Performance and evaluation of polymer-modified Asphalt Binder (Laboratory-based testing and analysis).

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DEPARTMENT OF CIVIL ENGINEERING

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UNDERTAKING

I Certify that research work titled "Performance and evaluation of polymer-modified Asphalt Binder (Laboratory-based testing and analysis)" is my work.

The Work has not presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged/referred.

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Chapter 1

Introduction

1.1 Introduction:

Road infrastructure is a critical component of modern society, facilitating the movement of people and goods and supporting economic development. Asphalt pavements, which cover a significant portion of our road networks, play a crucial role in providing smooth and durable driving surfaces. The performance and longevity of asphalt pavements depend largely on the properties of the asphalt binder used in their construction.

Traditional asphalt binders, is obtain from crude oil, have limitations in terms of their durability and resistance to aging and distresses such as rutting and cracking. Polymer-modified asphalt (PMA) binders have emerged as a solution to enhance the performance and longevity of asphalt pavements. By incorporating polymers into asphalt, PMA binders' exhibit improved properties, including enhanced elasticity, flexibility, and resistance to aging and deformation.

Despite the advantages of PMA binders, there is a need for further research to understand their long-term performance and aging characteristics. This project aims to address this need by conducting a comprehensive investigation into the longevity and performance of PMA binders. By focusing on the durability and aging characteristics of PMA binders, this research seeks to provide valuable insights into their behavior over time and their suitability for use in road construction.

The Research will utilize laboratory-based testing to evaluate various properties of PMA binders, including their rutting resistance, cracking resistance, durability, adhesion, and aging characteristics. These tests will provide a detailed understanding of how PMA binders perform under different conditions and loading scenarios. By analyzing the results of these tests, the project aims to identify the optimal mixtures and formulations of PMA binders for more sustainable and resilient road construction practices.

1.2 Composition of Conventional Asphalt:

1.2.1 Coarse aggregate:

Coarse aggregates are the granular particles that retain on NO #4 sieve.

OR

Coarse aggregates are particulates that are greater than 4.75mm

The strength and rut resistance of Asphalt is mostly depends upon on the aggregate mix is 100% crushed and with good shape (cubical) and strength limits for abrasion resistance and crushing strength. The sand used must be crushed sand as the internal friction contributes into the overall strength.

1.2.2 Fine Aggregate:

Fine aggregates generally consist of natural sand or crushed stone.

It can pass through #4 Sieve and retained on #200 sieve**.** Water absorption of a fine aggregate of any nominal size from any source must not exceed 3.5%. Soundness: The weighted percent loss from a fine aggregate must not exceed 12% of the test portion.

1.2.3 Filler:

Mineral filler used in asphalt mixtures consists of fine-grained mineral particles either naturally present or grinded separately, and added to the asphalt or cement concrete.

It has often been defined as the portion of aggregates passing through #200 sieve (ASTM D242, 2000)

1.2.4 Bitumen:

Bitumen is a mixture of hydrocarbon, obtained by the fraction distillation of crude oil,

OR

Bitumen can also be found as a natural deposit obtained during the refining process of petroleum or as a compound of naturally occurring asphalt with mineral substances in it.

1.3 Problem statement:

Due to uncontrolled axial load, high and low temperature produces distress in pavement surface course. To overcome this problems we add polymer in asphalt binders to improve it properties and resistance against distress. While polymer-modified asphalt binders offer significant benefits, questions remain about their long-term performance and durability. Aging processes, environmental factors, and variations in binder composition can all influence the binder's properties, potentially impacting road quality and lifespan. To address these concerns and facilitate informed decision-making in road construction, it is imperative to comprehensively study the aging and durability characteristics of polymer-modified asphalt binders.

1.4 Aims and Objective:

The main objective of this study;

1. The objective of this study was to evaluate the performance polymer in asphalt mixture using parameter of stiffness and Rutting.
2. To perform the consistency tests for different percentage of polymer in Asphalt to characterized the modified asphalt Binder.

3. To perform marshal max design to find the OBC (optimum binder content) and also check marshal max stability against each percentage.
4. To performed Wheel tracking test (WTT) for modified and unmodified to investigate the Tracking effect.

