ENVIRONMENTALLY SUSTAINABLE UTILIZATION OF RECYCLED PLASTIC WASTE IN BITUMINOUS PAVEMENT

By

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A thesis submitted to the Department of Civil Engineering in partial fulfillment for the degree of Bachelor of Science in Civil Engineering



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Spring-2025

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DECLARATION

It is hereby declared that, except for the contents where specific references are made, the work embodied in this thesis is the result of an investigation carried out by the authors under the supervision of **M.A. Bashar Bhuiyan**, Lecturer & Assistant Course Coordinator, Department of Civil Engineering of Sonargaon University.

Neither this thesis nor any part of it is concurrently submitted to any other institution in` candidature for

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Dedicated

to

"OUR PARENTS, FAMILY AND TEACHERS"

ACKNOWLEDGEMENTS

First, I would like to acknowledge the blessings of almighty Allah for successfully carrying out the study.We are like to express our sincere gratitude to our supervisor M.A. Bashar Bhuiyan, Lecturer, Department of Civil Engineering, Sonargaon University, for his constant support and guidelines during this course of research work, his careful instruction, valuable comments, and technical and constructive suggestions immensely contribute to the improvement of this thesis. We are like to express our profound gratitude to Prof. Shamim Ara Hossen, Vice- Chancellor & Prof. Bulbul Ahamed, Pro Vice- Chancellor, Sonargaon University, for guiding us in writing this thesis book. Furthermore, we are like to be thankful to Brig. Gen. (Retd) Prof. Habibur Rahman Kamal, (ndc, psc, Head of Department, SU) Department of Civil Engineering. We would like to express profound thanks to our all teachers (Department of Civil Engineering), family members, and friends for supporting and inspiring us to conduct the study. We would like to convey our deepest love and obedience to our caring parents for their support and guiding us throughout life which keeps us strong and honest to do things we needed to do. Finally, special thanks to our all well-wishers for their wholehearted inspiration throughout the period of this study.

ABSTRACT

The disposal of plastic waste has become a critical environmental issue, contributing to pollution and global warming. The Roads and Highways Department of Bangladesh manages over 375,000 kilometers of national, regional, and district roads, with an increasing need for more durable and cost-effective pavement solutions. In response to the environmental challenge posed by plastic waste, a novel approach utilizing recycled plastic in bituminous mixtures for road construction has shown significant promise. The plastic waste, primarily composed of polyethylene, polystyrene, and polypropylene, is shredded, coated over aggregates, and mixed with hot bitumen to create a strong, durable pavement. This not only enhances the properties of bituminous mixtures but also provides a solution to the disposal of plastic waste, reducing environmental pollution. The addition of waste plastic to bitumen improves the stability and strength of the compacted mixtures, as confirmed by Marshal stability tests, which demonstrate better performance compared to conventional mixtures. This technology offers several advantages, including increased resistance to common pavement defects such as potholes, ruts, and cracking, while also enhancing the pavement's durability. Furthermore, the incorporation of titanium dioxide as a smoke-absorbent material helps mitigate vehicular emissions, a significant environmental concern, particularly in Bangladesh's hot-humid climate. This paper discusses the use of waste plastic in bituminous mixes, focusing on the benefits of the modified binder in enhancing pavement performance, reducing maintenance costs, and promoting sustainable plastic waste management. The study highlights the potential of this innovative technology to revolutionize road construction by addressing both environmental and infrastructural challenges.

Keywords: Plastic waste, bituminous pavement, polymer-modified bitumen, waste plastic modified bitumen, environmental sustainability, Marshal stability, pavement durability.

LIST OF ABBREVIATIONS

AASHTO	Association of American State Highway and Transportation officials
ABS	Acronitrile Butadiene Styrene
AC	Asphalt Concrete
ADOT	Arizona Department of Transportation
ASTM	American Society for Testing and Materials
BBMP	Bruhat Bangalore Mahanagra Palike
BS	British Standard
BS	Butadiene-Styrene
BTF	Bangladesh Transport Foundation
CalTrans	California Department of Transportation
CR	Crum Rubber
CRM	Crum Rubber Modified
CRMB	Crumb Rubber Modified Bitumen
CRRI	Central Road Research Institute
CRT	Crumb Rubber from Tire
CTE	Centre for Transportation Engineering
CVA	Conventional Asphalt
DC	Direct Current
EVA	Ethylene Vinyl Acetate
FDOT	Florida Department of Transportation
GDOT	Georgia Department of Transportation
HDPE	High Density Polyethylene
HEATEC	Chemical Company
HMA	Hot Mix Asphalt
HWTD	Humburg Wheel Tracking Device
IRC	Indian Road Congress
KRATON	Branded Polymer (a product of Shell Company)
LDPE	Low Density Polyethylene
LGED	Local Government Engineering Department
LLDPE	Linear Low Density Polyethylene
NRMB	Natural Rubber Modified Bitumen
OBC	Optimum Bitumen Content
PE	Poly Ethylene
PET	Polyethylene Terephthalate
PMB	Polymer Modified Bitumen
PP	Poly Propylene
PVC	Polyvinyl Chloride
RAC	Rubberized Asphalt Concrete
RHD	Roads and Highways Department
RMA	Rubber Modified Asphalt
RMB	Rubber Modified Bitumen
RPE	Recycled Polyethylene

RUMAC	Rubber Modified Hot Mix Asphalt
SBS	Styrene-Butadiene-Styrene
SE	Styrene-Ethylene
TPE	Thermoplastic Elastomer
VB	Virgin Bitumen
VFA	Voids Filled with Asphalt
VMA	Voids in the Mineral Aggregate
VSS	Valley Slurry Seal
WSS	Western States Surfacing

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CHAPTER 1

Introduction

1.1 Background

Plastic waste is a huge threat of environment. Over the past five decades, plastics production has soared worldwide. A staggering 1 million plastic bottles are purchased every minute around the world. If all the plastic bottles sold in 2018 were gathered in a pile, it would be higher than the world's tallest building, the Burj Khalifa in Dubai.

Bangladesh is not immune to the plastic hazard. Because of the ever- increasing use of plastic in different industries, especially packaging. Bangladesh remains one of the top plastic polluted countries. Images of clogged rivers as a result of haphazard disposal of plastic bottles partly depict the gravity of the problem.

- Around 73,000 tons of plastic waste end up in the sea everyday through the Padma, Jamuna and Meghna rivers.
- Some of 14 million pieces of polythene bags are used every day in Dhaka city.
- Plastics comprise 8% of the total waste.

The usage of plastic in road construction is not a recent development. There is some possibility, according to recent studies in this direction, for the use of waste plastic in road building.Use plastic carry bags, throwaway cups, and PET cups gathered from trash dumping yards mostly on plastic highways. Plastic melts when it comes into contact with heated bitumen, coating the aggregate with an oily coating that is then applied to the road surface like a typical tar road. The environmental hazard posed by plastic is enormous. Research has shown that plastic garbage may be utilized in the construction of roads and that, when properly processed, it can extend the life of the road and provide an answer to environmental issues.

The plastic that is utilized in road building is not brand-new; it has long been made from waste materials like carry bags, water bottles, milk packets, glasses, and cups.

Every year, there is a rise in the demand for roadways. It is obvious that this tendency will continue in the future as the number of commercial vehicles with heavier axle loads continues to rise. The highway engineers are considering other options to address this expanding difficulty. Adding polymers to improve the service qualities of road paving applications was once contemplated, but it is now a viable option. To achieve improved service qualities over a wide temperature range, a variety of additives are used. Numerous studies conducted in numerous nations have supported the advantages of adding polymers to bitumen (Hossain, 2006). The fundamental barrier to such alterations, however, continues to be the incompatibility of polymer and bitumen matrix. Recently, waste plastic has been used in paving with positive results (BTF, 2008). Binders made from recycled plastic are more durable, less likely to crack, and more skid-resistant. Additionally, this form of treated asphalt has

demonstrated fatigue resistance under traffic stress. Using crumbed rubber polymers produced by KK Plastic Waste Management Pvt. Ltd. Bangalore, India, the Local Government Engineering Department (LGED) of Bangladesh has already built pilot trial pavement on three road sections during 2005–2006. One of the trial sections had 84%, 57%, and 15% less Cracks, Depression, and Raveling, respectively, than the nearby conventional structure, according to a post-construction review (Islam, 2008).

The waste plastic (Low Density Polyethylene, Polyethylene Terephthalate) will be used in experiments using a thermostatically and mechanically controlled blending system that can produce enough shear force. Then, several tests, including those for density, viscosity, penetration, ductility, loss on heating, etc., would be carried out on waste plastic-blend bitumen in order to see the rheological characteristics of the modified binder, which are crucial for choosing an appropriate less expensive modifier. The redesigned binder would undergo a field demonstration on a specific segment when all essential testing was completed and determined to be satisfactory. Another portion would be completed at the same time using the conventional pure binder.

Plastic roads, also referred to as waste plastic roads, outperform conventional bitumen-built roads in terms of performance. The bituminous mixture made from waste plastic has the following benefits.

1. Increased resilience to water stagnation and rain.
2. Improved mixture bonding and increased binding.
3. No UV or other radiation effects, and a 100% improvement in road strength.
4. With Marshall Stability value, the road becomes stronger and more capable of withstanding loads. This assists in addressing the present demand for more road transportation.
5. The price of building new roads has plummeted, and maintaining them now costs nearly nothing.
6. There won't be a difficulty with how to dispose of used plastic.
7. The value of recycled plastic will rise.
8. There will be a growth in employment for unskilled labor. As a result, the use of waste plastics in road construction has helped to create a better location for burying plastic trash without creating an issue with disposal.

The generation of plastic is growing every day. The primary plastic polymers, such as polyethylene, polypropylene, and polystyrene, exhibit adhesion characteristics while they are molten. The bitumen's melting point will rise due to plastic.

1.2 Statement of the Problem

The usage of plastic in human existence is growing every day since it's simple to handle, lightweight, unbreakable, and has so many other benefits that make living simple. The use of plastic products in Bangladesh is rising daily. Every day, a portion of the used plastic waste is collected at the landfills.

Therefore, one of the biggest issues civil engineers are dealing with is the management of waste plastic.

Polythene and products that are comparable to it, such as shopping bags, plastic bags, lunch sheets, etc., cannot be recycled, despite the fact that hard plastics like toys, bottles, and broken household objects can be recycled in part. Such things clog sewers, choke animals when they eat leftover food, and burn noxious fumes into the air.

Premature pavement breakdown happens in Bangladesh due to both the high summer temperatures and a lack of adequate drainage infrastructure. In the summer, the temperature soars, the pavement's ambient temperature approaches the typical bitumen's softening threshold, and a flow condition develops. This disease, known as hemorrhage, presents significant riding issues.

An asphalt binder film called bleeding forms on the pavement's surface. Typically, it produces a bright, reflective surface resembling glass that can become sticky when dry and slick when wet.

When asphalt binder fills aggregate holes in hot weather and subsequently extends to the pavement surface, bleeding happens. The addition of polymer (waste plastic) to bitumen raises the binder's softening point and could slow further leakage.



Figure 1.1 Waste Plastic Collection (LDPE & PET)

Another reason for pavement collapse in Bangladesh is rutting. Rut is a vertical depression created by traffic loading along the vehicle tire tracks. This surface flaw is more obvious and noticeable on the outer wheel track. Rutting is a permanent deformation of any pavement layer or subgrade, typically brought on by the displacement or consolidation of the pavement edge as a result of traffic pressure. If the pavement binders are not sufficiently elastic, the pavement may permanently distort. Because after reducing wheel loading, a weak elastic binder does not return to its initial position. When PMB is used to build pavement, the elasticity of the binder is appropriately increased.

Another major factor in Bangladeshi pavement collapse is cracking. It typically results in potholes on the pavement's surface. This is caused by both the volume of traffic and the asphalt concrete's capacity to withstand temperature variations. PMB use could be an alternative because conventional bituminous binder is very temperature sensitive.

In this sense, reducing the frequency of rehabilitation work and so offering an affordable alternative might be achieved by using waste plastic (polymer) in the building and maintenance of pavements. Reusing used plastic will also help solve the issue of how to dispose of solid garbage.

1.3 Objectives of the Research

1 To develop another way of road construction.
2 To test the bitumen and modified bitumen.
3 To enhance the properties of bituminous pavement.
4 To examine how waste plastic-modified bitumen affects the condition of roads.
5 To test the stability of specimen mixed with waste plastic

CHAPTER 2
Literature Review

2.1 Introduction

There is increased interest in environmentally friendly and sustainable methods for building and maintaining roads, according to a literature assessment on the use of waste plastic in bituminous pavement. Waste plastic materials can potentially alleviate environmental issues related to the disposal of plastic waste and improve the performance of paving materials by being added to bituminous mixtures.

