Performance Evaluation of Asphalt Mixture using Shredded Face Mask and Waste Baby Diapers.

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Islamabad, Pakistan (2023)

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A thesis submitted to the National University of Sciences and Technology, Islamabad, in partial fulfillment of the requirements for the degree of

Masters of Science in

Transportation Engineering

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DEDICATION

This thesis is dedicated to my family for their continuous encouragement, sacrifices, and support during my academic path. My accomplishments have been motivated by your love and confidence in me. It is also dedicated to my teachers for your direction, insight, and priceless knowledge, which have moulded my intellectual development and heightened my enthusiasm for research.

ACKNOWLEDGEMENTS

All praise be to "ALLAH Almighty," the most forgiving and merciful creator of the universe, who never said "NO" and who gave me the ability to add a single drop of awareness and cognition to the vast body of knowledge and wisdom already in existence. I express my sincere greetings to the "HOLY PROPHET MUHAMMAD (SAW)," the never-ending source of wisdom for the entire human race.

I would like to express my profound gratitude to my supervisor Dr. Arshad Hussain and also to GEC members, who served as my thesis advisors, for their constant leadership, knowledge, and tolerance during this study process. Your guidance has been priceless, and I am sincerely appreciative of your dedication to my intellectual and scholastic growth.

I'd like to express my heartfelt gratitude to my parents and my siblings for encouragement, and faith in my skills, have served as a constant source of inspiration for me. Your love and efforts are what helped me achieve what I have.

I especially thanks to my friends, Muhammad Usama Bin Ayyub, who has always supported me through my research journey as a friend as well as mentor. I would like to appreciate the support from my beloved colleagues Nangyaley Khan, Ilyas Khan, and Abbas Khan in my research voyage.

Muhammad Abbas Bangash

ABSTRACT

This research explores a new strategy to manage waste baby diapers (WBD) and face masks (FM) to reduce environmental concerns brought on by the spread of infectious and harmful organisms and also to improve the performance of asphalt mix. In this study WBD and FM is use as bitumen and aggregate modifier to enhance performance of asphalt mix. In particular, 4% of the shredded BD, based on the weight of the bitumen, was added directly during the melting process, whereas varied amounts of the shredded FM (0%, 0.5%, 1%, and 1.5%) were used as aggregate coating through the melting process. This study examined the stability, flow, rutting potential, tensile strength, and moisture damage characteristics of the controlled and Modified HMA mixtures using the Marshall Stability Test, Double Wheel Tracker Test, and Indirect Tensile Strength Test. The obtained results showed that the addition of WBD improved modified bitumen's (MB) resistance to heat and permanent deformations, and the FM treatment greatly improved the aggregates' physical and mechanical characteristics. The ideal WBD content of 4% was obtained by analyzing the results of physical tests on WBD-modified bitumen. In comparison to the controlled mixture, the WBD and SFM-modified asphalt mixtures performed better in terms of stability, flow, tensile strength, and rutting resistance. Combining 4% BD and 1.5% FM increased densification and contributed to strong bonds between aggregates and asphalt paste, which increased stability and indirect tensile strength by 39% and 18%, respectively, and decreased permanent deformations by 27%. These improvements resulted in a staggering 53% increase in resistance to rut depth. Notably, 8% more moisture resistance was also improved. Ultimately

Keywords: Shredded Face Masks (SFM), Waste Baby Diapers (WBD), Modified Bitumen (MB), Stability, Flow, Rutting Resistance, Tensile Strength, Moisture Damage**.**

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CHAPTER 1: INTRODUCTION

1.1 Background

Transport is crucial for the smooth operation of economic operations as well as for ensuring social well-being and population development that is productive. Transport guarantees the mobility of commodities and people, which is essential for the development of the community. At every income level, the development of the transport infrastructure is an essential component. A wide range of human activities that produce large amounts of garbage that pollute and exacerbate the already challenging climatic conditions in major cities throughout the world are linked to the problem of global warming. The increase in greenhouse gas emissions, which is made worse by the negligent treatment of human-produced solid waste, is one unsettling trend.

Plastic contamination results from inappropriate plastic disposal. Since plastic is not biodegradable, it poses a serious threat to the land and many waterbodies. As a result, many marine and terrestrial creatures have died. Research has shown that plastic can remain intact on the globe for more than 4500 years. (Kehinde et al.,2020)

Face masks and baby diapers are made of many layers of materials with various characteristics, such as plastics, nonwoven textiles, and superabsorbent polymers. These materials have qualities including enhanced moisture resistance, thermal stability, and flexibility that might be advantageous for asphalt mixes. Investigating the addition of used diapers and face masks to asphalt mixtures offers a special chance to tackle the problems of waste management and asphalt performance improvement at the same time.

