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Environment- friendly Pavement Construction Using Plastic Trash and Reclaimed Asphalt Pavement-An Overview

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Abstract

Plastic pollution has emerged as a significant environmental concern, with detrimental effects on ecosystems and human health. As a waste product contaminating air, water, and land, plastic poses a grave threat to the environment, perpetuating a global crisis. Its non-biodegradable nature means that once produced, plastic persists indefinitely, accumulating in landfills, water bodies, and natural habitats. This widespread accumulation of plastic waste not only compromises the aesthetic value of landscapes but also endangers wildlife and marine species through ingestion and entanglement. The construction ooffermen pavements offers a unique opportunity to address the plastic waste problem while simultaneously improving infrastructure resilience and sustainability. By incorporating discarded plastic into pavement construction processes, mitigation of the adverse environmental impact of plastic pollution while harnessing its beneficial properties. India, in particular, faces a pressing need to tackle plastic waste management due to its large population and rapid urbanization. By adopting innovative solutions like utilizing recycled plastic in road construction, India can make significant strides towards reducing plastic pollution while addressing common pavement defects such as potholes, ruts, and corrugation. This dual-purpose approach not only benefits the environment but also improves the quality and longevity of road infrastructure, ultimately enhancing the safety and efficiency of transportation networks. Recycled aggregates offer comparable or superior performance to virgin materials while reducing the demand for natural resources and minimizing construction waste. Incorporating plastic into road construction further enhances the sustainability and resilience of pavements, contributing to a circular economy model that prioritizes resource efficiency and environmental stewardship.

Keywords: Waste Plastic, Reclaimed Asphalt Pavement, Environment-friendly, Hot Mix Asphalt, Pavement.

INTRODUCTION

In India, the rate of waste plastic manufacturing is exceptionally high, and there are several dumping yards in every state and district where waste plastic is deposited, resulting in significant pollution, mosquito breeding, and other issues. It not only contributes to pollution, but it also has an impact on life on the earth. Malaria, respiratory issues, and a weakened immune system are just a few of the ailments brought on by the dumping of waste plastic. Plastic trash pollution pollutes not only the land but also the water environment. Plastic generation is very high as it is used in every packaging of materials and food items. Plastic is non-biodegradable; its production cost is low. Plastic waste management is compulsory as it

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threatens the marine, land, and aerial ecosystems. The world's oceans contain around 150 tonnes of plastic trash according to the World Bank document, 2021. Plastic Man of India solved the plastic waste problem by constructing a plastic tar road, which is still in use today. Since then, technology has progressed significantly. The Indian Roads Congress and the Central Pollution Control Board both employ the same strategy adopted by IRC: 37-2012.

Hot Mix Asphalt (HMA) materials can be fully recycled, as research indicates that components found in aged asphalt pavements, comprising both asphalt and aggregates, retain substantial value that can be integrated into fresh asphalt mixtures. This practice, known as Reclaimed Asphalt Pavement (RAP), has demonstrated economic and environmentally friendly benefits when employing RAP aggregates in highway construction. Many state highway agencies in the United States have embraced this approach, as evidenced by NCHRP 4-31,2003, although investigations into the properties of recycled aggregates in pavement construction have predominantly focused on unbound pavement layers.

Reclaimed asphalt pavement aggregates, recovered concrete aggregate (RCA), fly ash, recycled bricks, and recycled glass are the most often utilised recycled materials in the various layers of flexible pavements. Recycling industrial waste for reuse in geotechnical and pavement applications is necessary to provide sustainable solutions (1-2). The majority of the billions of tonnes of waste created worldwide may be recycled or reused, minimising any potential environmental harm. Cost of disposal in landfills and effects. Highways frequently lose their aggregates, which leads to unused aggregates. Without a practical way to reuse this content, it will end up in landfills. Performance of RAP in the field was provided by (3-4).

This study provides the overview of using RAP and waste plastic in pavement construction, to provide sustainable development in the pavement industry.