Dr.R.Vasudevan, (2007) - State that the bitumen mix made of polymers is a superior binder than bitumen taken alone. With a sufficient ductility, blend has lowered penetration value and raised softening point.

Zahra Niloofar Kalantar, (2012) - For the past two decades, many studies on polymer modified asphalt combination have been carried out. Although recycled polymer added to asphalt have also shown almost the same result in improving the road pavement performance as compared to virgin polymers, addition of virgin polymers to asphalt for the aim of enhancing the properties of asphalt over a wide temperature range in paving applications was considered quite some time ago. This paper reviews the application of polymers in asphalt pavements. The history and advantages of employing waste and virgin polymer in asphalt are given in this work in a critical assessment.

Amit Gawande (2012) - Rising population, urbanization, development activities, and changes in lifestyle that result in extensive littering on the landscape are driving an increasing quantum of plastic trash in municipal solid waste. Waste plastic's non-biodegradability and ugly appearance so make disposal of it a threat and a major worldwide issue. Since things are not disposed of scientifically and ground and water pollution is theoretically possible. This waste plastic partially replaced the traditional component to enhance desirable mechanical properties for a given road mix. Bitumen is the binder used in traditional road construction. Waste plastic bits can be utilized to modify such bitumen, and bitumen mix is produced that can be applied as a top layer coat for flexible pavement. This waste plastic modified bitumen mix exhibits increased resistant to water, density, stability, and binding power.

Rishi Singh Chhabra (2014) - Minimizing waste products is a necessary element of the contemporary development programs. Plastic finds application in the residential and business sectors. One is rather regular use of plastic bags and bottles. Plastic's non-biodegradability raises serious problems with the disposal of plastic waste. The plastic can be used as feedstock for ethanol related goods. It helps road development and other related building activities. The present review compiles the research on the consumption of waste plastic.

Sunil J. Kulkarni (2015) – An essential component of the modern development projects is the minimization of waste materials. Plastic finds use in both home and industrial sectors. One is

rather frequent use of plastic bags and bottles. The non-biodegradable character of plastic makes disposal of plastic garbage a significant issue. Ethanol related products can be made from the plastic as feedstock. Road building and other associated building operations can benefit from it. The present review aggregates the studies on waste plastic usage.

Here is a summary of significant research results from published works.

Background and Motivation: Because of the growing problem with plastic waste, scientists and engineers are looking into creative ways to recycle and reuse plastic trash. One such strategy that adheres to the ideas of circular economy and sustainability is the incorporation of waste plastic into bituminous pavements.

Waste Plastic kinds: Several waste plastic material kinds have been looked into for use in bituminous pavements. These include plastic bottles, bags, films, and other plastic waste gathered from landfills or recycling facilities.

Improvement of mechanical performance: Research suggests that adding waste plastic to bituminous mixtures can enhance their mechanical characteristics, including as Marshall stability, robust modulus, and fatigue life. The flexibility of the plastic may help provide improved resistance to breaking and deformation.

Modified Bitumen Properties: Bitumen modified with waste plastic has better rheological characteristics, such as a higher softening point, more penetration resistance, and storage stability. The durability and lifetime of the pavement may be improved as a result of these changes.

Decreased Rutting and Cracking: It has been demonstrated that the inclusion of waste plastic improves the rutting resistance and cracking performance of bituminous pavements, resulting in a decrease in maintenance requirements and an extension of service life.

Environmentally Sustainable/ Environmental Advantages:

1. Making use of recycled plastic in paving reduces the need for virgin bitumen, which lowers the consumption of fossil fuels and greenhouse gas emissions. Recycling plastic garbage also keeps it out of landfills and the ocean.

2. **Plastic Waste Reduction**: By utilizing recycled plastic, waste plastic materials (such as polyethylene, polystyrene, and polypropylene) are diverted from landfills and the environment. This significantly reduces plastic pollution, which is a major global concern. In Bangladesh, for instance, around 73,000 tons of plastic waste enter the sea daily, and a substantial portion of urban waste consists of plastic bags, bottles, and packaging materials.

3. **Improved Pavement Durability:** The incorporation of recycled plastics into bitumen enhances the material's mechanical properties, making pavements stronger and more resistant to wear and tear. This results in increased durability, reducing the need for frequent road repairs and maintenance. It also makes the roads more resistant to common issues such as rutting, cracking, and potholes, which is particularly important in areas with heavy traffic or high temperatures.

4. **Reduction in Greenhouse Gas Emissions**: Traditional bitumen production is energy-intensive, often relying on fossil fuels. By substituting some of the bitumen with recycled plastic, the demand for virgin bitumen can be reduced, leading to lower energy consumption and a reduction in greenhouse gas emissions associated with bitumen production.

5. **Longer Service Life:** Plastic-modified bitumen has better fatigue resistance and higher stability under temperature variations, making it more suitable for regions with extreme weather conditions. This prolongs the lifespan of the pavements, resulting in fewer replacements and less waste over time.

6. **Economic Benefits:** Using recycled plastic in road construction can lower the cost of building new roads. Additionally, this practice can stimulate the recycling industry and promote job creation in waste management and road construction sectors.

7. **Waste Management:** The incorporation of waste plastic into bituminous pavements provides a practical solution for managing plastic waste. This not only reduces the environmental burden but also ensures that plastic waste is repurposed in a way that benefits infrastructure projects.

Using recycled plastic in bituminous pavements offers a dual environmental advantage: it tackles the critical issue of plastic waste while also improving the performance and sustainability of road infrastructure.

The research concludes that adding waste plastic into bituminous pavements has potential as a novel approach to environmentally friendly road building. Although numerous potential benefit has been identified by study, further work is required to address technical issues and offer thorough instructions for implementation success. Field tests and long-term monitoring will help us better understand how well waste plastic modified pavements work and what kind of influence they have on the environment.

2.2 Modifier

Bitumen, a key material used to build roads and pavements, is frequently modified with additives. Bitumen's characteristics are improved by these additives, making it stronger, more flexible, and more resistant to various environmental influences. There are a few main alternatives when it comes to plastics used as additives in bitumen modification:

Polyethylene (PE): is a popular polyethylene that can be used to increase bitumen's flexibility, viscosity, and crack-resistance. It aids in improving bitumen's low-temperature characteristics, enabling use in colder climates.

Polypropylene (PP): Polypropylene (PP) is yet another typical plastic addition that improves bitumen performance. It increases bitumen's stiffness, resistance to rutting, and resistance to thermal cracking. In locations with heavy traffic and high temperatures, PP-modified bitumen is frequently employed.

Polymer-Modified Bitumen (PMB): This type of bitumen is modified by the addition of various polymers, including plastics, to enhance its qualities. Styrene-butadiene-styrene (SBS), styrene-butadiene rubber (SBR), ethylene-vinyl acetate (EVA), and other polymers can be found in PMBs. These additions improve the bitumen's flexibility, viscosity, fatigue resistance, and general durability.

Polyvinyl Chloride (PVC): Bitumen can be strengthened with PVC to make it more resilient to rutting, cracking, and deformation. In areas with high traffic volumes, bitumen treated with PVC is frequently employed.

Recycled Plastics: Recycled plastics have also been added to bitumen as additives in an effort to combat the problem of plastic waste. Bitumen's mechanical qualities are enhanced by adding recycled plastic materials, and this process also helps to recycle plastic trash and lessen its negative environmental effects.

Elastomeric Modified Bitumen: This sort of modified bitumen is made by combining elastomers, a kind of polymer, with bitumen. Styrene-butadiene rubber (SBR) and other elastomers provide bitumen outstanding elasticity, flexibility, and durability, making it appropriate for situations where significant movement and deformation are anticipated. It's crucial to remember that the particular plastic addition chosen depends on a number of variables, including the targeted performance characteristics, environmental conditions, traffic volumes, and the planned application of the modified bitumen. The right dosage and processing techniques also change depending on the kind of plastic and the desired result.

2.3 Rubber

Rubber is another type of material that is commonly used as an additive to modify bitumen. Rubber-modified bitumen, often referred to as Rubberized Bitumen (RMB) or Rubberized Asphalt, incorporates recycled tire rubber into bitumen to improve its properties. This practice not only enhances the performance of bitumen but also helps in the recycling of used tires, addressing waste management and environmental concerns.
There are two main methods for incorporating rubber into bitumen:

Dry Process: In this method, finely ground rubber particles from recycled tires are mixed with bitumen. The rubber particles are added to the bitumen during the mixing process. The rubber swells in the bitumen and forms a dispersed phase, which leads to improved elasticity, reduced brittleness at low temperatures, and enhanced resistance to cracking and rutting.

Wet Process: In the wet process, rubber is added to bitumen through a chemical reaction that involves creating a rubber-bitumen binder. The rubber is blended with bitumen and a chemical cross-linking agent, often using a high-shear blending process. This chemical interaction between rubber and bitumen enhances the elastic properties of the resulting modified binder.

2.4 Polymer

Polymer-modified bitumen (PMB) is a popular and effective type of modified bitumen that involves the addition of various polymers to enhance the performance characteristics of the bitumen. Polymers are large molecules made up of repeating units, and they can be tailored to provide specific properties to the bitumen, such as improved elasticity, durability, and resistance to deformation. There are several types of polymers used in polymer-modified bitumen:

Styrene-Butadiene-Styrene (SBS): SBS is a common polymer used to modify bitumen. It is a thermoplastic elastomer that enhances the elasticity and flexibility of the bitumen. SBS-modified bitumen is known for its excellent resistance to cracking, rutting, and fatigue, making it suitable for high-traffic areas and regions with temperature fluctuations. Styrene-Butadiene Rubber (SBR): SBR is another polymer that imparts elasticity and improved low-temperature properties to bitumen. It helps prevent cracking and enhances the overall durability of the pavement.

Ethylene-Vinyl Acetate (EVA): EVA is a thermoplastic polymer that improves the adhesion properties of bitumen and provides resistance to deformation. EVA-modified bitumen is often used in applications where good adhesion to aggregates and resistance to water damage are crucial.

Polyethylene (PE): PE is used in polymer-modified bitumen to enhance its viscosity and low-temperature properties. It contributes to improved flexibility and crack resistance.

Polypropylene (PP): PP-modified bitumen offers increased stiffness, rut resistance, and thermal stability. It is suitable for high-temperature environments and areas with heavy traffic loads.

Elastomers: Besides specific polymer types, elastomers like natural rubber and synthetic rubber can also be used to modify bitumen. These materials provide excellent elasticity, flexibility, and resilience to the bitumen.

The addition of polymers to bitumen changes its rheological and mechanical properties, allowing it to perform better under various stress conditions, including traffic loads, temperature changes, and environmental factors. Polymer-modified bitumen is commonly used in road construction, especially for critical areas such as intersections, roundabouts, and regions with extreme climate conditions. It provides longer-lasting and more durable pavements, reducing the need for frequent maintenance and repairs.

2.4.1 Identification of potential polymer as Modifier

Identifying the appropriate polymer as a modifier for bitumen involves a comprehensive evaluation of the desired performance characteristics, compatibility with bitumen, and the specific requirements of the project. Here's a step-by-step guide to help identify a potential polymer modifier:

Define Project Requirements:

1.Clearly outline the specific challenges your project faces, such as high traffic loads, temperature fluctuations, or environmental conditions.

2.Determine the desired properties you want to enhance in the modified bitumen, such as elasticity, fatigue resistance, rutting resistance, adhesion, or durability.

Research Polymer Types:

Research different types of polymers commonly used for bitumen modification, such as SBS, SBR, EVA, PE, PP, and various elastomers.

Understand the strengths and weaknesses of each polymer type in terms of the desired performance characteristics.

Consult Experts and Literature:

Seek advice from experts in the field of bitumen modification or polymer chemistry.

Consult relevant research papers, technical literature, and case studies to learn about successful polymer-bitumen combinations for similar projects.

Compatibility Testing:

Perform compatibility tests to ensure the polymer is compatible with the base bitumen. Compatibility tests involve blending the polymer with bitumen and assessing the resulting properties.

Evaluate the stability of the blend over time, looking for any signs of separation, phase changes, or chemical reactions.

Performance Tests:

Conduct performance tests on the polymer-modified bitumen to assess its behavior under various conditions. Common tests include:

Elastic recovery tests to measure elasticity and deformation resistance.

Penetration and softening point tests to evaluate consistency and temperature susceptibility.

Shear and fatigue tests to assess resistance to repeated loading.

Rheological tests to analyze flow and viscosity behavior.

Evaluate Cost and Availability:

Consider the cost of the polymer, its availability in your region, and any logistical factors related to procurement.

