UPCYCLING PLASTIC WASTE FOR ROAD CONSTRUCTION

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Abstract: This paper explores the concept of upcycling plastic waste for road construction as a sustainable solution to address the environmental challenges posed by plastic waste accumulation. The study investigates the potential of utilizing plastic waste materials, such as discarded bottles and packaging, in road construction processes. It examines the technical feasibility, environmental impact, and economic viability of incorporating plastic waste into asphalt mixtures and other road construction applications. The research evaluates the mechanical properties and performance characteristics of plastic-modified road materials through laboratory testing and field trials. The findings of this study shed light on the benefits and limitations of upcycling plastic waste for road construction, providing valuable insights for policymakers, engineers, and environmentalists interested in promoting sustainable waste management practices.

Keywords: Upcycling, plastic waste, road construction, sustainable solutions, environmental impact, asphalt mixtures, mechanical properties, performance characteristics, laboratory testing, field trials, waste management.

I. INTRODUCTION

The flexible pavements are preferred in India. These are economical about both initial construction cost and maintenance costs. Bituminous binders commonly used in surface courses are unmodified binders' bitumen (depending on the climatic conditions hot or cold) and modified binders by polymers (PMBs). Polymer-modified bitumen can improve fatigue life, temperature susceptibility and resistance to permanent deformation. The term Rheology is the study of flow of fluids and deformation of solids under the presence of stress and strain. Rheology has become a very useful tools in characterization of the bitumen performance on the pavement. Viscoelastic properties of bitumen binder can be described by rheological properties: they are phase angle (\( \phi \)) & complex shear modulus (\( G^* \)). complex shear modulus (\( G^* \)) is the measurement of total resistance of a material to deformation under the repeated action of shear stress, whereas phase angle (\( \phi \)) is angle made by a complex modulus with horizontal axis.

Generally, the rheological behavior of bitumen is very complex phenomenon which varies from purely viscous to elastic depending on the time of loading and temperature. A viscoelastic material, bitumen plays a very prominent role in determining the various aspects of road performance, for example, bituminous pavement need to be stiff at high temperature to prevent rutting and also needs to be flexible enough at low temperature to prevent cracking of pavement. These functional properties are required to enable pavement to accommodate the increasing traffic loading in varying climatic environment conditions. But unfortunately, due to the increased performance related to the requirement on the bituminous pavements, conventional bitumen does not always perform as it expected. The scope of this study is to improve Viscosity, Marshall Stability, Penetration value and softening point of the Bitumen, to utilize waste materials as a pavement ingredient, to improve the binding property and water resistance of the bitumen and Reduction in construction coast of road pavement.

1.2 Plastic – The Binder

Bitumen is a useful binder for road construction. The steady increase in high traffic intensity in terms of commercial vehicles, and the significant variation in daily and seasonal temperature demand improved road characteristics. Any
improvement in the property of the binder is needed. Waste plastics on heating soften at around 130°C. Thermo gravimetric analysis has shown that there is no gas evolution in the temperature range of 130-180°C. Moreover, the softened plastics have a binding property.

1.2 Waste Plastic Low Density Plastic (LDPE)
The production of plastic in India is increasing day by day. LDPE can be used mostly in packaging industry. Milk pouches are generally made up of LDPE. Most of the garbage that generates in household is due dairy product packages like milk pouches, yogurt pouches, buttermilk pouches. Also there are around 40 to 50 milk pouches generated in every tea stall. This plastic can be recycled but if it does not reach the recycling unit then it can create problems. So here plastic is also used for stabilization process.