The main objectives of the study are:

- To figure out the ideal amount of waste plastic to incorporate into the bitumen mixture in order to achieve the necessary strength.
- To ascertain the optimal amount of recycled asphalt aggregates to incorporate into the bitumen mixture for achieving the required strength.
- To perform a cost-benefit analysis and contrast the experimental findings with conventional pavement details.
- Examining the characteristics of bituminous and plastic RAP bituminous roads is the aim of this research.
- Waste that solid are transformed into a binder.
- To offer guidance on the appropriate disposal of plastic.
- To prolong the life of the pavement and lower the amount of bitumen in the mix.

LITERATURE REVIEW

Plastic Waste in Roads

Since the last two decades, waste plastic has been employed in bituminous pavements, and 10% of it has proven to be environmentally beneficial and cost-effective. It reduces the volume of air voids, shrinkage, and maintenance costs. Increases the bond strength between aggregates and bitumen and provide a pavement that stands with heavy traffic; percentage cost reduction for one cum material mix is 5.18% (5–11). The pavements made using waste plastic are durable compared to conventional flexible pavements (12). It can withstand greater weights and temperatures when used in road building. Coatings improve soundness, decrease porosity, and decrease moisture absorption in plastics. The polymer-coated aggregate bitumen mix is a better material for flexible pavement construction since it has a higher Marshall Stability value and an adequate Marshall Coefficient. A novel technique that both enhances and prolongs the life of road construction is plastic addition (13-14). This demonstrates the many advantages of polymer covering the aggregate, which helps to improve the quality of the flexible

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pavement for both the pavement and the aggregate (15). The softening point of the bitumen was increased by the addition of plastic waste; this is because the amount of plastic waste increases the softening point. A unique strategy for bolstering and extending the life of road construction is plastic addition (16). demonstrates how applying a polymer coating to aggregate has a number of benefits and, as a result, helps to improve the quality of flexible pavement for both the pavement and the aggregate (17). By adding plastic waste, the bitumen's softening point was raised. The softening point rises as the proportion of added plastic waste increases. The chemical makeup of the polymers utilised may have an impact on the softening point (18).The results show that using aggregates covered in plastic enhances the properties of aggregates that cause rutting. The Marshall Stability value has improved significantly, and the ideal bitumen content has decreased. Primarily, discarded plastic, a source of pollution, can be utilised for building roads, which can help reduce pollution to some degree (19). There's a chance that making a road out of plastic will come at a somewhat greater cost than using the conventional approach. But since the benefits of employing the technology far outweigh the drawbacks, this shouldn't discourage anyone from doing so (20). The use of waste plastic bottle as fibres in rigid pavement doesn’t increase the compressive strength but increases flexural strength by 5% as compared to normal mix The globe is expected to be free of plastic waste in the not-too-distant future because to research, durable, and ecologically friendly roads (21).

Reclaimed Asphalt Pavement (RAP)

Reclaimed Asphalt Pavement (RAP) is sustainable construction material obtained by milling and processing old asphalt pavements. It consists of a combination of aggregates and asphalt binder. RAP has gained increasing attention due to its potential for cost savings, environmental benefits, and reduced demand for virgin materials. The Physical Properties Researchers have extensively studied the physical properties of RAP aggregates, including gradation, particle shape, and texture. RAP aggregates tend to be angular and rough, which can impact their performance in asphalt mixtures (22). Use of RAP into new asphalt mixtures requires careful mix design. Researchers have proposed various mix design methodologies to optimize the RAP content while maintaining the desired performance characteristics (23). Several studies have evaluated the performance of asphalt mixtures containing RAP in terms of rutting resistance, cracking resistance, and moisture susceptibility (24). RAP utilization reduces the need for virgin aggregates and reduces the carbon footprint associated with asphalt production (25). Cost Savings Incorporating RAP into asphalt mixtures can lead to significant cost savings due to reduced material and transportation costs, challenges and Limitations a. Variability The variability in RAP properties, such as asphalt content and aggregate quality, can pose challenges for consistent performance in asphalt mixture. RAP binder is often aged, which can affect the properties of the asphalt mix. Researchers have explored ways to rejuvenate the binder to improve the performance of RAP mixtures (26). Innovative technologies continued research is needed to develop innovative technologies for better processing and utilization of RAP materials in sustainable pavement construction. Long-term field studies and monitoring are essential to assess the durability and performance of RAP mixtures over time (27).

