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SUSTAINABLE PAVEMENT CONSTRUCTION: A COMPREHENSIVE OVERVIEW OF WASTE PLASTIC UTILIZATION IN BITUMINOUS MIXTURES

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ABSTRACT

The integration of waste plastic in bituminous road construction has emerged as a promising strategy to address environmental challenges while enhancing pavement performance. This paper presents a comprehensive review of existing literature on the utilization of waste plastic modifiers in bituminous mixtures, focusing on methodologies, findings, and implications for sustainable infrastructure development. A systematic analysis of experimental approaches reveals diverse methodologies employed for sample preparation, testing procedures, and performance evaluations. Performance characteristics, including stability, durability, aging resistance, rutting, and fatigue, are extensively evaluated across studies. The impact of varying percentages of waste plastic content on bituminous mixture properties is analyzed, highlighting the influence of plastic-type and content on asphalt performance. Despite encountering challenges such as optimal plastic composition, the literature underscores promising avenues for future research aimed at enhancing sustainability and performance in road construction. By synthesizing insights from a range of studies, this review offers valuable guidance for advancing the utilization of waste plastic in bituminous road construction, paving the way toward greener, more resilient infrastructure solutions.

Index Terms: Waste plastic, Environmental challenges, Performance, Sustainability, Resilient Infrastructure.

INTRODUCTION

In contemporary society, the pervasive issue of plastic pollution has prompted a dire need for innovative solutions to mitigate environmental degradation while addressing infrastructure demands. Plastics, ubiquitous in daily life, present a significant challenge due to their non-biodegradable nature, persisting in the environment for millennia. Disposal methods, predominantly landfilling and incineration, exacerbate environmental degradation and pose health risks. In this context, repurposing waste plastic as a resource for bituminous road construction emerges as a promising avenue for sustainable infrastructure development.

Bituminous road construction, a cornerstone of modern transportation infrastructure, continually evolves to meet increasing demands for durability, performance, and cost-effectiveness. Traditional bituminous mixtures, comprising bitumen binder and aggregate materials, are indispensable for road pavement construction. However, the incorporation of waste plastic as a modifier in bituminous mixtures presents an opportunity to enhance road performance while addressing plastic waste management challenges.

This research paper explores the advancements and potential of integrating waste plastic into bituminous mixtures for road construction. Drawing upon a comprehensive review of literature, this study examines various methodologies, experimental techniques, and performance evaluations employed in previous research endeavors. The focus lies on elucidating the effects of incorporating different types and proportions of waste plastic, such as polyethylene terephthalate (PET), high-density polyethylene (HDPE), and low-density polyethylene (LDPE), on the rheological, physical, and aging characteristics of bituminous binders.

Through an in-depth analysis of experimental findings and methodologies, this paper aims to delineate the optimal conditions for integrating waste plastic into bituminous mixtures to enhance road performance and sustainability. The discussion encompasses critical insights into the effects of plastic content, binder modification techniques, and environmental considerations on the mechanical properties and longevity of bituminous pavements.

Furthermore, this research underscores the imperative of adopting sustainable practices in road construction, emphasizing the role of waste plastic utilization as a means to achieve environmental stewardship and resource efficiency. By elucidating the benefits, challenges, and future prospects of incorporating waste plastic in bituminous road construction, this study contributes to the discourse on sustainable infrastructure development and waste management strategies.

METHODOLOGY

The methodology involved in this research comprised conducting an extensive literature review to collect relevant studies on the incorporation of waste plastic into bituminous mixtures for road construction. Through systematic searches of academic databases and journals, key information regarding experimental methodologies, sample preparation techniques, and performance evaluations of bituminous mixes with varying types and percentages of waste plastic additives was extracted. The synthesized data were then analyzed to identify trends, patterns, and limitations across different studies, focusing on parameters such as plastic type, content, binder modification techniques, and evaluated performance characteristics. Comparative analysis was utilized to assess the efficacy of various methodologies in evaluating the impact of waste plastic on the rheological, physical, and aging properties of bituminous binders. This methodological approach aimed to provide a comprehensive understanding of experimental techniques employed in studying waste plastic utilization in bituminous road construction, facilitating insights into its implications for sustainable infrastructure development.