1.5 Significances of research:

The significance of the research on the performance and evaluation of polymer-modified asphalt (PMA) binders through laboratory-based testing and analysis lies in its potential to address critical challenges in road construction and maintenance. Here are some key points highlighting the significance of this research:

1) **Enhanced Performance:**

   PMA binders have the potential to significantly improve the performance of asphalt pavements compared to conventional asphalt binders. Understanding their performance characteristics through comprehensive laboratory testing can lead to the development of more durable and long-lasting roads.

2) **Sustainability:**

   By improving the durability of asphalt pavements, PMA binders can contribute to sustainability efforts in the transportation sector. Longer-lasting roads require less frequent maintenance and repair, reducing the consumption of materials and energy associated with road construction and maintenance.

3) **Cost-Effectiveness:**

   Developing optimized PMA binder formulations can lead to cost-effective road construction practices. By reducing the frequency of maintenance and repair activities, PMA binders can help save costs associated with road infrastructure management.

4) **Safety:**

   PMA binders can enhance the safety of road users by improving pavement performance. By reducing the occurrence of distresses such as rutting and cracking, PMA binders can help create smoother and safer driving surfaces.

5) **Innovation in Materials Science:**

   Research on PMA binders contributes to the field of materials science by exploring new formulations and additives that can improve the properties of asphalt binders. This can lead to innovations in other applications requiring high-performance binders.

6) **Infrastructure Resilience:**

   As climate change leads to more frequent and severe weather events, resilient infrastructure becomes increasingly important. PMA binders, with their enhanced properties, can help improve the resilience of asphalt pavements to withstand the effects of climate change.

1.6 Expected Outcome:

A comprehensive understanding of the durability and aging characteristics of polymer modified asphalt binders, enabling informed decisions in road construction.

Polymer-modified asphalt binders are recommended for improved durability and resilience in roads.

Identification of opportunities for cost savings through the optimization of binder materials without compromising pavement performance.

1.7 Thesis structure

Thesis includes five chapters and six appendices. A brief description of the chapters' contents is presented below:

Chapter 1: Introduction

This chapter is a briefly introduction, which highlights the concept of research. In addition, statement of problem, aim, objectives and methodology of research are described.

Chapter 2: Literature review

Brief introduction related to hot mix asphalt, polymers, plastic waste and its utilization in asphalt mix is included in this chapter. Moreover, previous researches relevant to polymer modified asphalt mixes including recycled plastics are reviewed.

Chapter (3) Research Methodology:

This chapter handles two topics first is the preliminary evaluation of used materials properties such as aggregates, bitumen and Polymers (CR+Plastic). Second is the description of experimental work which has been done to achieve study aims.

Chapter (4) Results and data analysis

The achieved results of laboratory work are illustrated in this chapter through three stages. First stage handles the results of Characterization of aggregates and asphalt binder. Second stage, Marshal Test results are analyzed in order to obtain the optimum bitumen content (OBC). The following step discusses the effect of adding different percentages of polymer on asphalt mix properties; finally the optimum polymer modifier content is obtained.

Chapter (5) Conclusion and recommendations

Conclusions derived from experimental results are presented. Moreover, the recommendations for the present study and other further studies are also provided in this chapter.

Chapter 2

Literature Review

2.1 Introduction:

Flexible pavements, such as asphalt roads, have a bitumen coating as the topmost layer and other built-in layers made of earth materials **[1-2].** The highest stress intensity occurs at the top layers, and relatively low stress is expected at lower layers. Hence, the pavement materials, especially asphalt mixture, have to be of superior strength. Asphalt mixture is a heterogeneous material composed of asphalt binder, aggregates, and air voids. Crushed aggregates usually account for 85% of the total volume of the mix in approximate, and asphalt binder constitutes around 10% and the remaining part is air voids **[3–4].** Because of extensive variation in climatic conditions, properties of construction materials, terrains, traffic volumes, and loading, the asphalt layer fails to withstand the pavement defects such as rutting, fatigue cracking, deformation, potholing, and wear and tear. Hence, the asphalt binder and asphalt mixture ought to be improved to attain the safest requirement of flexible pavement via addition of polymer additives **[5–6, 7].** As stated by **Naskar et al. [8],** polymer-made additives are proved effective in many aspects for modifying properties of the bitumen material in road pavement. This further contributes to increase in life span of the road and operation life. To most commonly practiced means of improving quality of the asphalt binder and asphalt mixture is via mitigating the rheological characteristics of binders and the asphalt mix. This can be executed by blending them with polymers like rubber and plastic **[5–6, 7].**