MATERIALS USED

When building plastic roads, which are composed of plastic mixed with various elements, aggregates measuring 20 mm, 10 mm, and stone dust or lime are frequently used as filler. Bitumen: Bitumen comes in grades 60/70 and 80/100, which can be utilised as binders.

The following categories of plastic wastes are useful for developing rural roads: films of polystyrene (PS) for hard foams and polypropylene (PP) and polyethylene (PE) for soft foams, in any thickness, films of polystyrene (PS), polypropylene (PP), and polyethylene (PE) up to 60 microns thick. PVC is not used due to its high toxicity.

RAP is a sustainable and cost-effective material used in road construction and maintenance. The reuse of RAP can significantly reduce the demand for virgin aggregates and minimize environmental impacts associated with asphalt production. Reclaimed Asphalt Pavement (RAP) has gained increasing attention in recent years due to their potential to reduce the environmental footprint of road construction and improve the sustainability of infrastructure projects. Research in this field continues to advance our understanding of RAP properties, performance, and environmental benefits, contributing to more sustainable and cost-effective pavement solutions.

Preparation of Plastic Waste Material

The use of plastic materials such as carry bags, drinks, and other items is expanding all the time. Plastic use has risen to 4 million metric tonnes according to Annual CPCB Report 2021-22, with the increase about 0.7 million metric tonnes compared to 2018-2019 report. Packing consumes around half to sixty percent of all plastics. Shredding plastic into small pieces ranging from 2.36mm to 4.75mm using a plastic shredding machine such as an Agglomerater or a Scrap Grinder. Agglomerater shreds thin films of polyethylene and polypropylene carry bags, while Scrap Grinder shreds solid plastic materials such as plastic bottles, drip lines, and so on.

Preparation of Reclaimed Asphalt Pavement (RAP)

RAP is obtained by milling or removing the old asphalt pavement from roads or parking lots using heavy machinery, such as milling machines or declaimers. The milled RAP material is transported to a central location or a recycling facility. During transportation, it's essential to minimize contamination and segregation of the RAP material. RAP material is stockpiled at the recycling facility or designated location. It should be kept clean and protected from moisture to prevent degradation. Samples of RAP material are often tested to determine its quality and suitability for recycling. This may include gradation testing, asphalt content analysis, and other performance-related tests. RAP material is typically crushed and screened to separate it into different sizes or gradations. This process can be done using crushers and screens specifically designed for RAP recycling. Depending on the specific mix design and project requirements, the RAP material may be blended with new or virgin aggregates to achieve the desired gradation and performance characteristics. In some cases, the aged asphalt binder on the RAP material is softened or partially removed through a process known as "rejuvenation" or "extraction" to improve the blending with new asphalt binder in the mix. The RAP aggregates are combined with new asphalt binder, additives, and sometimes virgin aggregates in a hot mix asphalt plant. The mixture is heated to the appropriate temperature and thoroughly mixed to produce a high-quality asphalt mix. The final asphalt mix is subjected to various quality control tests, such as Marshall stability, density, and performance-related tests, to ensure it meets the required specifications. Once the RAP-based asphalt mix passes quality control, it is loaded onto trucks and transported to the construction site for paving. The RAP-based asphalt mix is laid on the road surface and compacted using rollers to achieve the desired density and smoothness. In some cases, a surface treatment or overlay may be applied to further improve the pavement's durability and appearance. It's important to note that the specific procedures and regulations for recycling RAP aggregates may vary by location and project requirements. Environmental regulations, safety measures, and quality control procedures should be followed to ensure the successful recycling of RAP materials while maintaining the desired performance of the new asphalt pavement.