Consult with Suppliers:

Reach out to suppliers of polymer modifiers. They can provide technical information, recommendations, and data sheets for their products.

Consider Environmental Impact:

Assess the environmental implications of using the chosen polymer, especially if sustainability and eco-friendliness are important factors for your project.

Field Testing (Optional):

If feasible, consider conducting field trials using small sections of pavement to evaluate the real-world performance of the polymer-modified bitumen.

Select and Fine-Tune:

Based on the results of your research, testing, and consultation, select the polymer that best matches your project's requirements.

Fine-tune the polymer dosage and mixing procedures to achieve the desired performance.

Remember that bitumen modification is a complex process that requires expertise and careful consideration. It's important to collaborate with experts, conduct thorough testing, and select the polymer modifier that aligns with your project's goals and the specific challenges you aim to address.

2.4.2 Benefits of Polymer Modified Bitumen

The goal of bitumen polymer modification is to provide long-lasting pavement with increased stiffness and stability while lowering maintenance costs. Polymer use could occasionally drive up construction costs. In this instance, pavement quality improvement is used to assess the benefit. The usage of RPE (recycled polyethylene) and CR (crumb rubber) has advantages in terms of cost effectiveness and quality improvement, but also poses environmental risks. Three criteria are used to evaluate the advantages of PMB (Hossain, 2006).

Binder quality improvement: Polymers in bitumen increase the following bitumen qualities: increases the viscosity of the binders to allow for a thicker layer in the paving mixtures without too much drain down or bleeding.

1.It improves the binder's ability to handle cracking and dynamic deformation of the inner layers of the pavement.

2.It enhances the binder's mechanical resistance, particularly to tractive force, improving its behavior toward fatigue.

3.It promotes elasticity and resilience at high temperatures, which reduces bleeding by raising the softening point of the binder.

4.Rejuvenate old asphalt binders;

5.Increase the cohesiveness of the binder.

6.Reduce thermal susceptibility to both low and high temperature.

Pavement can be significantly improved because of its increased elasticity.

i. Pavement deformation is decreased.
ii. Increased aging and oxidation resistance because of the tire rubber's increased binder content, thicker binder films, and anti-oxidants.
iii. It offers increased resilience to fatigue.
iv. It offers better peeling resistance.
v. It offers enhanced capacity for self-healing.
vi. It offers more durability.

2.4.3 Limitations of Polymer Modified Bitumen

While polymer-modified bitumen offers many advantages, there are also certain limitations and challenges associated with its use. It's essential to be aware of these limitations to make informed decisions when selecting and applying polymer modifiers in bitumen:

Cost: Polymer-modified bitumen tends to be more expensive than conventional bitumen due to the cost of polymers and the modification process. The increased cost can impact project budgets, especially for large-scale applications.

Complex Mixing and Handling: Incorporating polymers into bitumen requires precise mixing and handling procedures to ensure proper dispersion and compatibility. Special equipment and procedures are often needed, which can increase project complexity and costs.

Compatibility Issues: Not all polymers are compatible with all types of bitumen. Incompatibility can lead to issues such as phase separation, reduced performance, or unstable properties over time. Compatibility testing is essential to avoid such problems.

Aging and Long-Term Performance: The long-term performance and aging characteristics of polymer-modified bitumen can vary based on factors like polymer type, dosage, and environmental conditions. Some types of polymers may exhibit reduced performance over time due to factors like oxidative degradation.

Environmental Concerns: The disposal of polymer-modified bitumen at the end of its life can be challenging due to the presence of non-biodegradable polymers. This raises environmental concerns, especially if recycling or reusing the modified bitumen is not feasible.

Specific Application Requirements: Different polymer types are suited to different applications. Selecting the right polymer for a specific project requires a deep understanding of the project's requirements, making the decision-making process more complex.

Variability in Performance: The performance of polymer-modified bitumen can vary based on factors like polymer quality, dosage, mixing methods, and curing conditions. Achieving consistent and desired performance across different batches can be challenging.

Construction Challenges: The use of polymer-modified bitumen may require adjustments to construction practices, such as temperature control during mixing and placement. Failing to adhere to these requirements can impact the final pavement quality.

Limited Field Experience: While polymer-modified bitumen has been used extensively in various regions, the long-term field performance of some polymer-bitumen combinations may not be fully documented, leading to uncertainty about their durability.

Expertise Required: Properly selecting, designing, and implementing polymer-modified bitumen projects requires specialized knowledge and experience. Lack of expertise can lead to improper application and suboptimal performance.

Despite these limitations, polymer-modified bitumen remains a valuable option for improving the performance of pavements, especially in demanding conditions. By carefully considering these limitations and addressing them through proper selection, testing, and application, the benefits of polymer modification can often outweigh the challenges.

2.5 Comparing Waste Plastic Modified Bitumen And Conventional Bitumen: Examining the characteristics, advantages, disadvantages, and environmental effects of waste plastic modified bitumen (WPMB) and ordinary bitumen is necessary to make a comparison.

Each choice has its own perks and restrictions. To help you grasp the differences between the two, here is a comparison

WPMB, or waste plastic modified bitumen:

Advantages:

Waste Utilization: WPMB offers a way to recycle and reuse waste plastic products, which helps to promote environmental sustainability and waste minimization.

Performance Enhanced: By adding waste plastic, bitumen's elasticity, flexibility, and resistance to cracking and deformation can be improved.

Temperature Sensitivity: When compared to traditional bitumen, WPMB may function better at low temperatures, making it suited for colder climates.

Reduced Rutting: The increased characteristics of the modified bitumen can result in better resistance to rutting brought on by severe traffic loads.

Environmental Benefits: By incorporating waste plastic into bitumen, plastic waste is converted into a useful resource and less of a burden on the environment.

Limitations:

Compatibility and Consistency: Due to differences in plastic types, sizes, and processing techniques, achieving consistent qualities with WPMB can be difficult.

Processing Difficulty: The proper mixing and treatment of waste plastic into bitumen necessitates the use of specific tools and techniques.

Long-Term Performance: There may be a lack of knowledge regarding the aging and long-term performance characteristics of WPMB, which raises questions about how durable it will be.

Environmental Concerns: Even with the usage of WPMB, plastics may still be found in the environment since eventually degrading materials may produce microplastics.

Conventional Bitumen:

Advantages:

Performance that Has Been Proven: Conventional bitumen has a long history of usage in road building, and its performance and behavior are well established.

Ease of Handling: Conventional bitumen requires less specialized machinery and procedures, making it easier to handle and mix.

Known Longevity: Under different environmental conditions, the long-term performance of conventional bitumen is well-documented and understood.

Limitations:

Traditional bitumen is produced using non-renewable fossil fuels, which adds to resource depletion and environmental problems.

Cracking Propensity: Conventional bitumen may be more prone to cracking, particularly in the presence of extreme temperature changes and high traffic volumes. The production of traditional bitumen from the extraction and processing of fossil fuels has a severe impact on the environment, including the emission of greenhouse gases.

Considerations:

Environmental Impact: While conventional bitumen contributes to the usage of fossil fuels and related environmental problems, WPMB offers a more environmentally friendly option by recycling waste plastic.

Performance: In terms of flexibility, rut resistance, and temperature sensitivity, WPMB may offer improved performance qualities.

Complexity: While ordinary bitumen is easier to work with, WPMB requires careful handling and processing due to the many types of plastic used.

Longevity: While conventional bitumen has a proven track record, the long-term performance of WPMB may still be under investigation.

The decision between conventional bitumen and waste plastic modified bitumen depends on the objectives of the project, the importance of the environment, the resources at hand, and technological considerations. Making an educated choice requires weighing the benefits and drawbacks of both options.

Table 2.1 A Few Characteristics of Various Polymers and Bitumen of Grade 80/100.

	LDPE	HDPE	PP	PS	PVC	PET	Bitumen (80/100 grade)
Sp Gravity	0.918-0.93	0.94-0.96	0.91-0.97	1.04-1.12	1.35-1.39	1.45-1.50	1.01-1.06
Melting Point, °C	100-120	130-140	120-170	235-250	130-190	265-310	54-173
Flash Point, °C	>231	>360	400		>388		>220
Thermal Decomposition, °C	>270	>270-350	270-300	>300			>300

[Source: BTF, 2008]

Table 2.2 A Few Features of a Variety of Polymers and Grade 80/100 Bitumen.

Properties	80/100 grade bitumen	8% by wt. LDPE:PP (3:1) in 80/100 grade bitumen	8% by wt. LDPE:PP (1:1) in 80/100 grade bitumen
Penetration, mm	80-100	43	37
Softening Point, °C	45-52	78	82.5
Ductility, cm	100	50	70

2.6 Method of Blending System

Blending waste plastic with bitumen involves several methods to ensure proper dispersion and compatibility between the two materials. The choice of blending method depends on factors like the type of plastic, the desired properties of the modified bitumen, available equipment, and project requirements. Here are some common methods used for blending plastic and bitumen.

Dry process:

Waste plastic is often cleaned, shredded, and ground into tiny pieces before being used in the dry process. The bitumen is then properly diluted with the ground plastic particles using mechanical mixing equipment. This can apply to rotary mixers, pug mills, or even adapted asphalt plants. To ensure optimal melting and dispersion of the plastic within the bitumen, the bitumen and plastic are heated together to a particular temperature. The mixture is then stirred to distribute the plastic evenly throughout the bitumen.

Wet Process:

The wet method involves combining discarded plastic with an appropriate solvent to produce a plastic solution or suspension. The bitumen is then combined with the plastic solution using high- shear mixing machinery. Better plastic molecule dispersion inside the bitumen is made possible by this method. The bitumen that has been plasticized is left behind as the solvent evaporates.

Mixed in an agitated vessel:

In this technique, bitumen is mixed with waste plastic in an agitated vessel. To help the plastic particles disperse evenly, the mixture is heated and constantly agitated. The mixture can be used for paving once the plastic has completely melted and been mixed with bitumen.

Mixing at High Shear:

In order to effectively disperse the plastic throughout the bitumen, high-shear mixers combine the bitumen and plastic at high speeds using mechanical force. This technique works very well for dispersing plastic particles finely, which improves performance

Plant for Modified Asphalt:

Some asphalt companies have specialized machinery for mixing bitumen with plastic.These facilities have the control necessary to handle the heating, blending, and mixing operations, resulting in consistently excellent outcomes.

Blend continuously:

During the manufacturing process, waste plastic pellets or granules can be added directly to the asphalt binder using continuous blending equipment. Before being employed in construction, the plastic particles are added to the binder stream and mixed using mechanical agitation. It's crucial to keep in mind that for the blending process to produce the best results, temperatures, mixing times, and other factors must be carefully regulated. In order to make sure that the modified bitumen achieves the required performance parameters, proper testing

and quality control processes are needed. The manner of blending that is chosen will also be influenced by the kind of plastic used, how much plastic is used, and the properties of the bitumen. To successfully blend plastic and bitumen for the best results in road building, compatibility tests and expert consultation are essential.

2.7 Use of Polymer Modified Bitumen (PMB) varies by country.

2.7.1Natural rubber latex is used in South Africa, Singapore, the UK, and the USA.

In Singapore, natural rubber latex was used to build roads for the first time ever in 1929. Before academics started showing renewed interest in natural rubber latex in roads, it took another 20 years due to the great depression, the second world war, and the gradual recovery of the global economy. Organizations like the Natural Rubber Producers Research Association (UK), the Transport Research Laboratory (UK), and others have started researching the effects of NRL modification on asphalt durability in road surfaces in the UK, USA, and South Africa. the utilization of natural rubber latex and natural rubber was first studied. Early research evaluated using un vulgarized and lightly vulcanized natural rubber powder and latex.

2.7.2 In the United States, Arizona, California, and Los Angeles use crumb rubber.

As part of a method known as crumb rubber modified asphalt (CRMA), recycled tire rubber is mixed with asphalt to provide more resilient and long-lasting road surfaces. This method enhances pavement performance while addressing difficulties with waste tire disposal. There are several techniques to add crumb rubber to asphalt, including the "dry process" or "wet process," both of which call for combining the rubber crumbs with asphalt binder.
The following are some applications for crumb rubber in the areas you mentioned:

Arizona:

When it comes to employing crumb rubber in asphalt mixtures, Arizona was a pioneer. The state has adopted the widespread usage of crumb rubber in rubberized asphalt. This improves the pavement's elasticity, durability, and resistance to rutting and cracking. Rubberized asphalt projects have been put into place on state highways and roads by the Arizona Department of Transportation (ADOT). In Arizona, crumb rubber modified asphalt (CRMA) has been used to both high- and low-traffic streets.