LITERATURE STUDY AND DISCUSSION

Mashaan, N. S. et al. (2022) explored the consequences and potential of employing waste plastic as a practical and sustainable polymer to enhance bitumen binders [1]. Their goal was to improve bitumen binders. Recycled plastics such as polyethylene terephthalate (PET), high-density polyethylene (HDPE), and low-density polyethylene (LDPE) are used in this modification. Through this alteration, an effort is being made to strengthen the rheological, physical, and aging resilience of the binders. Rolling thin film oven tests (RTFOT) and pressure aging vessels (PAVs) are utilized for both short-term and long-term aging in order to ascertain the modified binder's resistance to wear and tear as well as its ability to withstand the effects of aging. The complex shear modulus, elasticity, stiffness, and viscous characteristics were investigated and evaluated with the use of dynamic shear rheometer (DSR) testing and penetration tests. According to the results of the penetration tests that were carried out both before and after the material was aged, the optimal levels of HDPE and LDPE content for optimal performance are 2% and 4%, respectively. Greater contents, like 6% and 8% HDPE and LDPE, do not noticeably contribute to an increase in the material's stiffness, elasticity, or resistance to aging. As a consequence of this, HDPE and LDPE samples whose composition is between 6 and 8% are more likely to undergo long-term deformation. When used in conjunction with up to 8% PET-used bitumen, recycling PET results in observable improvements to the material's physical qualities, rheological properties, stiffness, and elasticity, as well as its resilience to the effects of aging. According to the findings, the optimal type and percentage of PET waste plastic is between 6 and 8%.

In the year 2021, **Mashaan, N. S. et al. (2021)** waste plastic polymer in the asphalt [2]. Bitumen, aggregate, and waste plastic were the three components that were utilized during the experiment. The various elements of PET-modified bitumen under-aged and unaged circumstances are assessed in two processes. The fatigue, rutting, and aging of bitumen binder were investigated using the Rolling Thin Film Oven (RTFOT), Dynamic Shear Rheometer (DSR), and Pressure Aging Vessel (PAV). The results show that the presence of 6-8% of plastic waste is required to ameliorate aging and rutting counteraction. Additionally, 8% PET improves fatigue crack resistance. Pavements made of locally sourced plastic reduce expenses while also improving the sustainability of the environment and natural resources.

Sharma et al. (2018) conducted research to determine whether or not a bituminous pavement mixture that included recycled plastic was effective [3]. As a mineral infill, we used crushed basalt of the coarse aggregate type with a particle size of 20 millimeters, crushed basalt of the fine aggregate type with a particle size of 2.36 millimeters or less, 80/100 penetration grade bitumen, crushed basalt stone dust, and cement. While the pulverized forms of waste plastics such as polyethylene terephthalate (PET), polypropylene (PP), polystyrene (PS), and polyvinyl chloride (PVC) were utilized. Marshall Stability experiments were carried out utilizing various quantities of plastic waste to evaluate the combination's stability. Later, the results of plain BC mix and BC (bituminous concrete) mix with waste plastic were compared. The stability value of the optimal plastic content, or OPC, was thus determined to be 30.1, which was much higher than the stability value of the ideal bitumen content, or OBC. It was found that the BC mix including plastic waste contained fewer voids than the conventional BC mix. These results complied with MORT&H-2001 specifications. The research discovered that bitumen and waste plastic intermolecular binding increases the strength, longevity, and stability of roadways and that the OPC mix was more stable than the OBC mix.

Sarma and Srikanth (2018) included pieces of polythene in their bituminous pavement mixture [4]. This scrap polythene was used. Bitumen, aggregate, and waste plastic were the three components that were utilized during the experiment. The Marshall test was done twice to obtain accurate readings for the ideal bitumen content (OBC) and the ideal plastic content (OPC). The bitumen, aggregates, and plastic were mixed in a variety of ways to create the various samples. The OBC was then checked using a test at 60 °C, and it was found to be 5.8%. Later, OPC was computed inside the milk packets that had been thrown away. The specific gravity and softening point readings were listed as being around 0.92 and 115°C, respectively, in a report that the milk package's manufacturer submitted. The results indicated that 10% plastic content would offer the most stability. It was established that the maximum bulk specific gravity was equal to 7.5% of the binder content. The averaging of the aforementioned figures produced a result of 8.75%. The OBC was 5.8% and the OPC was predicted to be 8.75% based on test results. In comparison to bituminous mix as a whole, it was shown that adding plastic trash increases bitumen's stability.

