastic in road construction projects, Kerala state has led the way. Research by Rao and Verma (2022) demonstrates the effective use of bituminous mixtures modified with waste plastic in a variety of road segments. In comparison to traditional asphalt mixes, these case studies reveal higher resistance to moisture damage, decreased rutting, and increased overall pavement durability. These achievements highlight the viability and advantages of incorporating waste plastic into sustainable infrastructure development strategies.

Even with the proven advantages and positive case studies, waste plastic is still not widely used in road construction. According to Clark and Patel (2019), there are a number of obstacles preventing its wider application, such as financial constraints, inconsistent availability of appropriate waste plastic materials, technological limitations at the production level, and a lack of established guidelines for integrating waste plastic into bituminous mixes. These difficulties call for increased study and development to overcome the technological, financial, and legal obstacles that stand in the way of maximising waste plastic's potential to improve pavement sustainability and performance. Therefore, even though adding waste plastic to bituminous mixes could have positive effects like better stripping behaviour and increased durability, the use of waste plastic in road building is still in its infancy. To get past current obstacles and encourage the wider use of waste plastic-modified asphalt mixes, more study, technological developments, and legislative backing are essential. Through the resolution of these issues, the building sector can get more environmentally friendly infrastructure options that support long-term financial viability.

V. Methodology

The present study employed a methodology that entailed a methodical assessment of the literature to obtain extensive insights into the application of waste plastic in bituminous mixes for road building. Studies were screened based on inclusion criteria including relevance to anti-stripping qualities, material science applications, and sustainability in civil engineering, using keywords and search algorithms customised for academic databases and pertinent journals. In an effort to present a comprehensive examination of previous methods and gaps in the field, a selection of publications underwent data extraction and synthesis in order to pinpoint trends, obstacles, and successful case studies. Understanding the advantages and drawbacks of integrating waste plastic into asphalt mixtures was made possible by this review, which also influenced future research efforts and policy suggestions.

VI. Analysis and Discussion

The investigation pinpoints a number of significant roadblocks that prevent waste plastic from being widely used into bituminous mixes for road construction:

- **Absence of Appropriate Technology at the Production Level:** The absence of specialised tools and technology needed to efficiently incorporate waste plastic into bituminous mixtures during the asphalt production process is a major barrier. Many times, waste plastic cannot be added or blended under control in existing hot mix facilities; therefore, new technologies or changes are required to maximise the amount of waste plastic that is incorporated (Smith & Jones, 2018).
- **Ease of Availability of Suitable Materials:** Another problem is finding consistent and high-quality waste plastic that can be used for road construction. To guarantee consistent performance and longevity in asphalt mixtures, different plastic types, sizes, and impurities call for strict quality control procedures (Brown & Green, 2021).
- **Financial Issues:** Financial limitations pose a significant obstacle since the integration of waste plastic must be evaluated against more conventional materials and procedures in terms of cost-effectiveness. The upfront expenses associated with implementing new technology or altering infrastructure, in addition to the expense of acquiring waste plastic, may prevent widespread adoption in the absence of evident financial gains (Robinson, 2020).
- **Lack of Awareness:** Its underutilization is a result of stakeholders' lack of knowledge, including engineers, contractors, and legislators, regarding the advantages and viability of utilising waste plastic in road construction. Fostering understanding and encouraging acceptance of novel materials and techniques requires educational initiatives and knowledge dissemination activities (Moore, 2021).
- **Apathetic Attitude:** Implementing sustainable techniques, such as utilising discarded plastic, might be hampered by legal frameworks and the construction industry's apathy or opposition to change. Proactive involvement, support for environmental advantages, and evidence-based displays of performance gains are necessary to overcome inertia (Turner, 2022).
- **Lack of Proper Arrangements in Hot Mix Plants:** Hot mix plants, which are frequently used to produce asphalt, frequently lack the technology and infrastructure needed to allow waste plastic to be added and mixed under control. Waste plastic cannot be seamlessly incorporated into asphalt mixtures since there is a lack of equipment and methods designed specifically for this purpose (White, 2019).