California:

Another state that has adopted the usage of modified asphalt with crumb rubber is California. In numerous road building projects, the California Department of Transportation (Caltrans) has been a pioneer in the use of rubberized asphalt. Rubberized asphalt is an excellent choice to enhance pavement performance due to the state's large traffic volumes, varied climatic conditions, and environmental considerations. Finding long-term solutions for tire waste management has led to the adoption of rubberized asphalt in California.

In Los Angeles:

In order to build roads, Los Angeles, a significant metropolis in California, uses rubberized asphalt. Rubberized asphalt is a desirable alternative to improve pavement durability and lower maintenance requirements due to the city's enormous road network and traffic demands.

Benefits of asphalt modified with crumb rubber

Rubberized asphalt has higher rut resistance, particularly in locations with heavy traffic loads.
Reduced Cracking: The rubberized asphalt's flexibility helps to minimize cracks.
Noise reduction: Rubberized asphalt is popular for its capacity to muffle sound, making it a good choice for metropolitan settings.

Superior Durability: Rubberized asphalt often has a longer lifespan than regular asphalt.

Environmentally Friendly: Recycling old tires with crumb rubber lessens the impact of tire disposal on the environment.

Despite the many benefits of crumb rubber modified asphalt, there have been discussions and debates about potential environmental and health risks associated to the discharge of micro plastics and chemicals from tire rubber into the environment. The efficiency and safety of crumb rubber modified asphalt projects must be guaranteed by proper quality control, monitoring, and adherence to regulations.

2.7.3 Plastic modified bitumen Used in Other Countries

Plastic modified bitumen, which involves incorporating plastic waste materials into bitumen to enhance its properties, has been adopted in various countries around the world. The use of plastic waste as an additive to bitumen helps address plastic pollution and provides a sustainable solution for road construction. Here are some examples of countries where plastic modified bitumen has been implemented:

India: India has been a leader in adopting plastic modified bitumen technology. The country faces significant challenges with plastic waste management, and using plastic waste in road construction has gained popularity. Several states in India, including Tamil Nadu, Maharashtra, and Kerala, have successfully implemented plastic modified bitumen projects.

Nigeria: To combat plastic pollution and enhance road condition, Nigeria has also used plastic modified bitumen initiatives. The technology is thought to be an effective way to manage plastic garbage and improve road infrastructure.

Malaysia: In an effort to control plastic waste and promote environmentally friendly road building techniques, Malaysia has used plastic modified bitumen.

2.8 Mix Design of Polymer Modified Binder

The mix design of polymer-modified bitumen involves determining the appropriate combination of bitumen, polymers, and other additives to achieve the desired performance characteristics. This process ensures that the modified binder meets the specific requirements of the project, considering factors such as traffic loads, climate conditions, and pavement performance expectations. Here's a general overview of the mix design process for polymer-modified binders:

Define Project Requirements:
Understand the project's objectives, including pavement performance expectations, traffic loads, and environmental conditions.

Select Polymer Type:

Choose the appropriate polymer type (SBS, SBR, EVA, etc.) based on the desired performance improvements and the specific challenges the pavement will face.

Determine Polymer Dosage: Determine the optimum polymer dosage by conducting laboratory tests. This involves blending various polymer percentages with bitumen and evaluating the resulting binder's propertied.

Aggregate Selection: Select aggregates based on their compatibility with the polymer-modified binder and the overall mix design requirements.

Laboratory Testing: Conduct a series of laboratory tests to evaluate the properties of the polymer-modified binder. Common tests include penetration, softening point, viscosity, elasticity, and fatigue resistance.

Mixing and Blending: Depending on the polymer type, blending method, and equipment available, mix the polymer with the bitumen. This might involve using high-shear mixers or specialized polymer blending equipment.

Performance Testing: Evaluate the performance of the polymer-modified binder using tests that mimic real-world conditions. Common tests include rutting, fatigue, low-temperature properties, and adhesion to aggregates.

Optimization: Fine-tune the mix design by adjusting polymer dosages or other additives based on the results of performance testing.

Field Validation (Optional): Consider field trials or pilot projects to validate the laboratory mix design under actual construction and traffic conditions.

Quality Control: Establish quality control procedures to ensure consistency in production and adherence to the designed mix.

Documentation: Document the mix design process, including polymer type, dosage, aggregate selection, and test results. This information is essential for future reference and quality assurance.

Implementation: Once the mix design is finalized, the polymer-modified binder can be used in construction projects, following established procedures for mixing and placement.

It's important to note that the mix design process for polymer-modified binders can be complex and requires expertise in polymer chemistry, asphalt technology, and pavement engineering. Collaboration with experts, manufacturers of polymer modifiers, and relevant testing laboratories is recommended to ensure the success of the mix design and the overall performance of the modified binder in real-world applications.

2.9 Where Bituminous Polymer Products should not be used?

Because of their ability to seal and waterproof, bituminous polymer products like membranes and coatings are frequently employed in infrastructure and building projects. But in some circumstances and environments, some goods might not be appropriate or should be used with caution.

Extremely high temperatures: It can cause bituminous polymer materials to soften or melt. As a result, they might not be appropriate for locations subjected to prolonged exposure to severe heat, like those close to industrial furnaces or have hot climates.

Chemical Exposure: When exposed to specific chemicals, solvents, or acids, bituminous materials may get damaged or degraded. Alternative materials might be better suitable in industrial situations when corrosive compounds are present in high concentrations.

UV Exposure: Bituminous materials can deteriorate over time when exposed to direct sunlight because they are sensitive to ultraviolet (UV) radiation. They might need to be mounted in a way that shields them from direct sunlight or covered with an appropriate protective coating to prevent UV damage.

Areas with Frequent Movement or Vibration: In areas with frequent movement or vibration, such as expansion joints in bridges, bituminous membranes and coatings might not be the ideal option. Flexible or elastomeric sealants may be more appropriate in certain circumstances.

Submerged or Constantly Wet Environments: Bituminous products are water-resistant, however they might not be appropriate for places with high groundwater levels or constant immersion. Concrete waterproofing or epoxy coatings, for example, may be required in such circumstances.

Conditions of Freeze-Thaw: Because of the expansion and contraction of the materials, bituminous products may be more susceptible to cracking or delamination in areas that see frequent freeze-thaw cycles. Alternative materials that can handle these circumstances better should be taken into account.

2.10 Overview:

The articles that came before it gave a quick overview of polymer modified bitumen. Its goal was to demonstrate polymer modification as a workable, affordable method of enhancing pavement performance. According to the literature review, modified binders are employed in many nations for all types of paving and maintenance projects, including chip seals, hot and cold crack filling, patching, slurry sealing, and even airport pavement. Wherever greater performance and durability are sought, they are widely used. Modified binders are steadily replacing the traditional bituminous binder due to their increased stability, durability, and flexibility. A survey of the literature showed that several countries are currently making use of the potential of polymer modification, particularly to address pavement distresses brought on by extremes in temperature, and in some countries, to lessen their waste disposal issues. However, there is minimal research that highlights its ability to lessen drainage-related pavement degradation. This might be because this type of pavement breakdown is not a major issue in wealthy nations. Due to severe drainage issues and an extended rainy season, the latter problem is quite important in Bangladesh, especially in built-up regions.

As a result, there is a critical need for research into polymer-modified bituminous materials and mixes, particularly in reference to how they behave when submerged.

According to the literature analysis in this chapter, the following is a summary of the key findings that emphasize the blending process and technique:

1. The only polymers that can be used to modify bitumen are thermoplastic ones.
2. Scrap tires, tubes, rubber, PET bottles, and used polythene bags can all be mixed with bitumen.
3. KRATON, POLYBILT and SBS (Styrene Butadiene Styrene) are commercially available polymers for bitumen modification.
4. Blending depends on bitumen and polymer compatibility, which depends on the type of polymer and bitumen's chemical makeup.
5. The compatibility of the polymer and bitumen (i.e., mixing), the blending temperature, the blending period, and the application of shear force are all necessary for successful polymer and bitumen blending.
6. To produce polymer-modified binder in large quantities, specialized blending plants are used in industrialized nations.
7. Polymer modified mixes are mixed, laid out, and compacted using standard tools and techniques.
8. Hot mixes with a modified binder made of waste plastic are designed using the Marshall and Hveem mix design methods.
9. Polymer (waste plastic) improves other rheological characteristics of bitumen by increasing viscosity, imparting flexibility, and decreasing temperature susceptibility

CHAPTER 3
Methodology

3.1 Introduction

In road construction, traditional bituminous materials are widely used, especially in flexible pavement. The demand for it is rising every day. However, it has some restrictions on the performances assessed by rheological properties. A significant problem is the modification of binders by adding polymers to them, and ongoing research in this field aims to develop new binders with superior rheological and mechanical properties, enabling the production and use of road bituminous mixes with performance. Waste plastic modified bituminous materials can significantly reduce environmental risks, increase the quality and durability of roads, and reduce the overall cost of maintaining roads. One of the main goals of this work is to determine how much and what type of alterations waste plastic causes in the geological behavior of bitumen when it is merged with it. This collection of exams of a reference binder and a binder modified from waste plastic is needed to investigate. The planned experimental layout is described in Art. 1.5 and is included in this chapter. The design includes choosing a blending method, looking for compatible waste plastic to blend, and evaluating mixes and binder with polymer modifications. The method used for tests and field demonstrations is also covered in this chapter.

Performances of compacted mixes are influenced by the mechanical and physical characteristics of the constituent materials as well as the binder quality. In addition to binder, aggregate makes up the majority of paving mix components. This chapter also includes a brief explanation of the characteristics of the aggregate that will be used in the experiment.

3.2 Method of Blending

In order to increase the performance of asphalt mixtures, polymer and bitumen blending is a typical technique used in road construction and pavement applications. The flexibility, resilience, and longevity of asphalt pavements to various environmental and traffic-related stresses can all be improved by polymer-modified bitumen (PMB). There are various ways to combine polymer and bitumen, each having benefits and drawbacks. Some of the most popular techniques are listed below:

Dry Mixing

In this procedure, hot bitumen is combined directly in a mixer with polymer pellets or powder.

Typically, the mixture is stirred at a constant temperature until the polymer particles are completely dissolved in the bitumen.

Thermoplastic polymers like SBS (Styrene-Butadiene-Styrene) and EVA (Ethylene Vinyl Acetate) can be processed using this technique.

Wet Mixing

In wet mixing, a polymer solution is initially made by dissolving the polymer in a solvent or a hot liquid (such as aromatic oil or a small amount of bitumen).

The residual bitumen is then combined with the polymer solution, and the solvent is then allowed to evaporate.

For polymers, like some varieties of rubber, that are challenging to disperse in bitumen, wet mixing is frequently employed.

3.2.1 Laboratory Milling Machine

In the laboratory, bitumen and polymer are mixed for experimental purposes using this milling machine. It consists of a container, an electric heater, and a rotor that generates shear force. This equipment allows for accurate temperature and shear force control of the blend. This machine can blend the majority of suitable polymers, including recycled polymers (scrap polymers, crumb rubber, and polyethylene bags)

3.2.2 Device for Manual Cooking

It is a manual method that functions on the same principles as a commercial blending system for blending polymer and bitumen. In this apparatus, manual stirring is used to provide the necessary shear force. All types of polymers cannot be blended using this procedure since it is challenging to manage the blending temperature and provide the necessary shear force. This device can be used to blend a few certain polymers that only need low shear forces.

3.3 Compatibility Test

Compatibility tests would be run on a variety of locally accessible recycled polymers, namely polythene bags and pet bottles, in order to locate a suitable modifier. Finding the suitable waste plastic that can be used as a bitumen modifier is the goal of this compatibility test.

3.4 Binder Tests

Testing would be done to determine the characteristics of binders (pure and modified), including their softening point, specific gravity, penetrability, ductility, viscosity, loss upon heating, and other factors. The AASHTO/ASTM standard protocol would be followed for the execution of all of these tests. Here is a quick explanation of the methodologies used in these tests as well as their importance.

3.4.1 Penetration Test

In the context of bitumen, a physical test to ascertain the consistency or hardness of bitumen or asphalt material is referred to as a penetration test. Road paving and roofing are two major uses of bitumen in the construction sector, and these materials' characteristics can affect how well they work and how long they last. A tool known as a "penetrometer" is used to test the bitumen for penetration.

3.4.2 Ductility Test

Bitumen, a substance frequently utilized in the construction of roads and pavements, has ductility as one of its key characteristics. Bitumen's ductility is its capacity to stretch or deform without cracking. For bitumen to be able to survive the pressures and strains it experiences in varied road and weather situations, it is essential. This attribute is evaluated using the ductility test.