1.2 Problem statement

It has become essential to modify asphalt pavements to generate HMA pavements that offer higher performance because of the sharp increase in axle loads, large traffic volumes, harsh weather conditions, and high temperatures. This alteration is essential to stop several sorts of distress from happening, including rutting, cracking, raveling, and other moisture-induced deformations. Giving material selection and combination design great thought is crucial to reduce this pain. research has shown that the traditional asphalt mixtures' incapacity to tolerate repeated wheel load applications is the main factor contributing to flexible pavement failure.

Due to the low resistance of normal asphalt mixtures to high tyre pressures and axle loads, polymer-modified asphalt is being used more frequently to address this issue. As a result, asphalt polymer modification is regarded as one of the best options for enhancing asphalt properties. When polymers are utilized, the useful temperature range for binders is substantially increased. The polymer can considerably enhance the binder properties of bitumen by increasing its stiffness and enhancing its temperature susceptibility, enabling the building of safer roadways and lowering maintenance costs.

1.3 Scope

The use of recycled waste materials in road pavements is now recognized as a desirable alternative for improving service performance in addition to being a sustainable solution. It has been demonstrated that adding a certain polymer to asphalt binder can enhance the functionality of road pavement. Disposing of discarded nappy trash and face masks has caused numerous environmental problems and is hazardous to public health. Concrete has been altered by many researchers using baby diapers. similarly, many researchers have used the face mask for the modification of asphalt mix. The goal of this research project is to improve the economics of the asphalt mix while addressing landfill and environmental issues by using various percentages of used baby diapers and face mask.

1.4 Research Objectives

The main objectives of this study are:

- To investigate the effects of waste diapers on the physical properties of bitumen
- To investigate the impact of face masks and waste diapers modified bitumen on HMA rutting.
- To investigate the impact of face masks and waste diapers modified bitumen concentration on asphalt mix moisture susceptibility.

- Identify the optimum percent of face masks and waste diapers to be added in the hot mix asphalt.
- Cost comparison of asphalt concrete mixture containing face mask and diaper-modified bitumen with virgin mixtures.

1.5 Waste Plastic Pollution in Pakistan

For many years, Pakistan has struggled with the inappropriate disposal of plastic waste. Plastic bags, packaging, waste diapers, and other single-use plastic goods frequently wind up as trash in the streets, waterways, and open areas, which harms wildlife and contributes to environmental pollution.

Non-biodegradable waste diapers present a serious difficulty for trash management in Pakistan. There is a discharge of hazardous materials and greenhouse gases as a result of incorrect nappy disposal in landfills. Furthermore, having diapers around might harm the soil and water sources.

Face mask use surged during the COVID-19 pandemic to stop the virus from spreading. However, the rising number of disposable face masks has worsened the plastic waste issue. Masks must be disposed of appropriately to avoid contributing to environmental pollution or posing health risks.

To address these issues, the Pakistani government and communities need to implement comprehensive waste management strategies.

1.6 Organization of Thesis

The following organization of the chapters of thesis has been made:

Chapter 1

Introduction to waste materials utilized in this study, problem statement, scope of the study, and objectives.

Chapter 2

The chapter 2 contains Research findings related to utilization of waste Baby Diapers, Waste Face Masks, and performance tests conducted on modified HMA.

Chapter 3

This chapter focus on the materials and procedures used to accomplish the objectives of the study. Procedures of different performance tests conducted.

Chapter 4

This chapter contains the analysis and results of OBC, Optimum modifier content, Volumetrics and Performance tests performed.

Chapter 5

The final chapter consists of conclusions drawn from the study and some recommendations for future studies.

2 CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The research and theory around how asphalt mixes containing polymers respond to several performance tests, including rutting, ITS, and moisture susceptibility, are briefly reviewed in this chapter. This chapter discusses the different kinds of modifiers used in asphalt, their effects, and the study done on the use of ethylene vinyl acetate as a modifier in asphalt and its effect on the performance of HMA pavements.

2.2 Flexible pavement

Flexible pavement is a type of road construction that distributes the load across a larger area to handle traffic loads and environmental pressures. It is made up of several layers, each of which has a distinct function to provide flexibility and durability. Roads, highways, and runways frequently employ this kind of pavement.

Flexible pavement has many benefits, including the capacity to adjust to shifting environmental factors like temperature changes and soil movement. Due to its flexibility, pavement can endure stresses brought on by traffic loads without suffering serious cracking or damage.

However, to ensure their durability and effectiveness, flexible pavements need routine maintenance. To increase the longevity of the pavement, regular inspections, crack sealing, and resurfacing are routine maintenance procedures.

In conclusion, flexible pavement is a dynamic and popular technique for building roads known for its capacity to evenly distribute traffic loads and endure a variety of environmental factors. It is a well-liked option for road infrastructure projects all around the world since it offers a smooth and long-lasting riding surface.