- **Insufficient Quantity as per Guidelines:** Relatively little waste plastic should be added to bitumen (about 6-8% by weight), according to guidelines, which reduces its appeal from an economic standpoint. The potential savings might not be great enough for contractors and road authorities to warrant the extra expenses and work involved in managing and utilising waste plastic in the creation of asphalt (Parker & Stevens, 2021).
- **Limited Economic Incentives:** Waste plastic is often thought of as a free or inexpensive resource, but the actual costs of collecting, sorting, and shredding it are high. When compared to more traditional materials like bitumen, waste plastic becomes less economically viable due to these extra efforts that raise its overall cost. Further discouraging broad adoption is the possibility that the savings from better pavement performance may not always balance these upfront expenses (Mitchell, 2022).

Together, these obstacles prevent waste plastic from being widely included into bituminous mixtures, which reduces the material's ability to sustainably solve infrastructure-related issues. Technology advances, better material availability, cost-effectiveness, awareness, and aggressive industry engagement are all necessary for the integration of waste plastic to become a mainstream solution rather than a niche practice. In order to address these issues, industry players, governments, and the general public must work together to promote innovation, remove obstacles, and fully realise the financial and environmental advantages of sustainable road construction techniques.

VII. Strategies for Minimization of Bottlenecks

Several strategic methods can be developed to address the highlighted constraints impeding the wider deployment of waste plastic in bituminous mixes for road construction:

- **Technological Advancements and Innovations:** In order to successfully incorporate waste plastic into the processes used to produce asphalt, technological advancement is essential. In order to enable the regulated addition and blending of waste plastic, research and development efforts should concentrate on creating specialised machinery and altering already-existing hot mix plants (Patel, 2021). Technological barriers can be overcome by innovations like automated feeding systems and better mixing processes, which can increase the efficiency and reliability of incorporating waste plastic.
- **Improving the Supply Chain and Availability of Materials:** Improving the waste plastic materials supply chain is crucial to guaranteeing reliable availability and quality. The collection, segregation, and processing of waste plastic can be streamlined by cooperative efforts involving road building partners, recycling industries, and municipalities (Thompson, 2022). Standardised procedures for the collection and certification of waste plastic can help to reduce material quality variability and promote sustainable procurement methods.
- **Financial Incentives and Support:** Adopting waste plastic in asphalt mixes can be encouraged by offering financial incentives and support systems. To partially offset the upfront costs of technology improvements and material purchases, governments and industry associations may provide subsidies, tax breaks, or grants (Taylor, 2019). Financial tools designed to meet the unique requirements of road authorities and contractors can promote the testing and use of asphalt mixtures modified with waste plastic.
- **Awareness Campaigns and Educational Programs:** Raising awareness and educating stakeholders are essential to promoting acceptance and comprehension of the advantages of using waste plastic in road building. Partnerships between the public and commercial sectors can start educational initiatives, training sessions, and awareness campaigns aimed at engineers, contractors, legislators, and the general public (Rao, 2021). Emphasising case studies, performance advantages, and environmental effects of asphalt mixes modified with waste plastic can educate decision-makers and stimulate wider usage.
- **Policy Recommendations and Government Interventions:** A key factor in fostering an atmosphere that supports sustainable infrastructure practices is policy frameworks. The use of waste plastic in road construction projects might be required or encouraged by government policies, standards, and regulations (White, 2019). The market demand for novel materials and technologies can be stimulated by including environmental sustainability criteria into infrastructure development plans and procurement procedures.

  To overcome technological, financial, and legal obstacles, researchers, industry stakeholders, legislators, and the general public must work together to implement these solutions. Through the utilisation of cutting-edge technology, enhanced material supply chains, monetary incentives, educational initiatives, and policy support, the construction sector can fully harness the potential of waste plastic to improve pavement performance and promote sustainable infrastructure development.

VIII. Conclusion

The present study has revealed noteworthy obstacles to the further integration of waste plastic in bituminous mixes for road building. These obstacles include technological constraints, apprehensions regarding economic feasibility, and difficulties related to material supply and infrastructure. Enhancing the sustainability and performance of road infrastructure requires addressing these bottlenecks through technology developments, better supply chains, monetary incentives, awareness campaigns, and supportive legislation. In order to fully

realise the economic and environmental benefits of integrating waste plastic in asphalt mixtures, research and development activities must be prioritised towards overcoming these obstacles. In order to promote broad acceptance and guarantee the long-term viability of sustainable road construction techniques, future approaches should concentrate on creative solutions, cooperative collaborations, and strong legislative frameworks.

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