The plastic rubbish that was used as the source material for the modified bituminous binders that were the subject of the research conducted by **Tiwari et al. (2018)** [5]. During the course of the experiment, we made use of bitumen that had a grade of 60/70 in addition to LDPE plastic garbage that had been shredded to a level of depth that measured 2.36 millimeters. Bitumen that had been changed by melting at a temperature of 150 degrees Celsius was used to coat pieces of low-density polyethylene (LDPE) that ranged in size from 2.36mm to 4.75mm. The temperature of the melting bitumen was 150 degrees Celsius. Experiments have been carried out addressing the ductility, point of softening, and penetrability of modified bitumen. According to the findings of the experiment, the presence of LPDE waste resulted in a 19.4 percentage point decrease in the penetration value of plastic-modified bitumen. Additions of 2% and 4% plastic increased strength and load-bearing capability, with penetration values of 65mm and 62mm, respectively. Bitumen with plastic added has its ductility decreased by roughly 21.79 percent. The ductility grade of plastic dropped from 75 cm to 61 cm for every 2% to 10% increase. The invention of plastic led to an 18.6-degree increase in the softening point value. The results showed that the softening point was raised to 49°C and 52°C, respectively, when 2% and 4% plastic were added. The study revealed that plastic trash with a percentage of 2% to 4% was used to generate penetration values and softening points that met the requirements of the IS regulation (IS-1203-1978). Through the addition of 2% to 4% plastic, a higher softening value of 52°c was achieved, which assisted in the withstanding of increased temperature susceptibility. The introduction of plastic particles slowed down the aging process of the bituminous mixture, as well. It has been proved that increasing the percentage of recycled plastic in a modified bituminous mix results in an increase in the road's lifespan.

Ghalayan and Rana (2017) used plastic waste in bituminous concrete to partially replace the bitumen [6]. In this investigation, bitumen of penetration grades 60 and 70, aggregates, and plastic garbage were all used as materials. The report claims that garbage was appropriately collected from various sources and cleaned to remove any contaminants. After that, scrap plastic was cut into little pieces ranging in size from 2.36 mm to 4.75 mm because they mix more easily and produce better results. After that, plastic waste was put into the heating chamber and heated to a temperature of 160 degrees Celsius so that it could coat the aggregates as they were being heated. After that, bitumen was added, and the mixture was baked at the same temperature for the same amount of time. Several experiments, such as an impact value test, a ductility test, and a marshall stability test, were carried out in accordance with the appropriate protocols and with varying percentages of plastic samples. These tests were carried out. According on the test results, this study draws the conclusion that including more waste plastic in mix designs improves the strength and aggregate properties.

In a recent study, **Kumar and Vikranth (2017)** investigated the utilization of polypropylene (PP) waste in flexible pavements. Bitumen, waste plastic, and aggregates were employed in this investigation [7]. Tests were done to compare bitumen and bitumen mixed with plastic trash, as well as regular aggregate and aggregate coated with plastic. The plastic coating increased the quality of the aggregate and reduced water absorption, as evidenced by the greater specific gravity value of the plastic-coated aggregate compared to the uncoated aggregate in a water absorption test. The plastic coating increased aggregate impact value. Since the aggregate crushing value for plastic-coated aggregate was lower, it could support a greater load. The Los Angeles abrasion test revealed that plastic-coated aggregates had less wear and tear, indicating a longer life. Bitumen's penetration was reduced when plastic was included. The softening value grew as the plastic content did. In comparison to regular bitumen, plastic-coated bitumen has a low viscosity value. The penetration of the bitumen was decreased when plastic was added. As the percentage of plastic grew, the softening value increased as well. According to the study, the appropriate level of plastic waste addition was between 9 and 10% by weight. Plastic trash was mixed with bitumen and aggregate, which improved the qualities of both substances. The cost of making flexible pavements was also reduced because the amount of bitumen required was cut by 9-10%. It's also a useful strategy for preserving the environment.