Muhammad Irfan et al., 2016 [9] investigate that the use of crumb rubber as modifier to improve the mechanical properties that extend pavement service life by reducing the rate of permanent deformation of conventional asphalt mixtures. This study assesses the effectiveness of crumb rubber-modified asphalt mixtures on pavement performance. Laboratory tests revealed significant improvements with crumb rubber, showing a 30% increase in Marshall Stability and a 43% rise in resilient modulus compared to control mixtures. Additionally, the permanent deformation of crumb rubber-modified mixtures improved by 12%. Field investigations demonstrated a notable 36.16% decrease in International Roughness Index for the treated asphalt, surpassing the 24.20% reduction observed in control pavements. These findings highlight the enhanced performance of crumb rubber-modified mixtures, indicating their potential to improve pavement durability and quality under varying conditions of loading and climate.

Kakar, M. R., Mikhailenko, P., at al. (2021) [10] illustrated the benefits of using waste polymer, specifically local waste Polyethylene Terephthalate (PET), in asphalt binder C320 for road surfacing in Australia. Evaluating PET-modified bitumen through laboratory tests, it was found that 6-8% PET content improved rutting and aging resistances, with 8% PET enhancing fatigue cracking resistance. This sustainable approach not only reduces costs but also enhances environmental sustainability and resource efficiency in pavement construction.

2.2 Conventional Asphalt:

Conventional asphalt, also known as hot mix asphalt (HMA), is the most common type of asphalt pavement used around the world. It is a composite material made up of:

Coarse aggregate: Coarse aggregates are particulates that are greater than 4.75mm. The strength and rut resistance of Asphalt is mostly depends upon on the aggregate mix is 100% crushed and with good shape (cubical) and strength limits for abrasion resistance and crushing strength. The sand used must be crushed sand as the internal friction contributes into the overall strength.

Fine aggregate: Fine aggregates generally consist of natural sand or crushed stone. It can pass through #4 Sieve and retained on #200 sieve**.** Water absorption of a fine aggregate of any nominal size from any source must not exceed 3.5%. Soundness: The weighted percent loss from a fine aggregate must not exceed 12% of the test portion

Mineral filler: Very fine particles, such as limestone dust or Portland cement, that fill the voids between the larger aggregate particles and improve the workability of the mix.

Asphalt binder: A dark, viscous liquid derived from crude oil that binds the aggregate particles together.

These components are mixed together at high temperatures, typically around 325°F (163°C), and then laid down on a prepared base course. The asphalt then cools and hardens, forming a strong and durable pavement surface.

Conventional asphalt is a widely used and versatile material, but it does have some drawbacks. One concern is that the high temperatures required to produce and lay HMA can be energy-intensive and contribute to greenhouse gas emissions. Additionally, conventional asphalt pavements can become brittle in cold weather and crack more easily.

2.2.1 Application Of conventional Asphalt:

Conventional asphalt, also known as asphalt concrete, is widely used in various applications in the construction industry. One of its primary applications is in road construction, where it is used to pave new roads and highways, as well as to resurface existing ones. Conventional asphalt provides a durable and smooth surface that can withstand heavy traffic loads and varying weather conditions, making it ideal for use in road construction projects of all sizes.

Another common application of conventional asphalt is in the construction of parking lots. Asphalt is a popular choice for parking lots due to its durability, ease of installation, and cost-effectiveness. It provides a smooth and durable surface that can withstand the weight of vehicles and heavy traffic. Additionally, asphalt is commonly used for residential driveways due to its durability and ease of maintenance.

Conventional asphalt is also used in the construction of airport runways and taxiways. Asphalt is able to withstand the weight of heavy aircraft and provides a smooth and durable surface for airplanes to land and take off. Overall, conventional asphalt is a versatile material that is used in a wide range of applications in the construction industry due to its durability, ease of installation, and cost-effectiveness.

2.2.2 Problem in Conventional Asphalt:

Conventional asphalt, while widely used, does have some inherent problems and challenges. One of the main issues is its susceptibility to cracking and rutting over time, especially in regions with extreme temperature fluctuations. These cracks and ruts can lead to water infiltration, further deterioration of the pavement, and safety hazards for vehicles.