Preparation of Bituminous Mixes

The steps below outline the basic procedure for creating a road from plastic waste when building a road utilising it. The first step involves gathering different plastic trash from different sources, as previously described. Additional wastes are extracted from the plastic debris collected from different landfills during the second stage. The waste is meticulously cleaned and dried in the third phase. The trash collected after segregation and cleaning-drying is then crushed and graded into an IS sieve with a size range of 2.36 mm to 4.75 mm using a shredding machine.

Before being placed in the mixing chamber, the aggregate mix is heated to 165° to 170°, and to avoid inadequate bonding, the bitumen is heated to 160°. After a minute or so, the surface of the aggregates in the mixing chamber is evenly covered with the shredded plastic trash, giving the mixture an oily appearance. The road is then laid using aggregates combined with a mixture of bitumen and plastic trash at temperatures between 110°C and 120°C.

The proportion of shredded plastic waste should be 10% and 8%, respectively. To blend bitumen for use in plastic road construction, an ideal level of plastic trash is 8%. Waste plastic is first gathered, segregated, and stored. Certain plastics, such flux sheets and polyvinyl chloride (PVC), need to be kept apart due to safety concerns. The next step is to clean the plastic. Since packaging accounted for 55% of the collected plastic waste in India, it is likely to contain residual materials such small food particles that need to be cleaned. After that, the plastic goes through a shredding process that reduces it to the proper thickness of 2-4 mm. After heating the aggregates to roughly 160-170°C, the plastic is added, and after 30-40 seconds, a homogeneous coating is visible. It has an oily appearance due to this covering. The bitumen is then added and well mixed before being laid. At a temperature of roughly 155-163℃, the bitumen is added. To ensure that the binding is robust, the temperature is carefully controlled. The waste plastic is directly mixed with the hot bitumen at 160°C in the wet process, and the mixture is then stirred with a mechanical stirrer. Additional stabilizers are present in this mixture, which need adequate chilling. It is not widely used since it necessitates much greater capital, plants, and equipment than the dry process.

DISCUSSION

The debate about the proper and inappropriate usage of plastics in connection to environmental protection can go on forever without producing results unless real grassroots initiatives are undertaken by all those who can contribute. It has been demonstrated through field testing that using plastic wastes as an additive in road building can prolong their useful life while also addressing environmental concerns. This article's goal is to showcase current developments in the construction of plastic roadways out of waste plastic. Plastic waste generation has increased as a result of the rapid urbanisation and development. Plastic lasts a long time in the environment since it is not biodegradable in the natural world. Discarding plastic waste at a landfill exposes water bodies to hazardous materials that seep into the groundwater and soil. The disposal of plastic garbage remains a significant concern for local governments, especially in urban areas, as a result of littering practices and inadequate waste management systems and infrastructure. As was previously mentioned, disposing of plastic waste is a serious problem for emerging nations like India, but the country also needs a vast road network to support its social and economic advancement. Since bitumen is scarce, road construction needs to be finished as soon as possible.