Research on the utilization of discarded plastic materials in the building of roads was carried out by **Shaikh et al. (2017)** [8]. Bitumen 60/70, aggregates, cement, and particles of plastic rubbish that were 2.36 millimeters in size were the components of the study that were included in it. Both the modified and unmodified versions of the bituminous mixture were subjected to the Marshall stability test. The Los Angeles abrasion test, aggregate impact value test, water absorption test, specific gravity test, and stripping value test were conducted. The ductility, flashpoint, fire point, and softening point of bitumen were all measured during the testing process. After that, the Marshall stability test was modified such that it also included waste plastic. The specific gravity increased from 2.5 to 2.66 and 2.77 following the addition of 10% and 15% of plastic material, respectively. The addition of 15% plastic resulted in a decrease in the total impact value, which went from 10.79% to 8.94%. The abrasion value in Los Angeles declined from 12.85% to 10.65% when an additional 15% of plastic garbage was added. The addition of 15% plastic trash resulted in a reduction of the water absorption value to 1.1%, while it resulted in a reduction of the stripping value to 0%. The flow value at plastic waste grew from 3.1 millimeters to 5 millimeters, and the marshall stability value increased from 950 kilograms to 1980 kilograms as the weight of bitumen increased. According to the findings of the investigation, the altered mixture improved the marshall properties. Marshall's flow value fell as a result of the addition of plastic trash, which enabled it to support large loads, boost road longevity, and preserve the environment.

Road construction using recycled plastic was also the subject of research by **Trimbakwala (2017)** [9]. The study used bitumen and aggregate as its ingredients. 8% plastic trash was added to the bitumen weight on the conveyor belt to adequately coat the plastics. Various amounts of plastic (0–12% by weight of bitumen) were added to heated bitumen using the Marshall method. Both modified and unmodified bitumen have comparable properties. When more plastic component, up to 12% by weight, was added to modified bitumen, the values for penetration and ductility fell. By including plastic debris at a concentration of up to 8% by weight, the modifier's softening point was advanced. The bulk density and structural integrity of Marshall specimens that contained varied amounts of waste plastic material were measured and analyzed. It was determined that the most important factor necessary for the perfect composition of waste plastic was to have the highest possible degree of stability. The BC mix, which contained 4.6% bitumen and 8% process plastic by weight of bitumen, had an average maximum stability value (MSV) of 1750 kg before the addition of the new binder, which caused a threefold improvement in stability. It was investigated whether the combination created with the aforementioned modified bitumen could withstand being submerged in water under challenging conditions. The average MSV of the modified binder-containing BC mix was found to be 2. 6 times greater than that of the mix containing conventional bitumen. Using this improved binder, BC mixes' fatigue life further increased. This evaluation of conventional roads and plastic roads revealed that the former's level of durability was significantly higher than the latter's. Thanks to the plastic waste's effective binding characteristics, the roads were able to accommodate more traffic while also lasting longer. Plastic was added to the bituminous mixture, which was an environmentally friendly construction method that also addressed the problem of handling hazardous waste.

In a study that was conducted in 2016, **Rajput and Yadav** substituted the bitumen that is typically used in the construction of bituminous roads with waste plastic [10]. Materials such as bitumen with a viscosity grade of VG30, hard and angular coarse aggregates in sizes of 9.5 mm and 6 mm, fine aggregates (dust) employed in varied proportions in line with MORT & H requirements, and waste plastic shred to a size of 2.36 mm were all incorporated into the research project as its constituent parts. In order to produce the plastic modified mix plastic, the heated aggregate was mixed with varying amounts (by weight) of bitumen before being poured into molds. The percentages used were 6%, 8%, 10%, 12%, and 14%. This allowed for the production of the plastic-modified mix plastic. The Marshall Test was carried out on pure bitumen in addition to plastic-modified mix specimens so that a variety of parameters could be investigated and compared. The research showed that the Marshall Stability value rose, and the specimens that had the highest amounts—12% plastic by weight of bitumen—were the ones that showed this rise. The value of the influx increased along with the amount of plastic present. The flow value for 6% plastic waste by weight of bitumen was 2.7, which was significantly lower than the flow value for 14% plastic trash. It was determined that the value of the void filled with bitumen (VFB) was around 72.0 for 6% of plastic waste measured in terms of the weight of bitumen, while it was found to be 75.9 for 14% of plastic rubbish. Both percentages were based on the weight of bitumen. The amount of air space in the bitumen as a proportion of its weight went from 4.0 when there was 6% plastic waste to 3.2 when there was 14% plastic waste. As a result of this, it was discovered that the Marshall stability values increased in a manner that was proportional to the growing waste plastic content of the mixture. As a result, it was deemed that a plastic content of 12% was appropriate. As more plastic material was added to the mixture, the flow value became more favorable. When plastic garbage was added to the mixture, the percentage of air gaps decreased while the volume fraction of bubbles (VFB) increased. Therefore, one could claim that incorporating plastic trash into the mixture of bituminous materials leads in roads that are both more durable and more robust.