3.4.3 Specific Gravity Test

A frequently used test to ascertain the density or mass per unit volume of bituminous materials is the specific gravity test on bitumen. A crucial characteristic is specific gravity since it can reveal details about the purity and make-up of bitumen. It is frequently employed in quality control and in determining the amount of bitumen present in a particular sample. This test is helpful for quality assurance and figuring out how much impurity is present in bituminous materials. In order to secure reliable findings, it is crucial to adhere to defined practices and maintain precise measurements when doing the specific gravity test. It is crucial to refer to pertinent specifications and standards for specific requirements because specific gravity values might vary depending on the type of bitumen and the application for which it is designed.

3.4.4 Viscosity Test

A crucial characteristic of bitumen that gauges its resistance to flow is its viscosity. The performance of bitumen in many applications, particularly in the creation of asphalt, can be considerably impacted by its viscosity. Bitumen is subjected to a viscosity test to ascertain its flow properties under particular circumstances. The "Saybolt Viscometer" or "Viscosity Bath" method is one of several ways to measure the viscosity of bitumen. Bitumen's viscosity is a crucial characteristic that affects how well it performs in a variety of applications. It is crucial to refer to pertinent specifications and standards for specific viscosity requirements because they can vary based on the bitumen's intended purpose.

3.4.5 Softening Point Test

To ascertain the temperature at which a bituminous sample softens and starts to flow under specific circumstances, the softening point test on bitumen is carried out. This test is essential for determining whether bitumen is suitable for use in different contexts, such as roofing and road building. The Ring-and-Ball apparatus method is the one that is most frequently used to establish the bitumen's softening point. Bitumen's softening point is commonly stated in degrees Celsius (°C). It denotes the temperature at which the bitumen softens to the point where the ball can penetrate it for a predetermined distance (often 25.4 mm or 1 inch) and make contact with the ring. When choosing the right bitumen grade for a given application, the softening point is a crucial factor. Bitumen may need to fall within a certain range of softening points depending on the use. The bitumen's ability to tolerate high temperatures without becoming too soft, which is crucial for maintaining road integrity, can be determined, for instance, by the softening point in the construction of roads. In contrast, bitumen with a lower softening point may be preferable in roofing applications to ensure ease of application.

3.4.6 Flash And Fire Point Test

The flash and fire point test is only intended to ensure safety. It shows the highest temperature at which the materials can be heated without risk. The temperature at which bituminous materials, when heated, release vapors that will momentarily catch fire or flash when in contact with a tiny object, is known as the flash point. The temperature at which the developed vapours will catch fire and continue to burn is known as the fire point.

3.4.7 Loss On Heating Test

It is a measurement of the mass of asphaltic and oily components lost during the heating of binders. A higher rate of material loss is undesirable. First, a container containing 50.0 ± 0.5g of the sample is filled, cooled to room temperature, and then weighed to the nearest 0.01g. After that, for five hours, the container containing the sample is kept at a temperature of 163° ± 1°C. The sample is heated, then taken out of the fabric, allowed to cool to room temperature, and weighed once more. Following are the calculations for the loss on heating:

% loss = [(A-B)/A']*100

Where A = the sample plus the container's original weight

B = is the sum of the heated sample and the container's ultimate weight.

A' = the sample's initial weight

3.5 Test on Mixes

3.5.1 Marshal Stability And Flow Test

When assessing the performance and quality of asphalt mixtures, the Marshal Stability and Flow Test is frequently employed in the field of asphalt engineering and pavement building. It evaluates an asphalt mixture's capacity to withstand rutting and maintain stability under traffic volumes and environmental factors. The examination bears Francis Hveem Marshal's name, who created it.

An outline of the Marshal Stability and Flow Test is provided below:

Sample Preparation: A cylindrical specimen of compacted asphalt mixture is made in the lab in order to conduct the test. This sample normally has a diameter of 4 inches (101.6 mm) and a height of 2.5 inches (63.5 mm).

Compaction: A Marshall compactor is used to compact the asphalt mixture to replicate the density it would reach in the field. To compact the sample, a predetermined number of blows are administered (often 75 strikes on each side).

Stability Check: The specimen is compacted and then put within a Marshall stability testing apparatus. After that, a steel plunger is driven into the specimen's core at a specific rate until it breaks. The Marshall stability is the maximum load (in pounds or newton’s) that the specimen can withstand before failing. The asphalt mixture's capacity to withstand deformation and failure under load is indicated by this figure.

Flow Test: In addition to stability, the test also measures the flow of the asphalt specimen. The amount of lateral deformation or displacement brought on by the imposed load is known as the flow. It is frequently expressed in millimeters and indicates how easily the asphalt mixture may deform when loaded without experiencing excessive flow. A pavement can develop ruts due to excessive flow.

Calculation of Density: The specimen's weight and volume are used to determine the density of the compacted specimen. This density figure is used to calculate the amount of air spaces present in the asphalt mixture, a crucial factor in determining how long the pavement will last and how well it will function.

Reporting and analysis: The maximum load (stability), flow value, and density from the Marshal Stability and Flow Test are all provided. These values are used by engineers to evaluate the asphalt mixture's quality and, if necessary, modify the mix design.

In order to ensure the long-term performance and durability of road pavements, the test is essential in planning and creating asphalt mixtures that can endure the stresses and strains of traffic, temperature fluctuations, and other environmental conditions. Based on their unique local conditions and requirements, several areas and agencies could have specific standards for acceptable Marshal Stability and Flow values.

3.5.2 Determination of Specific Gravity

Each type of material's Bulk Specific Gravity (BSG) must be determined in order to calculate volumes from weights when appropriate. The following formula is used to get the Bulk Specific Gravity (BSG) of the total aggregate from the BSGs of the separate coarse aggregate, fine aggregate, and mineral filler fractions:

$$G_{SB} = \frac{P1+P2.....Pn}{\frac{P1}{G1}+\frac{P2}{G2}+\cdots\frac{Pn}{Gn}}$$

Where

G_{sb} = is the aggregate's bulk specific gravity.

P1, P2……..Pn = Individual percentage based on aggregate weight.
G1, G2,……Gn.= Individual bulk specific gravity of the aggregate

3.5.3 Effective Specific Gravity of Aggregate

The Effective Specific Gravity of the Aggregate, (Gse), when based on the Maximum Specific (Gmm) of a Bituminous Mixture, comprises all vacant areas within the Aggregate Particles, excluding those that absorb Bitumen, and is calculated by:

$$G_{se} = \frac{100 - Pb}{\frac{100}{Gmm} - \frac{Pb}{Gb}}$$

Where,

G_{se} = stands for aggregate's effective specific gravity.

G_{mm} = is the combined material's maximum specific gravity when there are no air voids, and

$$G_{mm} = \frac{100}{\frac{Ps}{Gse} - \frac{Pb}{Gb}}$$

Where,

Ps = Aggregate content, percent by mixture's total weight.

Pb = Bitumen content, as a percentage of the mixture's overall weight.

Gse = stands for aggregate's effective specific gravity.
Gb = is the bitumen's specific gravity.

3.5.4 Effective Bitumen content of the mixes

Absorbent bitumen is not included in the effective bitumen content. It is determined by using:

$$P_{be} = P_b - \frac{Pba * Ps}{100}$$

Where,
P_{be} = Effective bitumen content, percent by the total eight of the mixture
Pb = Bitumen content, as a percentage of the entire mixture.
P_{ba} = Absorbed bitumen, expressed as a percentage of aggregate weight.
Ps = Aggregate content, percent by mixture's total weight

3.5.5 Air Void

The term "air void" refers to the air spaces between the bitumen-coated aggregates in paving mixtures. It has a huge impact on how well a pavement performs. A paving mixture with too many air gaps may strip, enabling water to remain inside. The following formula is used to determine the air void of compacted mixtures.

$Va = 100 (G_{mb} G_{mm}) /G_{mm}$

Va = the air void in the compacted mixture. % of the whole volume

G_{mm} = The paving mixture's maximum specific gravity

G_{mb} = The paving mixture's bulk specific gravity

3.6 Material Characteristics

The two main components of flexible pavement are. Aggregate and binder are these two substances. Binder has a significant impact on how well pavement performs. Bitumen is typically employed as a binder in the creation of pavement. This research endeavor will examine the properties of polymer (waste plastic) modified bitumen (PMB). Virgin bitumen, waste plastic, and aggregate would be needed as raw materials for the study project. The remaining ingredients are kept the same during the entire experiment in order to evaluate exclusively the impact of waste plastic on the binder and mixtures. The following is a brief overview of these components and their properties.

3.6.1 Polymer / waste plastic

A huge molecule made up of repetitive structural units is referred to as a polymer, which is a general phrase. Long chains are created by joining together these structural components, or monomers, through chemical bonds. Plastics, rubber, and synthetic fibers are only a few examples of the diverse materials that contain polymers.

On the other side, waste plastic describes plastic items that have been abandoned and are no longer in use. Due to its permanence in the environment and harmful effects on ecosystems and human health, plastic garbage is a major environmental concern. It has become difficult to manage plastic garbage on a global scale.

Various Polymer Types:

Polymers come in a variety of forms, including natural polymers like cellulose, starch, and proteins as well as synthetic polymers like polyethylene, polypropylene, and polyvinyl chloride.

Plastics, which have a wide range of uses, from packaging materials to consumer goods to car parts, are frequently made using synthetic polymers.

3.6.2 Bitumen

Bitumen is an extremely viscous, dark-colored petroleum compound that is also known as asphalt or tar (in some situations). It can be obtained by refining crude oil or is a naturally occurring material found in deposits. Bitumen is utilized in a variety of different industrial and commercial applications, although it is most commonly used in the construction and road paving industries. In a bituminous pavement, bitumen holds the aggregate together. The source of the crude, the refinement procedure, and the chemical make-up of the bitumen all affect its quality. The chemical composition has an impact on bitumen and polymer compatibility. Bitumen is typically given a "grade" designation, despite the fact that this does not reflect its general quality. The qualities of the base bitumen have an impact on how well the modified bitumen performs. In this study, bitumen with a 60/70 penetration rating is employed.

3.6.3 Aggregate

When discussing construction and civil engineering, the term "aggregate" refers to a granular substance that is a component of concrete, asphalt, and other building materials. Sand, gravel, crushed stone, and even recycled materials like recycled concrete are common sources of aggregates, as are other natural deposits like sand and gravel. They are a crucial component of building supplies and are utilized to give constructions strength, stability, and durability. One of the main materials used to build pavements is aggregate, which also contributes significantly to the structure of the pavement. In the building of bituminous concrete pavements, aggregate is employed as the granular base course, sub base course, and surface course.

The mix attributes are greatly influenced by the mechanical and physical characteristics of the aggregate, such as hardness, toughness, and durability.

3.6.4 Coarse Aggregate

Construction and civil engineering professionals use the term "coarse aggregate" to refer to a variety of granular materials that are typically bigger in size than fine aggregates. These compounds are used in a variety of construction applications, typically to give concrete or asphalt mixtures strength and stability. A sizeable fraction of the overall volume of concrete or asphalt is made up of coarse aggregates.

3.6.5 Fine aggregate

In construction and civil engineering, the phrase "fine aggregate" refers to a particular kind of granular material with smaller particles than coarse aggregate. Sand, broken stone, or gravel fragments smaller than 3/8 inch (9.5 mm) in diameter often make up fine aggregates. They are essential in the creation of mortar, concrete, and other building supplies.

3.7 Gradation of Aggregate

The distribution of different particle sizes within a sample of aggregate material is referred to as gradation of aggregate, also known as particle size distribution. It is a crucial characteristic that influences the performance, durability, workability, and strength of concrete, asphalt, and other building materials. A sieve analysis is commonly used to determine the gradation of aggregate. In this procedure, the aggregate is divided into various size fractions using a succession of sieves with progressively smaller apertures.

Table 3.1 Gradation of Combined Aggregate

Sieve Size	Range Of % Finer By Wight	Average % Finer By Wight	% Retained	Type Of Aggregate(%)
3/8"	63-73	68	32	Coarse Aggregate 64%, Fine Aggregate 31% & Mineral Filler 5%
No 4	45-55	50	50	
No 8	31-41	36	64	
No 50	7-17	12	88	
No 200	3-7	5	95	
Pan	0	0	100	

CHAPTER 4
Laboratory Investigation and Test Results

4.1 Introduction

The project's primary goals are to: i) identify the engineering and rheological characteristics of modified waste plastic binder; and ii) examine the impact of modified waste plastic bitumen on the quality of the road; and iii) evaluate the field performance of the section of bituminous pavement blended with waste plastic. Waste plastic is employed as a modifier in this project. Penetration, ductility, softening point, flash & fire point, specific gravity, and loss on heating tests are performed on both virgin bitumen (VB) and polymer modified bitumen (PMB) in order to evaluate quality improvement and compare the two types of binder. The compacted pavement mixes made with reference bitumen and polymer-modified bitumen are also subjected to Marshall testing. It should be noted that all test samples of the modified binder were created using waste plastic as a modifier.