So are the following,

1. Rutting
2. Fatigue cracking
3. Bitumen Bleeding

Rutting:

A rut is a permanent, longitudinal surface depression that occurs in the wheel paths of a flexible pavement due to heavy traffic.

Fatigue cracking:

Fatigue cracking, also known as crocodile cracking or alligator cracking, starts as a series of interconnected road cracks that develop to break the road surface into multiple, irregular shaped pieces, usually less than 500mm in size. Fatigue crakes occurs due to cyclic or repeated loading. Fatigue cracking is almost always a sign that the pavement and its supporting foundation are unable to bear the weight of traffic.

Bitumen Bleeding:

The rise of bitumen to the surface of pavement during hot weather is called bitumen bleeding.

2.3 Polymer Modified Asphalt:

Polymer-modified asphalt is a type of asphalt binder that has been enhanced with polymer additives to improve its properties and performance. The addition of polymers, which are long-chain molecules, modifies the binder's characteristics, making it more elastic, durable, and resistant to cracking and rutting compared to conventional asphalt.

There are several types of polymers that can be used to modify asphalt, including styrene-butadiene-styrene (SBS), styrene-butadiene rubber (SBR), and ethylene-vinyl acetate (EVA), plastic and crumb rubber. These polymers are typically blended with the asphalt binder at high temperatures to ensure proper mixing and distribution.

2.3.1 Benefit of Polymer Modified Asphalt:

Polymer modified asphalt, a type of asphalt mix that incorporates polymers into the binder, offers numerous advantages that significantly enhance the performance and longevity of asphalt pavement. Here is a detailed overview of the benefits:

1. **Enhanced Flexural Properties**: The addition of polymers improves the flexural properties of asphalt, making it more resistant to deformation and rutting. This enhancement ensures better structural integrity and longevity of the pavement.
2. **Improved Performance across Temperatures**: Polymer modified asphalt exhibits superior performance across a wide range of temperatures, including both high and low extremes. This versatility allows the pavement to maintain its structural integrity and performance under varying climatic conditions.
3. **Resistance to Cracking**: Polymers enhance the resistance of asphalt to cracking, particularly in areas prone to thermal stresses and heavy traffic loads. This benefit significantly reduces maintenance needs and extends the life of the pavement.
4. **Waterproofing Properties**: The incorporation of polymers enhances the waterproofing capabilities of asphalt surfaces. This feature helps protect the pavement from water infiltration, preventing damage caused by moisture, chloride intrusion, and corrosion, thereby extending the lifespan of the pavement.
5. **Longer Service Life**: Polymer modified asphalt offers increased durability and longevity compared to traditional asphalt mixes. The improved performance properties result in a longer service life for the pavement, reducing maintenance requirements and overall lifecycle costs.
6. **Maintenance Advantages**: Dry polymer additives provide maintenance advantages by eliminating the need for heated storage tanks typically required for liquid additives. This simplifies storage logistics and allows for precise ordering based on project specifications, enhancing operational efficiency.
7. **Reduced Air Voids**: The use of dry polymer modifiers in asphalt mixes helps reduce air voids within the material. This results in a denser mix with improved waterproofing properties and lower hydraulic conductivity, contributing to a more durable and long-lasting surface course.

2.4 Classification of Polymer Modified Asphalt:

Polymer Modified Asphalt enhances the structural coalition of pavement .polymer have of different type such as Crumb Rubber, Plastic, Both used Combined etc. Each gives the asphalt different properties.

2.4.1 Crumb Rubber Use as a polymer modifier:

In this waste crumb rubber which is obtained from tier waste are to be used as polymer modified in asphalt for to enhance the properties of road pavement.

The deterioration of pavements can be attributed to heavy axle loads, extreme climatic conditions, and poor subgrade conditions. To minimize pavement degradation and increase service life, modifying the materials in the surface layer to enhance resistance to rutting and cracking is essential. Various studies have focused on binder modification, including the use of modifiers like styrene-butadiene rubber (SBR), styrene-butadiene-styrene (SBS), ethylene-vinyl acetate (EVA), and crumb rubber (CR). SBS and SBR are commercial copolymers that can increase initial construction costs, while CR, derived from scrap tires, is a more cost-effective option that also addresses waste-tire disposal issues and also reduce this issue.

Some researcher are already work on this their finding are below.