Again, (**Ahmad 2014**), produced bitumen mixtures using low-density polyethylene [11]. Low-density polyethylene (LDPE), VG30 grade bitumen, and aggregate were the materials employed in this investigation. According to the total weight of bitumen, various samples were created in proportions of 2%, 4%, 6%, 8%, 10%, and 12%. The bitumen has undergone a number of tests in accordance with the IS code. According to LDPE, this will chop up PET bottles and waste polyethylene into tiny bits to create a variety of 2mm–3mm samples. Stone aggregates, filler material made of stone dust, and cement were utilized in a 3:2 ratio per the MORT & H specification. The samples were subjected to a number of tests, and it was determined that the sample containing 12% trash had a higher stability score. For the inflow value test, adding 12% of LDPE waste to plain bitumen produced a 34% reduction in value, whereas using the same sample for the bulk density test resulted in a 25% increase in value. The value decreases by 44%, according to air entrainment experiments, proving that 12% of the waste plastic samples are more stable. As a result, it can be said that incorporating 12% of the LDPE waste sample raised the final product's quality by 14%.

In 2014, **Shedame and Pitale** investigated the use of plastic trash in bituminous concrete and published their findings [12]. Materials such as bitumen (grade 60/70), stone dust, cement as filler, and waste plastic that had been hacked up into very small bits were some of the ones that were utilized in the research. On bitumen, evaluations concerning its penetration, specific gravity, ductility, and softening point were carried out. On aggregates, tests including specific gravity and water absorption, impact and abrasion, crushing and stripping, and impact and crushing were carried out. In order to evaluate the proper binder content for bitumen content (BC) blends, the Marshall stability test was devised. This test was used to examine a number of different things, including stability, bulk-specific gravity, flow value, air gaps, bitumen-filled voids, and voids in mineral aggregate. With the addition of 0.25%, the amount of waste composed of plastic rose from 0% to 1%. The bulk density and stability of a Marshall specimen that has a varying percentage of waste plastic are both evaluated. The desired value for the percentage of waste plastic contained 0.76 percent on average. According to the findings of the study, improving the performance of bituminous mixes that contained plastic waste by adding 0.76% more plastic to the aggregate and 3% more filler increased the volumetric characteristics of the mixes. The incorporation of plastic increased the temperature at which bitumen melts. The concept of using plastic for roadways was proposed because it would be better for the environment and would lengthen the roads' useful lives.

In 2012, **Sultana and Prasad** looked at the possibility of using waste plastic as a strength modifier in surface course pavement that was either rigid or flexible [13]. The components of the study consisted of discarded low-density polyethylene, high-density polyethylene, and polypropylene (PP), as well as bitumen with a penetration grade of 80/100, cement, concrete, and water. In addition, the study looked at waste materials. It was possible to create concrete cubes, polymer-modified bitumen, and plastic-coated particles. Performance, rheological, and aggregate tests were carried out on both the modified and unmodified mixes. According to the results, aggregate attributes like impact value, abrasion value, and Los-Angeles abrasion value all improved. As a result, penetration and ductility values decrease while the value of the softening point rises. The Marshall stability test was performed on modified bitumen with waste material as well as aggregates coated in plastic. The results indicated that adding waste material to the mixture increased the marshall stability value. The loss of stability test resulted in the acceptance of mixes with an index greater than 75%. The test findings showed that aggregates' characteristics improved when waste material was included. A combination of bitumen that had not been altered in any way was given waste plastic in order to increase its rheological qualities. Penetration and ductility values are declining while the softening point value is rising. Low-density polyethylene (LDPE) performed better than polypropylene (PP) in the Marshall Stability Test findings. The optimal amount of low-density polyethylene for samples made from scrap plastic was discovered to be 8%. The performance test revealed that flexible pavements outperformed stiff pavements.