The ideal bitumen concentration of the clean semi-dense bituminous concrete mixes was 10% greater than that of the modified semi-dense bituminous concrete mixes produced with waste plastic. 1.6 percent less Marshall Stability was found in pristine semi-dense bituminous concrete mixes at appropriate bitumen percentages than in modified semi-dense bituminous concrete mixes that included waste plastic. The optimised bitumen concentration resulted in a 0.43 percent increase in bulk density for plain semi-dense bituminous concrete mixes compared to modified semi-dense bituminous concrete mixes that used waste plastic. When comparing the volume of Air Voids between modified semi-dense bituminous concrete mixes containing waste plastic and clean semi-dense bituminous concrete mixes at ideal bitumen level, the former had an 8.1% reduction. The limitations imposed by MORTH applied to both plain and modified semi-dense bituminous mixes containing voids filled with bitumen and voids in mineral aggregates. Marshall's findings showed that using semi-dense bituminous concrete mixtures including 10% waste plastic produced superior out comes, hence using waste plastic may be advised. To support this assertion, additional laboratory testing and external performance study are necessary. A plastic binder is used to bond bitumen to the aggregate. The characteristics of bitumen and aggregate both get better as waste plastic content rises. When compared to conventional flexible pavements, the use of waste plastic in flexible pavements yields positive outcomes. It has been found that the presence of plastic waste in bituminous mixtures extends the lifespan of the road, hence reducing maintenance costs. The cost reduction percentage for a specific material mix is 5.18 percent, based on the project's cost analysis (NCHRP 4-31, 2003). A bituminous mix road surface with plastic-coated aggregates was tested on semi-dense bituminous concrete (SDBC), bituminous concrete (BC), and thick bituminous Macadam (TBM). The study found that adding aggregates covered in plastic enhanced the Marshall stability value by 1.5 to 2 times. Additionally, the weight of bitumen was decreased by over 10%. Stretches of surface restoration using plastic coated aggregate demonstrated better functional performance when compared to the control mix in terms of improved surface condition, delayed the development and progression of potholes and cracks, desirable frictional resistance, and surface texture (28). The result of using leftover PVC that was previously used to make electrical fittings, pipelines, mineral water bottles, and other such products He investigated the properties of the mixture (2.5 percent, 5 percent, 7.5 percent, 10 percent, 12.5 percent, 15 percent, 17.5 percent, and 20 percent by the weight of bitumen) by combining PVC with bitumen. As per the test methodology, the investigation aimed to evaluate bituminous mixtures' Marshall design features and coarse aggregate strength attributes. Based on the experiment's outcomes, bitumen was modified using leftover PVC from homes and other waste materials to create mixtures with higher strengths and better bitumen adhesion qualities. In hot climates where poor penetration grade bitumen was used for road building, the suggested amount of PVC modifier was up to 10% by weight of bitumen used (29). The comparison of bituminous mixes including plastic/polymer (PP) at eight and fifteen percent by weight of bitumen to standard bituminous mix performance Significant improvements in indices like indirect tensile strength, rutting, Marshall stability, and sustained stability were recorded in bituminous concrete mixes treated with PP. This study proved that, in practical applications, bituminous concrete mixes with PP modifications had increased sensitivity to moisture and durability (30). The usage of waste plastic coated aggregates bitumen mix composite for road application was investigated using the green technique. The three waste polymers most frequently utilised in packaging were polyethylene, polypropylene, and polystyrene. A higher Marshall Stability value in the range of 18–20 KN increased the road's capacity to support loads by 100% (31-32).

RAP in asphalt mixtures conserve natural resources, lower energy consumption, and reduce carbon emissions. This sustainability aspect aligns with the principles of the circular economy, where materials are recycled and reused. RAP aggregates are cost-effective because they are readily available and typically less expensive than virgin aggregates (33). It has been demonstrates that using RAP can result in significant cost savings in asphalt pavement construction and rehabilitation projects. This cost efficiency makes RAP a compelling choice for many transportation agencies and contractors. One of the challenges with RAP is maintaining the desired engineering properties of asphalt mixtures. The importance of proper RAP blending and quality control to ensure the mix's performance meets design requirements has been highlighted and advances in mix design and technology have allowed for the incorporation of higher percentages of RAP without compromising performance (34). The environmental impact of RAP use is a subject of interest in sustainable construction. In life cycle assessment (LCA) to evaluate the environmental benefits and potential drawbacks of RAP utilization. Properly managed RAP materials can reduce greenhouse gas emissions and energy consumption compared to traditional asphalt production. Regulatory frameworks play a crucial role in promoting or hindering the use of RAP. Transportation agencies are increasingly recognizing the benefits of RAP, and policies are evolving to support its incorporation into road construction. The National Asphalt Pavement Association (NAPA, 2021) provides valuable resources and guidelines on RAP usage, which reflect the industry's efforts to navigate regulatory challenges (35). Through the combination of fibers and biodegradable resins, research efforts are moving closer to creating a new class of entirely biodegradable green composites. The main draws of green composites are their sustainability, biodegradability, and environmental friendliness—in other words, their true greenness. Green composites can be utilized successfully in a variety of applications, including mass-produced consumer goods with limited life spans or goods meant to be used only once or for a brief period of time before being disposed of (36).