Xu et al. 2014 [11] developed a novel method for preparing activated CR, and after comparing the performance of the activated CR asphalt mixtures with that of ordinary CR asphalt mixtures, they concluded that the activated CR mixtures were superior.

Dias et al. 2014 [12] illustrated the mechanical response of two gap-graded CR asphalt mixtures produced by the dry process, compared their performance vis-à-vis that of a mixture devoid of rubber granulate, and concluded that the rubber-blended mixtures performed better than their counter parts.

Al-Khateeb and Ramadan 2015 [13] investigated the effect of rubber additives on the following rheological properties of asphalt binders: Superpave rutting parameter, fatigue parameter, and storage modulus at various percentages. The authors determined that the addition of rubber yielded increases in rutting resistance and fatigue resistance.

López Moro et al. 2013 [14] illustrated the use of CR as a modifier in AC mixtures via the dry process in a microscopic study and concluded that the addition of CR led to increased strength and reduced rutting.

2.4.2 Plastic Use as a polymer modifier:

Due to fast economic and industrial growth, the waste plastic in world has witnessed an extraordinary increase. Apart from economic growth, an increase in traffic load has led to the weakening of existent road pavements. Currently, world has faced the fundamental concern of recycling waste plastic. . The potential for recycled plastic to improve the performance properties of asphalt mixtures has been demonstrated in the UK, Canada, The Netherlands, India, the Middle East and other countries as declared in the literature review. For instance, Canada used plastic waste as an additive in warm mix asphalt in **2012 [15],** and The Netherlands consume waste plastic in road construction in **2015 [16].**

Some researcher are already work on this their finding are below.

Al-Hadidy et al., 2009 [17] investigates the use of pyrolysis low-density polyethylene (LDPE) as a modifier for asphalt paving materials, focusing on its potential to improve performance and service life. Five different blends were subjected to binder testing and found to have higher softening points, maintain ductility within a specified range, and reduce percentage loss of weight due to heat and air. The inclusion of LDPE in SMA mixtures was shown to satisfy performance requirements for high-temperature, low-temperature, and moisture zones. Multi-layer elastic analysis program BISAR was used to estimate improvements in service life or reduction in thickness of SMA and base layer for the same service life due to modification of the SMA mixtures.

Ameri M et al., 2017 [18] suggest that the using of devulcanized polyethylene terephthalate (PET) enhance asphalt mixes. Seven mixtures with varying DWP percentages were tested, showing increased Marshall Stability, reduced moisture susceptibility, and rutting depth compared to control mixes. Mixtures with 7.5–10% DWP exhibited superior performance in high-temperature, low-temperature, and rainy conditions. The research suggests that incorporating LDPE in SMA mixtures can improve pavement durability and performance

2.5 Combined performance of Waste Plastic and Crumb Rubber in Modifying Properties of Asphalt:

So Our Research will be based on the above topic which is "**Combined performance of Waste Plastic and Crumb Rubber in Modifying Properties of Asphalt".**

Because there is no such study on the combined performance of these two. Several studies have investigated the potential of crumb rubber and polyethylene terephthalate (PET) polymers to modify asphalt properties, but there is no consensus on the optimal additive amounts for significant modification. This study aims to fill this gap by examining the effect of PET plastic polymer and crumb rubber on overall asphalt mix performance. The research specifically focuses on determining the optimal dosage of these additives for effective modification, aiming to provide valuable insights for asphalt engineering and sustainability.

According to Scott and Mashaan et al. [19, 20], huge amount of tyres and plastics produced around the world are the main causes of environmental pollution and other environment-related problems. In relation to this, the production of tyres is rising in Ethiopia particularly in the metropolis with accelerated demand for vehicles since recent years. As the demand for automobiles grows, so does the demand for tyres, resulting in an increase in tyre waste. Tyre debris is commonly discarded in the cities with no regard to the environment, and there are only a few recycling alternatives available in the country, including reuse, open-air burning, material recycling, and rethreading.

According to Obinur Rahman et al. [21] reported that waste polyethylene modifer up to 10% can be used in warmer areas from the view point of improving stability and void characteristics.

I. M. Khan, S. Kabir, et al., [22] The behavior of asphalt is significantly affected by seasonal temperature changes and loading conditions due to its viscoelastic nature. Flexible pavement often experiences various types of distress, with rutting and fatigue cracks being common occurrences.