4.2 Binder Test Result

Seven conventional tests are performed on the binders. Some important properties of binder such as temperature susceptibility, consistency, adhesive quality, etc. are assessed from these test results.

4.2.1 Penetration test result

In general, bituminous materials' semisolid and solid states of consistency are assessed using the penetration. Bituminous minerals that are semisolid are categorized into standard rating for consistency. The penetration test has little significance because grade does not equal quality in respect to binder quality. This test is empirical. Results of a penetration test conducted on Table 4.1 displays modified and untreated bitumen. The penetration of residue from the loss on heating test is also shown in the table.

Figure 4.1 displays a penetration versus waste plastic content plot. As seen in figure 4.2, the penetration value drops fairly equally in cases where the LOH test is conducted both before and after. As a result, bitumen becomes more firm and consistent as a result of waste plastic.

The bituminous binder gives the bituminous pavement mixtures cohesion or tensile strength. For bitumen to be used in tropical climates, deeper penetration values are typically preferred to stop bleeding in pavement. On the other hand, bitumen gradually hardens in the field as a result of oxidation or aging.

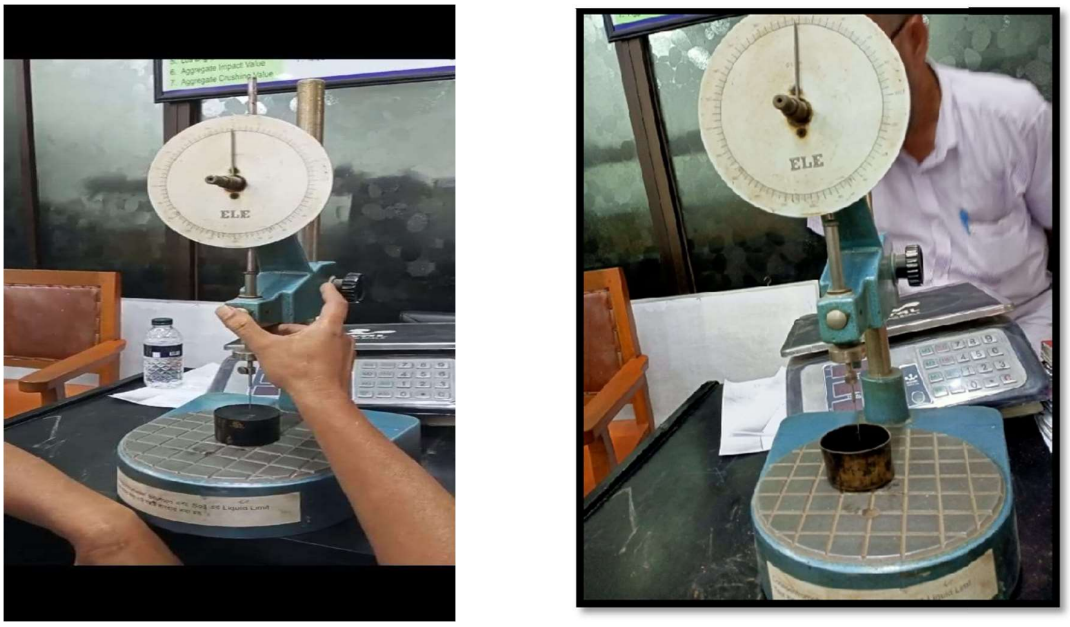


Figure 4.1 Penetration Test by Cone Penetrometer

Table 4.1 The Results of Penetration Test on Pure and Waste Plastic Modified Bitumen.

Test Method	Waste Plastic Content (%)	Penetration (1/10mm)	Penetration of Residue from LOH(1/10mm)
AASHTO T49-93 ASTM D5-86	0.00 (Pure Bitumen)	70	63
	2.5	58	25
	5	41	18
	7.5	22	15
	10	19	11
	7.5*	47	45

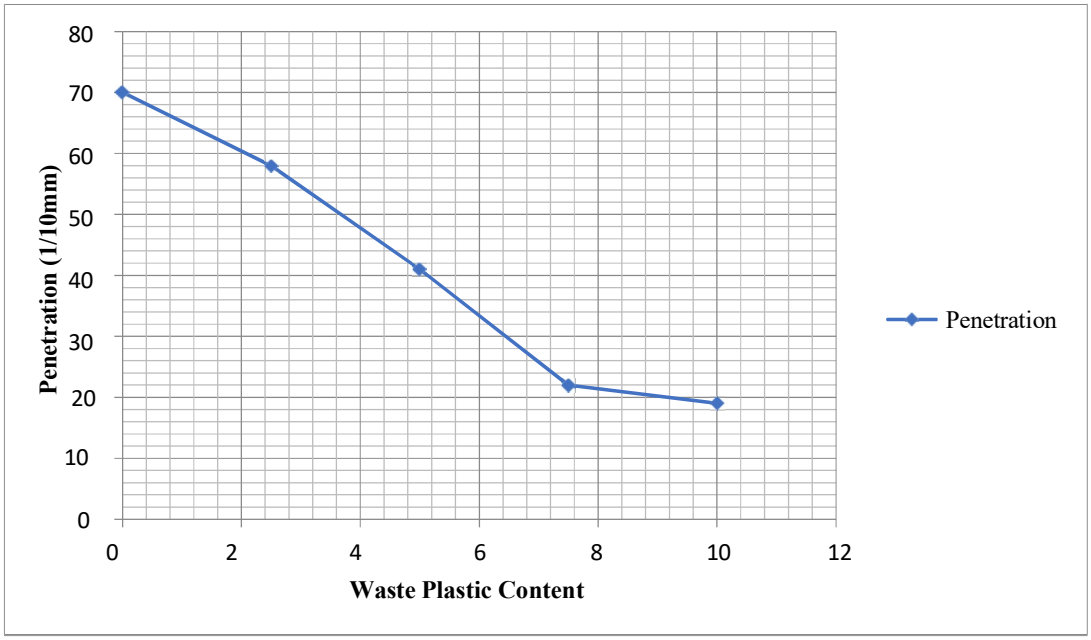


Figure 4.2 Variation of Penetration with Waste Plastic Content

4.2.2 Ductility Test

The results of the ductility test are shown in Table 4.2 and Figure 4.3. The findings show that as the amount of waste plastic in a binder increases, ductility drastically declines. The original bitumen had a ductility of more than 100 cm. For 10% of waste plastic content, its ductility value drops to 14. When compared to the reference bitumen, which has a ductility value of more than 100 cm, the resultant loss of ductility with this waste plastic component is greater than 86%. This suggests that the ductility property of pure bitumen is significantly impacted by the use of waste plastic as a modifier. It is also clear from Figure 4.4 that the relationship between the change in ductility value and waste plastic content is nonlinear. The ductility property changes more quickly.



Figure 4.3 Ductility Test of Modified Bitumen.

Table 4.2 The Results of Ductility Test on Pure and Waste Plastic Modified Bitumen.

Test Method	Waste Plastic Content (%)	Ductility (cm)
AASHTO T51-93 ASTM D113-79	0.0 (pure bitumen)	100
	2.5	33
	5	29
	7.5	16
	10	15
	7.5*	42

*PET Bottle

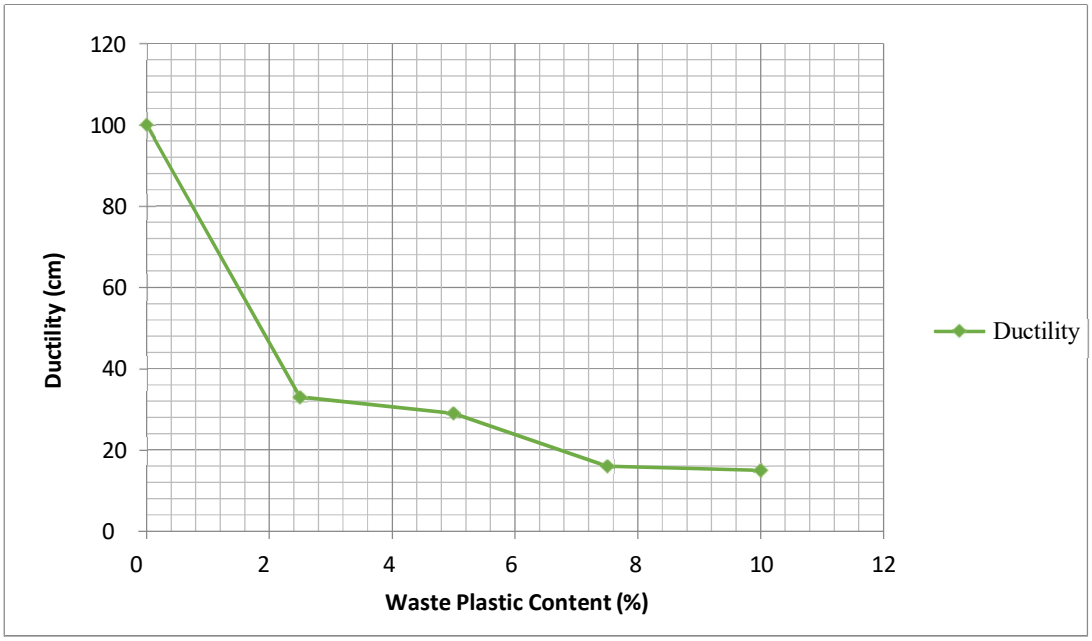


Figure 4.4 Variation of Ductility with Waste Plastic Content

4.2.3 Softening Point Test

Table 4.3 and Figure 4.5 show the findings of the softening point test. The temperature at which a binder transforms from a semi-solid to a liquid condition when subjected to the weight of an ordinary steel ball is known as the softening point. It is not a melting point measurement.

The softening point test is actually used to gauge the sensitivity of the binder to temperature. Figure 4.6 shows that when there is a 10% component of waste plastic, the softening point rises to 70°C from 50°C. Higher temperatures will be needed to soften the modified binder since polymer content increases the consistency of the binder. From 6, it can be determined that the softening point has increased by around 40% with the addition of 10% waste plastic to the virgin binder.



Figure 4.5 Softening Point Test of Modified bitumen.

Table 4.3 The Results of Softening point on Pure and Waste Plastic Modified Bitumen.

Test Method	Waste Plastic Content (%)	Softening Point (C)
AASHTO T53-92 ASTM D36-89	0.0 (pure bitumen)	50
	2.5	53
	5	59
	7.5	69
	10	73
	7.5*	58

*PET Bottle

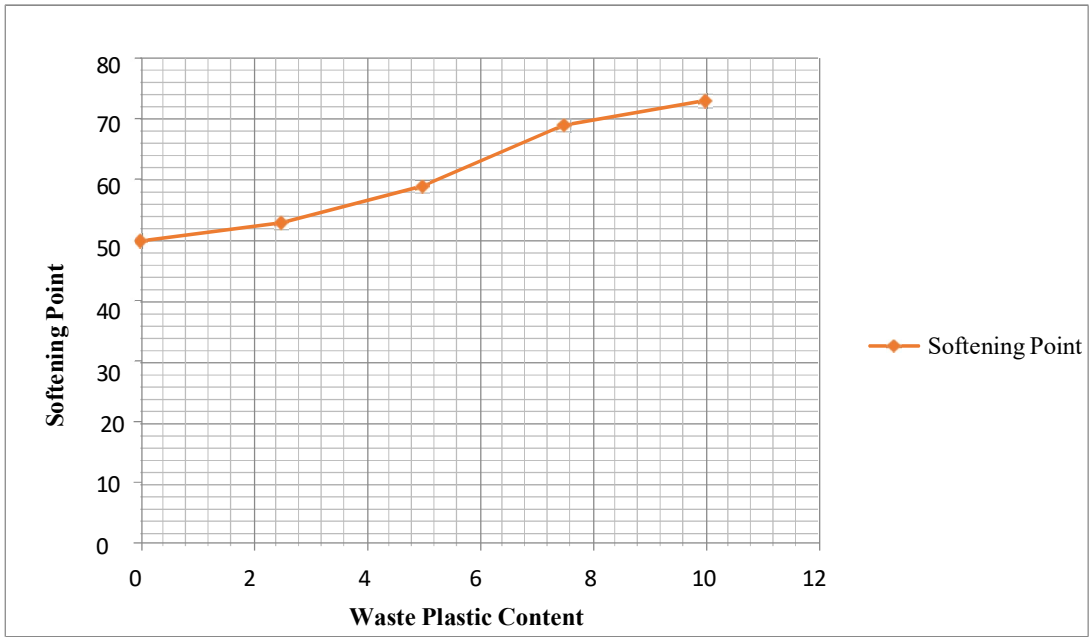


Figure 4.6 Variation of Softening with Waste Plastic Content

4.2.4 The Impact of Used Plastic in Points of Ductility, Penetration, and Softening Point

The combined Figure 4.7 shows how waste plastic affects ductility, penetration, and softening points. The findings of penetration, ductility, and softening point tests reveal that adding more waste plastic increases the binder's stiffness while decreasing its temperature susceptibility