1.3 Role of plastic in the pavement
Plastic has been used in pavement applications for many years due to its durability and ability to withstand heavy loads. It is commonly used as a reinforcing material in asphalt concrete, which helps to improve the strength and durability of the pavement. Recently, there has been an increased interest in the use of recycled plastic or Plastic in pavement applications. The use of recycled plastic in pavement construction helps to reduce waste plastic, and it has been shown to improve the durability and performance of the pavement. The modification of Plastic can also help to make it more compatible with asphalt and improve its performance as a reinforcing material. This can be achieved by adding additives to the Plastic, which can improve its adhesion to asphalt and reduce its susceptibility to cracking. Another advantage of using modified Plastic in pavement applications is its ability to reduce the temperature of the pavement surface. The modified Plastic can reflect more sunlight than traditional asphalt, which helps to reduce the heat island effect in urban areas and improve the comfort of pedestrians and cyclists. The modification of Plastic is a necessary step towards finding sustainable solutions to reduce plastic waste and minimize its impact on the environment. The use of modified Plastic in pavement applications is a promising area for research and development, and it has the potential to significantly improve the performance and sustainability of pavement construction.

II. LITERATURE REVIEW

D. B. Eme et.al (2019) Plastic or water sachet is a major environmental pollutant, a no biodegradable material. The usefulness of this pollutant (Plastic) in the highway industry was investigated by studying its effects on some selected properties of Hot Mix Asphalt, such as, bulk density, stability and flow of the asphalt concrete mix. Specimen preparation was done using Marshall Mix design procedure. The optimum binder content was determined as 5.20% and three samples each for five variations of Plastic content (2%, 4%, 6%, 8% and 10%) by weight of optimum binder content. It was observed from the study, that the stability and density of asphalt increased with Plastic content, while a linear reduction in the flow and penetration values was observed with Plastic content.

Neetu Rani et.al (2018) Bituminous concrete is a composite material mostly used in construction projects like roads surfacing, airports, parking lots etc. It consists of asphalt or bitumen and minerals aggregate which are mixed together & laid down in layers then compacted. Various percentage of Plastic is used for preparation of mixes with a selected aggregate grading as in the given in the IRC code. The role of the Plastic in the mix is studies for various engineering properties by preparation Marshall Samples of BC mixtures with and without Plastic. Marshall Properties such as stability, flow value used to determine optimum Plastic content for given grade of bitumen (80/100). Plastic is used in bitumen in this work by 0 to 5%.

A.I. Al-Hadidy et.al (2020) The present study investigates the potential use of pyrolysis low density Plastic (LDPE) as a modifier for asphalt paving materials. Five different blends including conventional mix were subjected to binder testing such as rheological tests, as well as to some other tests related to the homogeneity of the system. Further, its effect on the moisture sensitivity and low temperature performance of stone matrix asphalt (SMA) mixtures was studied. Research results indicate that modified binders showed higher softening point, keeping the values of ductility at minimum range of specification of (100+ cm), and caused a reduction in percentage loss of weight due to heat and air (i.e. increase durability of original asphalt). The results indicated that the inclusion of LDPE in SMA mixtures can satisfy the performance requirement of high-temperature, low temperature and much rain zone.

Jyoti Prakash Giri et.al (2018) Recycling or waste utilization in transportation construction industry is important for sustainability. Keeping this in mind, an attempt has been made in this study to explore the use of waste materials such
as recycled concrete aggregates (RCA) and waste milk packaging Plastic in bituminous paving mixes. In this study, dense bituminous macadam mixes were prepared with RCA as coarse aggregates and two different types of filler, i.e. cement and stone dust. For the purpose of comparison, paving mixes were also prepared using natural aggregate and other materials as above. It was observed that all the mixtures prepared with various combinations satisfy the requirements in terms of Marshall test parameters and moisture susceptibility specified by Ministry of Road Transport and Highways, India. Further, the use of waste Plastic generally improves the engineering properties especially at a higher temperature, in terms of dynamic moduli value and rutting behaviour of mixtures.