This study focuses on enhancing the base bitumen by incorporating Low Density and High Density Polyethylene, as well as Crumb rubber. The evaluation of the modified binder's behavior in relation to rutting and fatigue cracking is based on parameters such as complex modulus (G*) and phase angle (δ) obtained from Dynamic Shear Rheometer (DSR) testing. The results indicate that the incorporation of Low Density Polyethylene (LDPE), High Density Polyethylene (HDPE), and Crumb Rubber (CR) led to a significant improvement in the binder's rheological properties.

Getnet Mekuria Alemu et al., 2022 [23] Investigate that the performance of crumb rubber and polyethylene terephthalate (PET) plastic polymer in asphalt mixtures to enhance the mechanical properties of asphalt pavement. Experimental tests were conducted on both the asphalt binder and asphalt mixture using different proportions of crumb rubber and PET plastic polymer to investigate the effect of mix ratios on asphalt performance. The results showed that a combination of 10% crumb rubber chips and 2% PET plastic polymer by weight was the ideal mix ratio for modifying asphalt mixture properties.

The addition of 10% crumb rubber to the asphalt binder resulted in a 1.56% reduction in penetration and a 4.33% increase in the softening point. The optimum mix ratio led to a 0.17% increase in Marshal Stability, a 20.07% decrease in flow, and a 20.71% increase in stiffness of the asphalt mixture. Additionally, the tensile strength of the asphalt mixture improved with the addition of the fillers and binder materials. Overall, the combined application of crumb rubber and PET plastic polymer showed better performance in modifying the properties of the asphalt mix compared to their separate use.

Chapter 3

Methodology

Targeted SDGs:

1) SUSTAINABLE DEVELOPMENT GOAL: 9

"Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation"

2) SUSTAINABLE DEVELOPMENT GOAL: 12

"Ensure sustainable consumption and production patterns"

Study Design:

The study design was such that materials are collected, and their tests were conducted for different parameters using standard methods. Asphalt mix design was prepared from these materials. Samples were prepared from that mix design, and performed their tests for different parameters using standard methods.