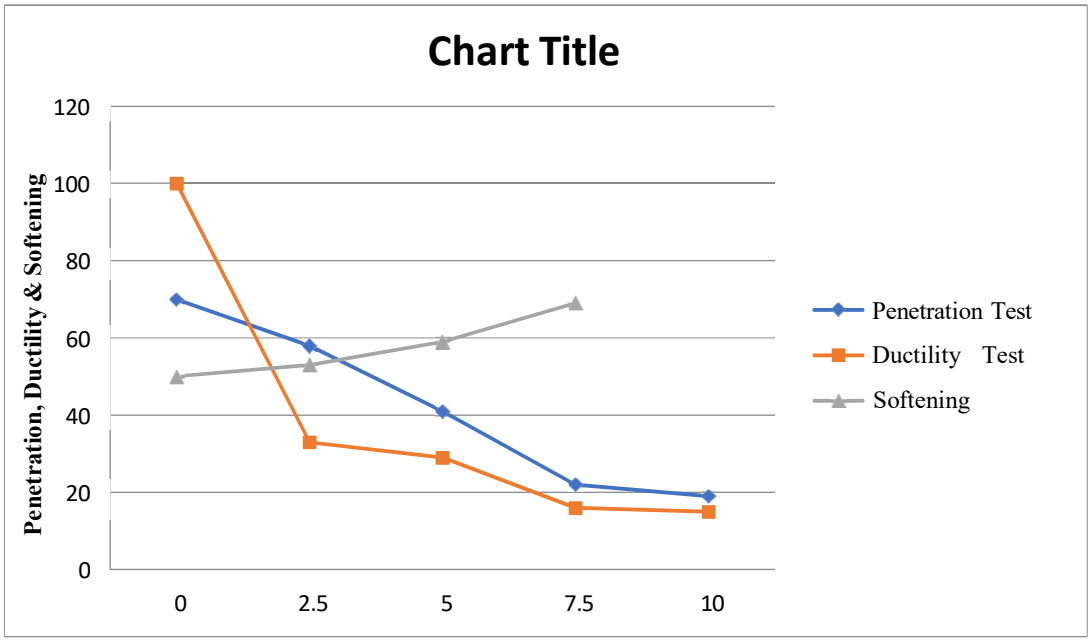


Figure 4.7 Variation of Penetration, Ductility & Softening Point with Waste Plastic Content in Bitumen.

4.2.5 Specific Gravity Test

In Table 4.4 and Figure 4.8, the specific gravity test findings are displayed. The Table and Figure show that when the amount of waste plastic in modified bitumen increases, its specific gravity falls. Virgin bitumen has a specific gravity of 1.025. This value is now 1.10 for a 10% waste plastic content. It is possible that waste plastic (LDPE) has a lower specific gravity than bitumen.

Table 4.4 The Results of Specific Gravity test on Pure and Waste Plastic Modified Bitumen.

Test Method	Waste Plastic Content (%)	Specific Gravity
AASHTO T228-93 ASTM D70-76	0.0 (pure bitumen)	1.025
	2.5	1.019
	5	1.015
	7.5	1.013
	10	1.008
	7.5*	1.029

*PET Bottle

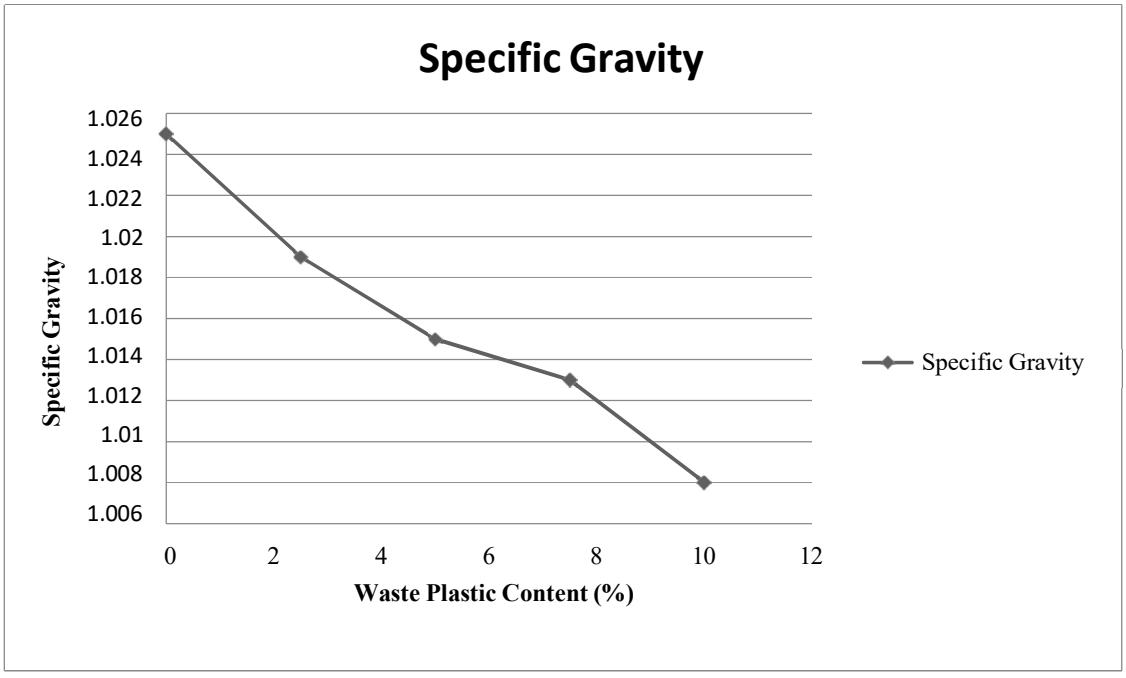


Figure 4.8 Variation of Specific Gravity with Waste Plastic Content

4.2.6 Loss on Heating Test

The test calculates the amount of bitumen volatiles lost as a result of heating. Table 4.5 displays the loss on heating test results. To weigh the substance for this test, a very delicate balance is needed. However, there could be some inaccuracy in the data because a sensitive balance was not present in the lab. No conclusive conclusion could be drawn from the results shown in Table 4.5 regarding the impact of waste plastic on the loss of heating of the modified binder. The results of the experiments indicate that the amount of extra waste plastic that bitumen loses volatile material owing to heating is negligible. Material loss for reference bitumen is 0.02% and for modified bitumen including 7.5% waste plastic is found to be 0.04%. Lack of knowledge could lead to this.

Table 4.5 The Results of Loss on Heating Test on Pure and Waste Plastic Modified Bitumen.

Test Method	Waste Plastic Content (%)	Loss on Heating (%)
AASHTO T47-83 ASTM D06-86	0.0 (pure bitumen)	0.03
	2.5	0.03
	5	0.04
	7.5	0.04
	10	0.03
	7.5*	0.03

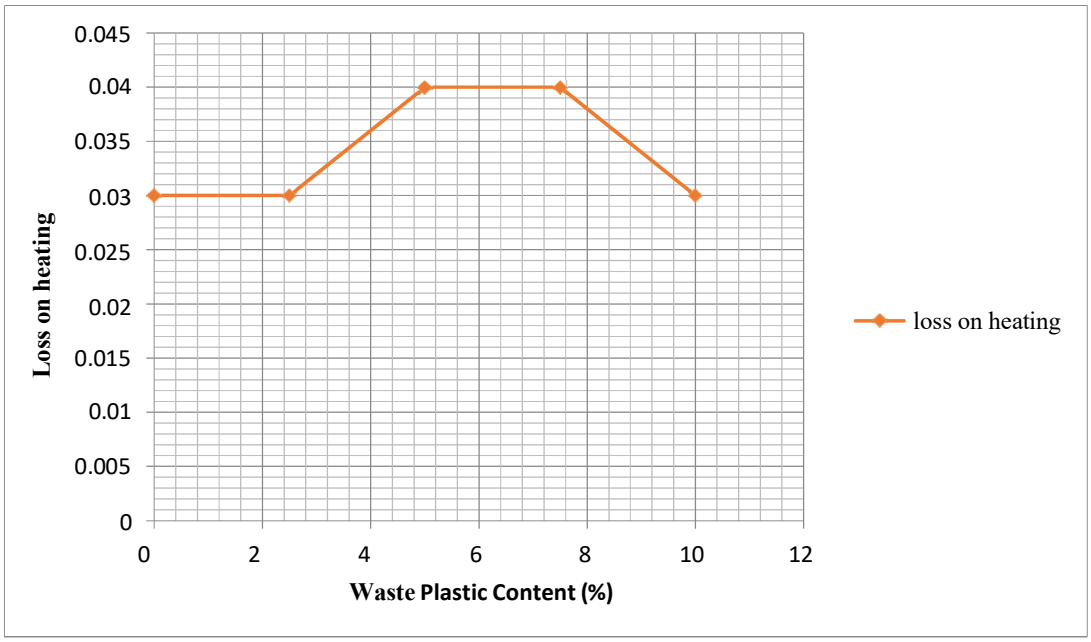


Figure 4.9 Variation of Loss on Heating with Waste Plastic Content

4.2.7 Flash and Fire Point Test Results

Purely a safety test, the flash and fire point test. In table 4.6 the test results are displayed. The findings demonstrate that, up to a maximum level of 7.5%, waste plastic content causes an increase in both flash and fire points. The greater flash and fire point values brought on by the inclusion of waste plastic are encouraging in terms of safety.

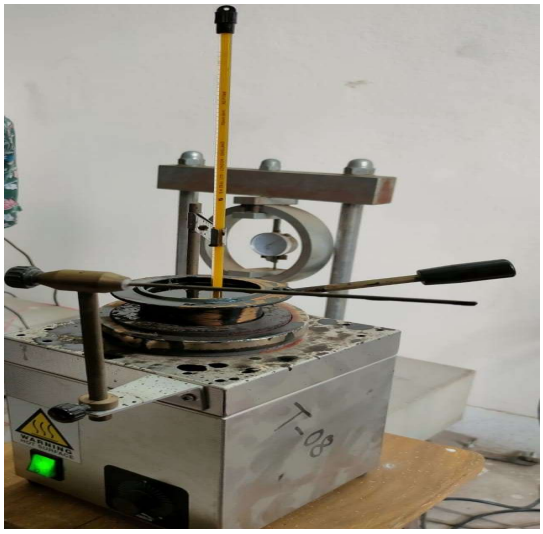


Figure 4.10 Flash and Fire Point Test of Modified Bitumen

Table 4.6 The Results of Flash and Fire Point test on Pure and Waste Plastic Modified Bitumen.