Chalachew Nigussie et.al (2019) Increasing urbanization and industrialization have contributed for increased plastic generation in Ethiopia. Unsafe disposal of waste plastic is a serious environmental problem. The application of waste plastics to modify bitumen for asphalting of roads can possibly minimize those problems since the Plastic modified roads showed superior resistance to environmental stresses in countries if the technology has been implemented. PET plastic bottle is generated daily in Bahir Dar city and released as a waste after usage. Releasing them to the environment, they pose negative impact to the environment. So to overcome such problem reducing solid disposal there is an idea to utilize waste PET bottle plastic in bitumen modification for asphalt road construction pavement using wet process technology. The conditions used were: plastic content (0%, 2%, 3.5%, 5%, 6.5%, and 8%) by mass of bitumen, plain bitumen content in testing of its maximum stability (4.5%, 5%, 5.5%, and 6.5%) by mass of aggregates.

III. RESEARCH METHODOLOGY

The use of Plastic in bituminous roads is a method of improving the performance and durability of roads by incorporating plastic waste in the construction process. The following methodology can be used for the implementation of this technique:

1. **Collection of Plastic**
   Collect Plastic waste from various sources such as households, commercial establishments, and industries. The collected Plastic should be cleaned and sorted according to their quality.

2. **Shredding:**
   The Plastic collected needs to be shredded into small pieces using a shredding machine. The size of the shredded pieces should be such that they can be easily mixed with the bitumen.

3. **Mixing with Bitumen**
   The shredded Plastic needs to be added to the bitumen mix during the construction process. The amount of Plastic added to the bitumen mix should be carefully determined so as to not affect the desired properties of the bitumen.

4. **Preparation of Mix**
   The bitumen mix is prepared by heating the bitumen to a certain temperature and adding the required amount of aggregates. The shredded Plastic is then added to the mix and thoroughly mixed to ensure a uniform distribution of the plastic waste.
5. Laying the Road
The prepared bituminous mix is then laid on the road surface using a paving machine. The thickness of the bituminous layer should be carefully controlled to ensure proper compaction.

6. Compaction
The laid bituminous layer is then compacted using a roller to ensure proper bonding between the bituminous layer and the road surface.

7. Quality Control
The quality of the constructed road should be tested to ensure that it meets the desired specifications. The durability, stability, and strength of the road should be assessed.

8. Maintenance
Regular maintenance of the road should be carried out to ensure its longevity and durability. The use of Plastic in the bituminous mix can increase the lifespan of the road by reducing the formation of cracks and potholes.

the use of Plastic in bituminous roads is an effective way to improve the performance and durability of roads while also reducing plastic waste. The above methodology can be used for the implementation of this technique.

3.1 Tests on Aggregate
1. Sieve Analysis of Aggregate
2. Impact Value Test
3. Impact Value Test (Aggregate + Plastic)
4. Abrasion Test
5. Crushing Value Test

3.2 Test on Bitumen
1. Penetration Test
2. Ductility Test
3. Softening Point Test

3.3 Test on Bituminous Mix Design
1. Marshall Stability Test

4. CONCLUSION
Upcycling plastic waste for road construction presents a promising solution to the growing problem of plastic pollution and the need for sustainable infrastructure development. By incorporating plastic waste into road construction materials, we can address two major challenges simultaneously: reducing plastic waste accumulation and improving the quality and durability of roads.

Upcycling plastic waste for road construction offers several benefits. Firstly, it helps divert plastic waste from landfills and oceans, reducing environmental pollution and the negative impacts on wildlife and ecosystems. Secondly, incorporating plastic waste into roads can enhance their strength, flexibility, and longevity, resulting in more durable and resilient infrastructure. Additionally, this approach reduces the consumption of traditional construction materials such as bitumen and aggregates, conserving natural resources and reducing carbon emissions associated with their extraction and production.

Furthermore, upcycled plastic roads have shown resistance to weathering, water damage, and cracking, making them suitable for various climates and contributing to reduced maintenance costs. The use of plastic waste in road construction also promotes circular economy principles by transforming waste into a valuable resource.

While challenges remain, such as ensuring proper quality control and addressing concerns about microplastic release, the potential benefits of upcycling plastic waste for road construction make it a promising avenue for sustainable infrastructure development and a step towards a cleaner and greener future.

REFERENCES