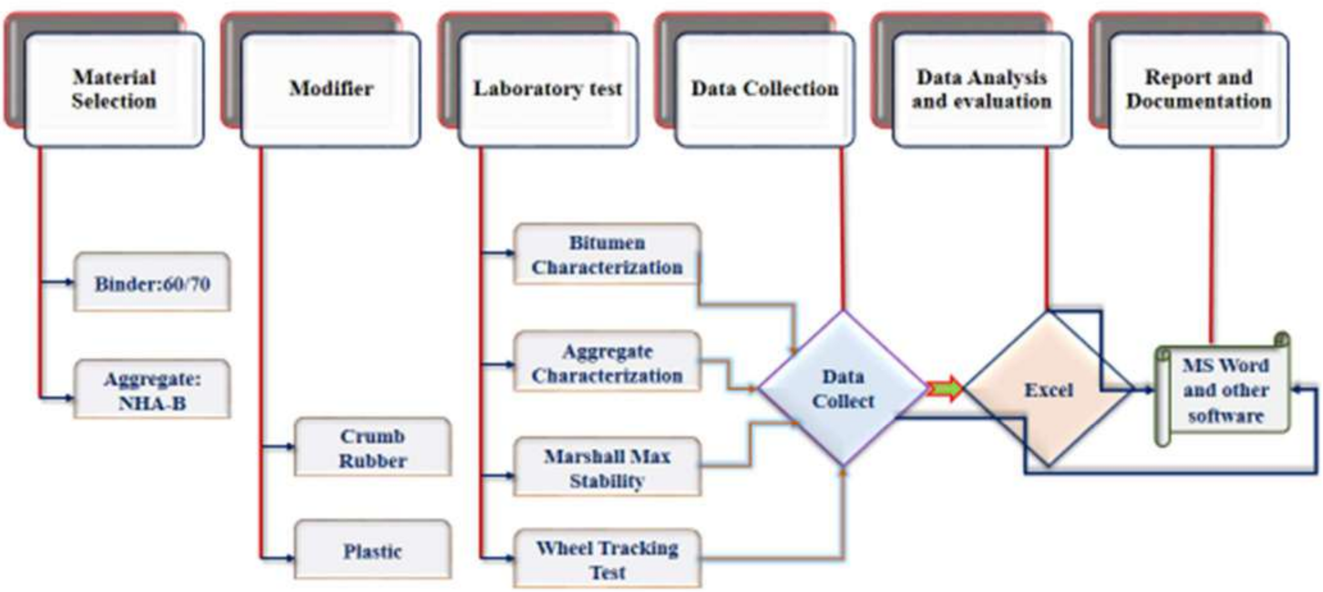

Figure (3.1): Flow chart of laboratory testing procedure

3.1 Sample Collection:

The materials needed for this study to produce polymer modified asphalt mixture are aggregates, bitumen, filler, and (Crumb Rubber+Plastic).We took aggregates from Babozi Crush Plant and Bitumen from Attock Refinery Limited. Crumb rubber and plastic waste are collect from the industrial area of Peshawar.

Table (3.1): Sources of Material from where material is to be collected

Materials	**Source**	**Quantity**
BITUMEN	Attock Refinery	10 kg
AGGREGATE	Babozi Crush Plant	50 kg
Plastic	Peshawar karkhano	5 kg
CR	Peshawar Karkhano	5 kg

3.2 Methodology and Implementations:

Summing down all the important points and tasks we are going to perform to complete this research below in points,

- First of all we will collect all the possible data available related to this topic from research papers, journals, articles etc.
- We will list down different test on Aggregate characterization and Bitumen Characterization.
- We will list down the different Asphalt test that would be performed on conventional Asphalt sample and polymer modified Asphalt Sample.
- Then we will decide the number of samples to be prepared that includes Marshal sample for marshal stability test and sample for IDT test) and calculate the materials required which would include (Coarse aggregate, fine aggregate, filler, bitumen and different percentage of (plastic and crumb rubber) such as 2%, 4%,6%,8%,and 10%.
- After that all the samples would be casted as per ASTM standards.
- After that Marshall Stability and IDT test will be perform on the Sample.
- After that comparison would be drawn between conventional Asphalt and polymer modifier asphalt with different %percentage of modifier.

3.3 Methodology:

The following test are to be performed in the project

1) Bitumen Characterization
   - Penetration Test on Bituminous Materials
   - Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester
   - To determine the softening point of asphaltic bitumen by Ring- And-Ball Apparatus
   - Standard Test Method for Ductility of Bituminous Materials
2) Aggregate Characterization
   - Standard Test Method gradation of coarse and fine aggregates
   - Standard test method for Water Absorption and Specific Gravity Test on Aggregates
   - Standard test method for Determination of Los-Angeles Abrasion Value
   - Shape test (Flakiness index and Elongation index)
   - Aggregate Impact value

3) Test on Modifier
   - XRD X-ray Diffraction
   - EDX
4) Main Test of the Project:
   - Marshal Mix Design test
   - IDT test

3.4 Penetration Test on Bituminous Materials (ASTM D-5):

The test was conduct determines the consistency and grade of bituminous materials by measuring the depth in tenths of a millimeter (penetration) that a standard needle penetrates vertically into a sample of the material under known conditions of loading, time, and temperature.

3.5 Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester (ASTM D-92)

The test was conduct to determine the Flash point Fire point of petroleum products i.e., bitumen. The flash point of a material is the lowest temperature at which the application of test flame causes the vapors from the material to catch fire for a moment in the form of a flash under specified conditions of the test. The fire point is the lowest temperature at which the application of test flame causes the material to ignite and burn at least for 5 seconds under specified conditions of the test. These tests are safety tests that are performed to determine the critical temperature at or above which safety measures should be taken. At high temperature, particles in the form of vapors escaping the surface of bituminous materials, depending upon their grade catch fire.

3.6 To determine the softening point of asphaltic bitumen by Ring- And-Ball Apparatus (ASTM D-36)

The test conduct to find the Softening Point of Bitumen. The softening point is defined as the mean of the temperatures at which the bitumen disks soften and sag downwards a distance of 25 mm under the weight of a steel ball. The test gives an idea of the temperature at which the bituminous materials attain a certain viscosity. Bitumen with higher softening point may be preferred in warmer places. Softening point should be higher than the hottest day temperature, which is anticipated in that area otherwise bitumen may sufficiently soften and result in bleeding and development of ruts.