Test Method	Waste Plastic Content (%)	Flash Point (℃)	Fire Point (℃)
AASHTO T48-91 ASTM D92-85	0.0 (pure bitumen)	288	341
	2.5	293	342
	5	326	353
	7.5	337	352
	10	296	312
	7.5*	321	351

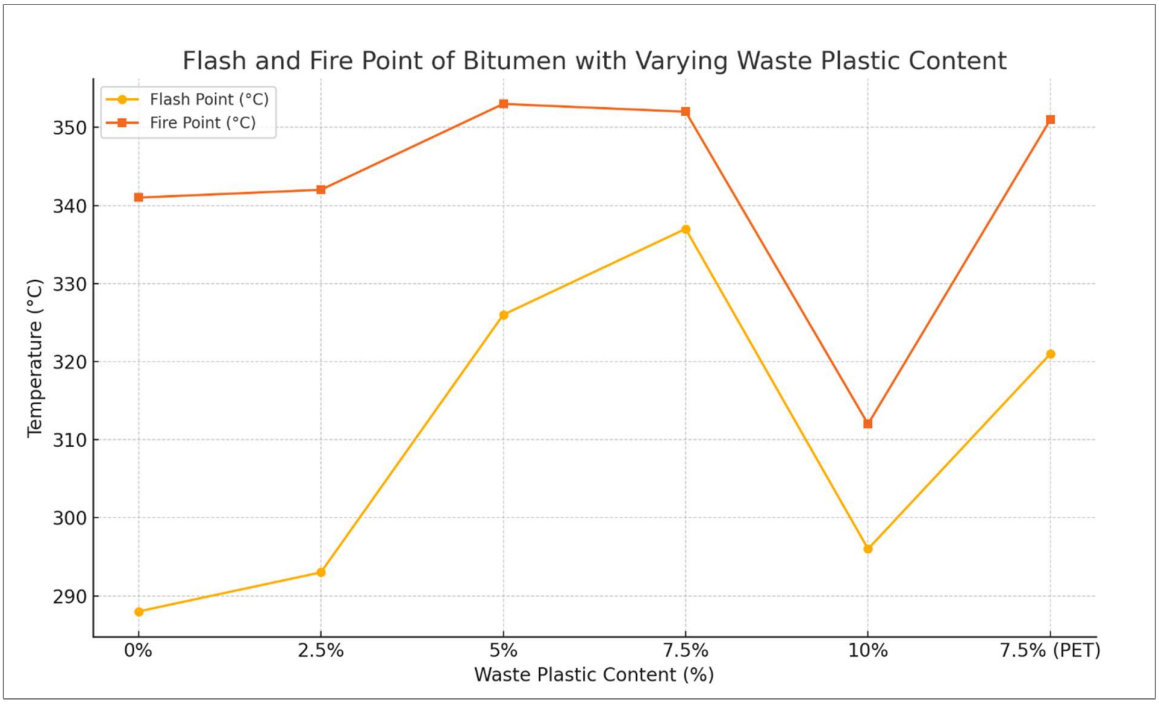


Figure 4.11 Flash and Fire Point of Bitumen with Varying Waste Plastic Content

4.3 Comparison of the Test Results of Mechanically Blended Binder with those of Manually Blended Binder

It is evident from all the test results shown in the following table 4.7 that whether waste plastic is blended mechanically or manually has no discernible impact on the qualities of the binder. Additionally, it is observed that the penetration of the hand blended binder is higher, which is preferable.

Table 4.7 Comparison of the Test Results with those of Previous Researcher (Hossain, 2006)

Polymer Content (%)	Penetration at 25°C (1/10mm)		Softening Point		Specific Gravity		Ductility at 27°C		Loss on Heating (%)	
Plastic is Used in this Study and waste type is used in the study of Hossain	Result of this study	Result of this Hossain	Result of this study	Result of this Hossain	Result of this Study	Result of this Hossain	Result of this study	Result of this Hossain	Result of this study	Result of this Hossain
0.0	70	89	50	49	1.025	1.030	100	100	0.03	0.060
2.5	58	61	53	55	1.019	1.039	33	79	0.03	0.009
5	41	50	59	58	1.015	1.044	29	59	0.04	0.007
7.5	22	32	69	64	1.013	1.054	16	29	0.04	0.005
10	19	22	73	69	1.008	1.060	15	16	0.03	0.004

4.4 Marshall Test Results

4.4.1 General

Here, a comparative analysis of pure and waste plastic blended bitumen is presented in order to evaluate their performance. All of the Marshall Test characteristics are utilized as a measure of index for the performance evaluation of modified mixes. Volumetric analysis of the test specimens is also provided here in addition to Marshall Stability and Flow testing. The Marshall Test raw data and associated calculations are contained in the Appendix at the conclusion of this report.

4.4.2 Marshall Stability

The stability test results are shown in Table 4.8 and Figure 4.12 The stability versus binder content curves are shown in Figure 4.13. The trend of the stability curves for the mixes with changed binders is almost identical to that of the mixes with pure bitumen, as can be seen in the Figure. The chart also shows that, up to a certain percentage of binder content, all combinations become more stable. The increasing trend of six successive curves shows unmistakably that bitumen's stability rises as its waste plastic component rises (up to 7.5%).



Figure 4.12 Marshall Stability and Flow Test.

Table 4.8 Marshall Stability Values for Mixes with Pure and Waste Plastic Modified Bitumen (Binder Content 5%)

Waste Plastic	Marshall Stability (lb)
0	1485
2.5	1870
5	1810
7.5	2335
10	1947
7.5*	2165

*Result of PET Bottle

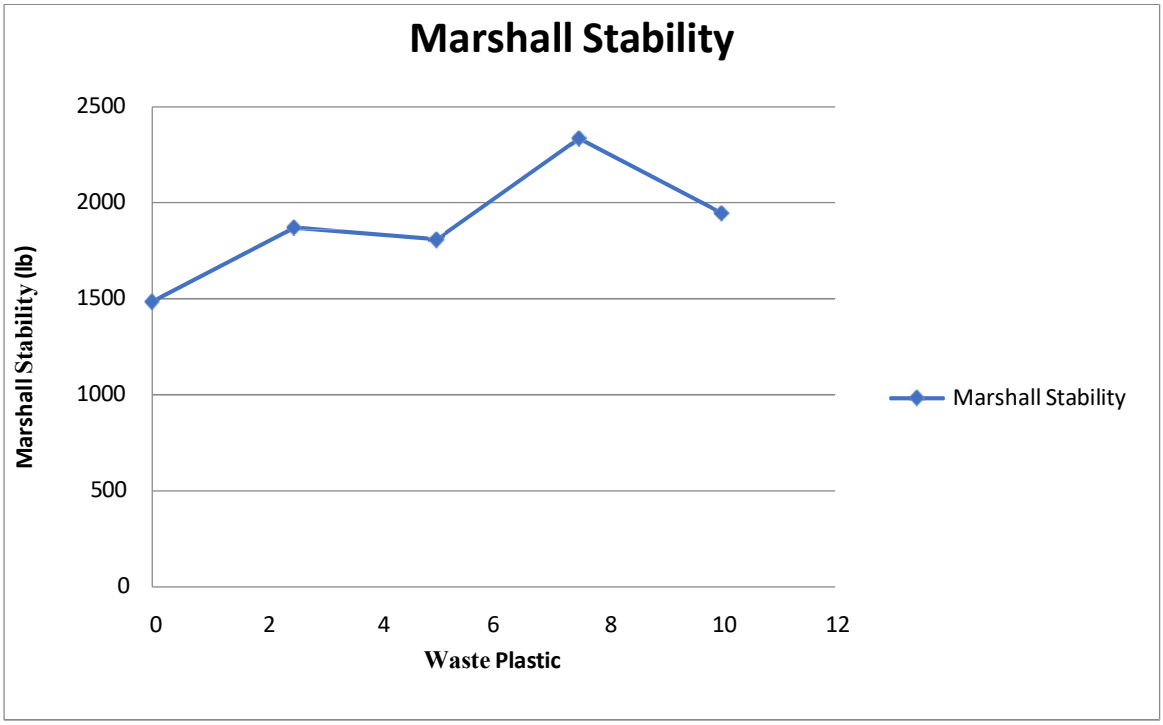


Figure 4.13 Variation of Marshall Stability Value for mixes with Pure and Waste Plastic Content.

4.4.3 Flow Value

The maximum deformation at which a Marshall specimen fails is termed as the flow value. It is a measure of deformation. Higher flow value of bituminous pavement indicates lower rigidity. The variation of Marshall Flow values with binder content is presented in Table 4.9 and Figure 4.14

From the results it can be observed that for all the binder contents the flow values increase with the increase of waste plastic content up to an optimum level (7.5%). So, it can be said that modifier could not be used in any proportion to modify binder. Other research results (Shell Chemicals) also reveal that though due to application of polymer in bitumen increases the flow values but at the same time it significantly improves the elastic property of Bitumen.

Table 4.9 Marshall Flow Values for Mixes with Pure and Waste Plastic Modified Bitumen (Binder Content 5%)

Waste plastic (%)	Marshal Flow (lb)
0	11
2.5	16
5	14
7.5	19
10	14.5
7.5*	20

* Result of PET Bottle

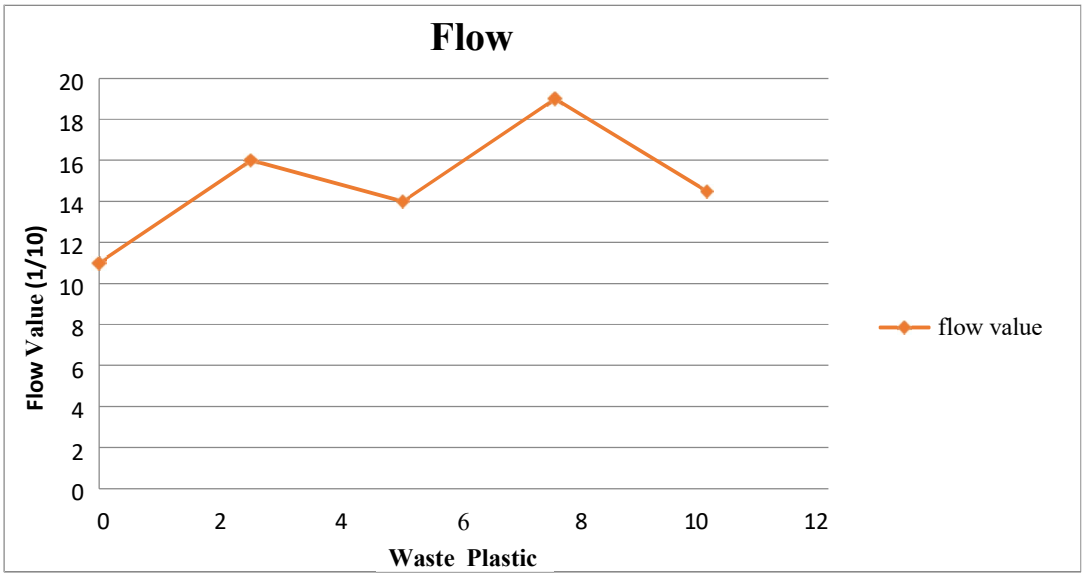


Figure 4.14 Variation of Marshall Flow Value for mixes with pure and Waste Plastic Content

Chapter 5
Conclusion And Recommendation

5.1 Introduction

This study's major goals were to identify waste plastics that may be combined with bitumen and evaluate the performance of such roads. The improved binder was explored through thorough laboratory experimentation in accordance with other research aims. In order to compare their rheological properties, virgin bitumen and waste plastic modified bitumen were compared. The Marshall Method of mix design was used to examine the Marshall Stability, Flow, and other characteristics of bituminous mixes made using this modified binder and pure bitumen.

5.2 Conclusion On Experimental Result

5.2.1 Rheological characteristics of modified waste plastic binder

By using tests like penetration, ductility, softening point, flash and fire point, specific gravity, etc., the rheological characteristics of binders (pure bitumen and modified bitumen) were assessed. By examining the test findings on the binders, the following inferences can be made:

• As the amount of waste plastic in bitumen increases, the penetration of the modified binder for waste plastic reduces. When 7.5% waste plastic is added to bitumen, it has been found that penetration is reduced by more than 70% compared to pure bitumen.

• As more waste plastic is added to bitumen, the ductility of the modified waste plastic binder rapidly declines. According to results of an experimental examination, bitumen with a 7.5% waste plastic concentration loses more than 83% of its ductility when compared to pure bitumen.

As the amount of plastic in the bitumen rises, so does the softening point.

When 7.5% waste plastic is present in bitumen, the softening point rises by around 36% in comparison to virgin bitumen.

• The loss from heating and modified binder with a specific gravity close to pure bitumen.

5.2.2 Waste plastic modified bituminous mix characteristics

The required experiments were carried out on compacted mixes made with waste plastic modified bitumen and normal bitumen. The results of the tests on the mixtures show that:

• The stabilities of the compacted mixes dramatically increase as bitumen content of waste plastic rises to 7.5%, and then show a diminishing trend at 10% waste plastic content. The ideal amount of waste plastic might therefore be assumed to be 7.5%.

- According to the results of the Marshall Specimen stability test, adding 7.5% waste plastic to the binder boosts Marshall Stability by roughly 21% compared to 5% binder content. This means that 7.5% waste plastic can be added to bituminous mixtures to increase their strength without modifying any other mix ingredients.
- The flow values obtained during the Marshall experiments exhibit a rising pattern as the amount of waste plastic in the mixture rises to 7.5%.

5.3 RECOMMENDATION

According to the study's findings, Bangladesh's traditional road pavement could perform much better if waste plastics were added as a modifier to the bituminous coating. The suggestions are listed below.

1. Government agencies like RHD, LGED, and City Corporations should come up with at least one comprehensive project of processing waste plastics and constructing roads using the waste plastic modified bituminous mix.
2. City Corporations in Bangladesh may use the Bangalore City Corporation's collection methods for plastic garbage. The collection method might involve the private sector.

Improvements must be made to the locally made machinery and equipment for shredding and combining waste plastics. It is important to support and include the private sector. The government might offer the required financial inducements.

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