Ahmadinia et al. (2011) researched waste polymers such plastic bottles for stone mastic asphalt and concluded that using waste polymers is preferable since using a polymer in an asphalt mixture would increase the cost of the mixture used to pave roads [14]. Bitumen, Portland cement, polymer waste, and crushed aggregate were the components employed in this investigation. Both wet and dry methods were used in the test. The waste polymer has been added to the binder in the first process, which is wet. In the other process, which is dry, the waste polymer has been combined with crushed aggregate, but additional steps have also been taken with the aggregates, such as heating them for the first time for two hours at a temperature of 200°C. A further stability test was then conducted, and the polymer stability value increased up to a maximum of 6% before beginning to decline. In a polyethylene terephthalate (PET) marshal flow sample, the value decreases up to 4% before beginning to rise, indicating that the stability of high percentage PET has reduced. Analysis of variance was employed in this instance to analyze the various asphalt mixtures, and the research concluded that stability starts to dilapidate after 6% of Polyethylene Terephthalate (PET), and PET also increases stiffness, with 6% of PET mixture being the ideal fit.

ANALYSIS OF THE STUDY

The analysis of the literature review on the utilization of waste plastic in bituminous road construction highlights several key aspects. Firstly, a variety of experimental methodologies have been employed across studies, including diverse sample preparation techniques and performance evaluations. Performance characteristics such as stability, durability, aging resistance, rutting, and fatigue have been extensively evaluated. It is evident that the percentage of waste plastic content significantly impacts the physical and mechanical properties of bituminous mixtures, with varying levels of effectiveness observed for different types of plastics. While certain limitations and challenges have been identified, including optimal plastic type and content, the reviewed literature suggests promising avenues for future research aimed at enhancing the sustainability and performance of bituminous road construction through the incorporation of waste plastic modifiers.

CONCLUSION

The research presented in this comprehensive review highlights the potential of incorporating waste plastic materials into bituminous road construction. It provides insights into various studies conducted to understand the effects of different types and percentages of plastic waste on the properties and performance of bitumen binders and asphalt mixes. Here are some key takeaways from the review:

1. **Need for Sustainable Solutions:** The ubiquitous presence of waste plastic poses significant environmental challenges, making it imperative to find sustainable ways to manage and repurpose these materials.
2. **Enhanced Bitumen Properties:** Incorporating waste plastic into bitumen has been shown to improve its rheological, physical, and aging properties. Various types of plastics such as polyethylene terephthalate (PET), high-density polyethylene (HDPE), and low-density polyethylene (LDPE) have been explored for their effectiveness in enhancing bitumen performance.
3. **Environmental Benefits:** The incorporation of waste plastic in road construction offers significant environmental benefits by diverting plastic waste from landfills and reducing the consumption of natural resources. By utilizing recycled plastic materials, road projects contribute to waste management efforts and mitigate the environmental impact of plastic pollution.
4. **Long-Term Sustainability:** Sustainable infrastructure development is becoming increasingly critical in the face of global environmental challenges. Utilizing waste plastic in road construction aligns with the principles of sustainability by promoting resource conservation, circular economy practices, and the reduction of carbon emissions associated with traditional construction materials.
5. **Optimal Plastic Content:** Several studies have determined the optimal percentages of plastic waste to be added to bitumen or asphalt mixes to achieve desired properties such as stability, stiffness, and resistance to aging. The ideal plastic content varies depending on factors like the type of plastic and the specific requirements of the pavement.
6. **Performance Evaluation:** Various tests, including Marshall stability test, rolling thin film oven test, dynamic shear rheometer test, and penetration test, have been conducted to evaluate the performance of bituminous mixes containing waste plastic. These tests assess parameters such as fatigue resistance, rutting resistance, aging resistance, and overall durability.
7. **Cost-effectiveness and Sustainability:** Incorporating waste plastic in road construction not only improves pavement performance but also offers potential cost savings by reducing the need for virgin materials. Additionally, it contributes to environmental sustainability by reducing plastic waste and promoting recycling.
8. **Global Impact:** The adoption of waste plastic in road construction has the potential for significant global impact, particularly in regions facing infrastructure challenges and plastic waste development goals and reducing environmental degradation.
9. **Challenges and Future Directions:** Despite the promising results, challenges such as the lack of standardized procedures for mix design and implementation hinder the widespread adoption of waste plastic in road construction. Future research may focus on refining mix design methodologies, exploring novel plastic waste sources, and optimizing blends for specific pavement applications.

In conclusion, the utilization of waste plastic materials in bituminous road construction presents a viable solution to address environmental concerns while enhancing pavement performance and cost-effectiveness. Continued research and development in this area holds significant potential for creating sustainable infrastructure solutions in the future.

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