3.7 Standard Test Method for Ductility of Bituminous Materials (ASTM D-113)

The aim of this laboratory test is to determine the ductility value of a given sample of bitumen. The ductility of bituminous material is the distance in centimeters to which it will elongate before breaking when a briquette specimen of the material is pulled at a specified speed and temperature. Ductility is the property of bitumen that permits it to undergo deformation and elongation during service. If bitumen does not have any ductility it would result in cracks and their propagation therefore for good quality flexible pavement ductility is very necessary.

3.8 Standard Test Method gradation of coarse and fine aggregates (ASTM C-33)

To assess the particle size distribution (gradation) of a granular material.
To check that the aggregate is Gap graded, well graded, Uniform Graded and Open graded.
Also select the sizes of the aggregate.

3.9 Standard test method for Water Absorption and Specific Gravity Test on Aggregates (ASTM C-127)

The increase in the weight of aggregate due to water in the pores of the material, but not including water adhering to the outside surface of the particles, expressed as a percentage of the dry weight is known as **Absorption.**

The ratio of the weight in air of a unit volume of aggregate (including the permeable and impermeable voids in the particles, but not including the voids between particles) at a stated temperature to the weight in air of an equal volume of gas-free distilled water at a stated temperature is known as **Bulk Specific Gravity.**

3.10 Standard test method for Determination of Los-Angeles Abrasion Value (ASTM C-131)

Abrasion Test is the measure of aggregate toughness and abrasion resistance such as crushing, degradation and disintegration. The aggregates are used for the surface course of the highway pavements and they are subjected to wearing due to movement of traffic. The percentage wear due to rubbing with steel balls is determined and is known as abrasion value.

3.11 Shape test (Flakiness index and Elongation index) (IS-2386)

Main objective of this test is to determine the flakiness index and elongated index of a given aggregates sample. Flakiness index and elongated tests are conducted on coarse aggregates to assess the shape of aggregates. Elongated and flaky particles reduce workability and stability of mix. Elongated particles do not undergo good degree of interlocking as a result of which mixes are difficult to compact. Also, there is a probability of breaking down of particles under heavy loads so these are not desirable in base coarse or bituminous or concrete mixes.

3.12 Aggregate Impact Value

This test is conduct for to find the impact value of aggregate. Aggregate impact test manifests the degree of toughness of aggregate which represent capacity of aggregate to absorb energy. Greater the energy absorbed by a material, lesser will be the A.I.V and stronger will be the sample. Therefore, aggregate must be chosen after performing" aggregate impact test"

3.13 XRD X-ray Diffraction:

X-ray diffraction (XRD) can be a valuable tool for analyzing both plastics and crumb rubber. In the case of plastics, XRD can be used to identify the crystalline structure of the material, which is important for understanding its properties and behavior. For example, different polymers have different crystalline structures, and XRD can help distinguish between them.

XRD can also be used to analyze crumb rubber, which is typically made from recycled tires. In this case, XRD can help identify the presence of various components in the rubber, such as carbon black and other fillers, as well as any changes in the crystalline structure that may occur during processing or use.

3.14 EDX Energy-dispersive X-ray spectroscopy:

Energy-dispersive X-ray spectroscopy (EDX) is another analytical technique that can be used to analyze both plastics and crumb rubber. EDX is used to determine the elemental composition of a sample by measuring the characteristic X-rays emitted when the sample is bombarded with high-energy X-rays.

In the case of plastics, EDX can be used to identify the elements present in the material, which can provide information about its composition and any additives that may be present. This can be useful for quality control and material characterization purposes.

EDX can also be used to analyze crumb rubber, providing information about the elemental composition of the rubber and any fillers or other materials present in the sample. This can be useful for determining the quality of the rubber and for identifying any contaminants that may be present.

3.15 Marshal Mix Design test:

For the NHA Class B gradation, the OBC computed from the Marshall Mix design testing procedure was 4.5%. This optimum content was adopted in preparing the CR-modified AC mixtures using 60/70 grade modified binders. The Marshall Mix stability was checked against each percentage, and the increase in stability was determined.

3.16 Wheel tracking test WTT:

Rutting is defined as surface depression in the wheel path area caused under repeated loading..
As traffic passes, pavement is depressed due to high localized stresses because of tire pavement interaction. At some point, this depression is non recoverable and leads to permanent deformation.
Can be assessed by Wheel Tracking Test (WTT).
In term of Rut depth.

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