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Advantages of a well-built plastic road:

The road's strength and performance improve.

- There will be no stripping and no potholes. Maintenance costs are reduced to nearly nothing.
- Reduces the amount of bitumen used by roughly 10%, lowering the entire cost.
- Provides work for rag collectors.
- As a result, pollution is reduced.
- Strong and durable pavement.

Drawbacks of plastic roads:

- After the road has been laid, the components of the road are no longer inert.
- Toxic substances present in the combined plastic wastes would begin to leach.
- During the construction of the road presence of chlorine will undoubtedly result in the production of HCL gas.
- As a result of the plastic, a sticky film will form.
- Once the road has begun to be used, fine polymer particles will be released.

Advantages of RAP roads:

- Using RAP reduces the need for new aggregate production, which conserves natural resources and decreases the environmental pollution associated with quarrying.
- RAP allows for the reuse of aggregates that might otherwise end up in landfills, reducing the environmental impact of waste disposal.
- RAP is typically less expensive than natural aggregates, resulting in potential cost savings for road construction and maintenance projects.
- Since RAP materials are often sourced from existing road surfaces, transportation costs can be lower compared to bringing in new materials.
- RAP can provide similar performance characteristics to conventional pavement when properly processed and mixed, including durability and skid resistance.
- RAP can help reduce the occurrence of reflective cracking in pavement overlays.
- Using RAP can speed up road construction and rehabilitation projects because it requires less material preparation and transportation.

Drawbacks of RAP roads:

- The quality of RAP materials can vary depending on the source, the age of the pavement being recycled, and the processing methods used. This variability can impact the performance of the resulting road.
- Achieving the right blend of RAP with new asphalt can be challenging, and improper blending can result in reduced pavement performance.
- RAP may not be suitable for all road types and applications, especially high-traffic or high-stress areas, due to potential durability concerns.
- RAP materials can contain contaminants such as oils, solvents, or asbestos from previous road surfaces, which may require special handling and disposal considerations.
- RAP roads may require more frequent maintenance and rehabilitation compared to roads constructed with virgin materials, which could offset some initial cost savings. There is coating of asphalt on RAP which makes them hydrophobic.

Table 1. Comparison between plastic and ordinary pavement.

Property	Roads with plastic	Ordinary conventional roads
Soundness	High	Medium
Durability	Better	Good
Binding	Better	Good

Strength	High	Medium
Stability	More	Less
Moisture Absorption	Very less	Less

CONCLUSION

The conclusions made from this study are as follows:

- The alarming rise of plastic garbage worldwide has prompted a demand for global action to fight the problem. Because it attempts to improve the effective and efficient use of resources, the usage of this waste plastic has employed measures that, if effectively implemented, might solve urban and industrial waste in both developed and developing countries.
- A comprehensive solution that tackles environmental issues, encourages sustainable practices, and improves infrastructure performance is provided by the incorporation of waste plastic in pavement construction. Adopting cutting-edge strategies like plastic-modified pavements can make a big difference at the nexus where infrastructure development and environmental preservation meet as work towards a more sustainable future.
- It encourages the use of secondary materials rather than primary materials by encouraging waste recycling and reuse and waste reduction through better utilization.
- Reducing the amount of plastic waste in the environment and employing it in high strength and durable pavement construction.
- Improving people's and ecosystems' overall health.
- The problem of plastic trash is becoming more serious all across the world. Plastic waste management is required to deal with the challenge. This method of plastic trash disposal is not only cost-effective but also environmentally friendly.
- RAP stockpiles, which are recyclable and valuable, have undoubtedly increased as a result of waste materials produced during asphalt pavement rehabilitation. This study has shed light on the effectiveness of these aggregates in resisting wear even when the pavement's service life has ended, meaning that the strength is still within the parameters established by the standard.
- Costs will be brought down if a lot of aggregates are taken out of RAP materials.
- The waste created when recovered HMA is used in new HMA mixture, therefore natural resources (aggregates) can be preserved to some extent.

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