The surface course is the flexible pavement's topmost layer. It is used to give automobiles a smooth, skid-resistant riding surface. The binder course is located beneath the surface course. To distribute the load from automobiles to the lower layers, this layer is essential. Additionally, it improves the pavement's resistance to temperature changes and stops water from seeping into the lower layers. The base course serves as an additional layer of support and weight distribution underneath the binder course. It facilitates load distribution across a broader region, avoiding the subgrade from extensive load. the layer that is closest to the ground is subgrade, which is the natural soil or compacted material on which the flexible pavement is built. The subgrade must be solidly compacted and strong enough to support the weight of the traffic and the pavement.

For the determination of the optimum bitumen content of asphalt, two methods can be used

- Marshall mix design
- Superpave mix design

In this study, we will use the Marshall mix design approach to create our HMA mixture and figure out the optimum bitumen content.

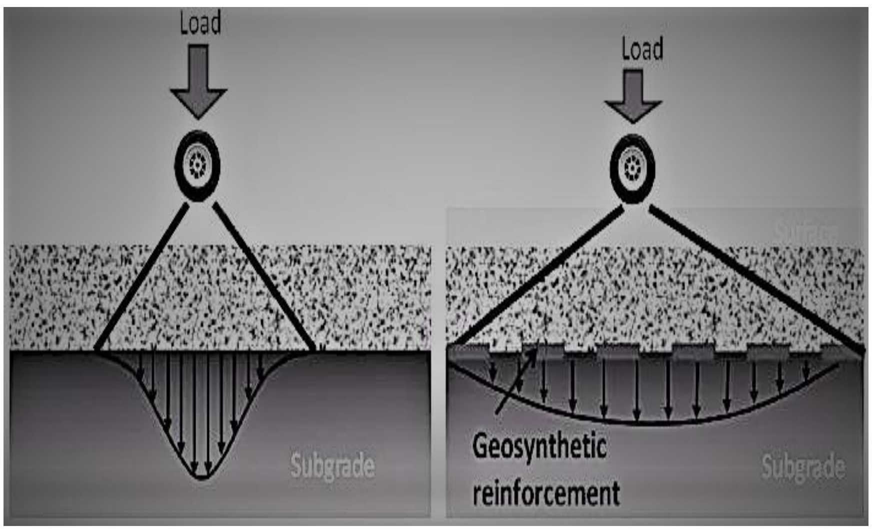

Figure 2.1 Flexible Pavement load distribution

2.3 Use of Waste Plastic in Asphalt Pavements

Plastic is frequently used in many areas of human life. The creation of a significant volume of trash plastic will harm the environment because there aren't enough facilities to treat plastic garbage. Low-density polyethylene (LDPE), high-density polyethylene (HDPE), polyethylene terephthalate (PET), polypropylene (PP), polyvinyl chloride (PVC), ethylene vinyl acetate (EVA), and polystyrene (PS) are the most common types of waste plastic discovered in

Pakistan's municipal solid waste (MSW). The creation of flexible pavements, which not only produce asphalt pavements that are economically and environmentally advantageous but also shield the environment from its negative effects, is one of the most effective ways to recycle this hazardous material. Asphalt is a hydrocarbon material with chemical properties similar to plastic. Polymers can be applied to asphalt pavements to improve their performance and provide them greater qualities in terms of their durability to different deformations. The following is a collection of research findings about the use of various waste plastics in asphalt pavements.

2.3.1 Polyethylene terephthalate (PET)

PET, which has been extensively used for drinking bottles, is a thermoplastic polymer resin belonging to the polyester family with the chemical formula (C10H8O4)n. PET bottles can be recycled and turned into fibers and granulates. Asphalt made from recycled materials, including PET plastic, has been investigated as a viable waste management and sustainability solution. One such method is the partial replacement of the bitumen binder in asphalt mixtures with recovered plastic waste, particularly PET. Asphalt's main ingredient, bitumen, serves as a binder to keep the mixture together Shredded PET bottle material, which replaces aggregate in the asphalt mixture, has a size range of 1.18 to 2.36 mm (Rahman and Wahab, 2013). PET has a 1.32 specific gravity, tensile strengths between 300 and 350 MPa, an elastic modulus of 13 GPa, and an elongation of 7.5%(Yoo and Al-Qadi, 2014). However, the future of sustainable PET packaging polymers may depend on a mix of bottle-to-bottle recycling, monomers from renewable resources, or other novel additions derived from PET bottles (Gürü et al., 2014). The research also showed that the improvement in TSR indicated greater adhesion between asphalt binder and aggregates in humid environment.(Ferreira et al., 2022).

2.3.2 High-density polyethylene (HDPE)

Low density (0.930 g/cm3), linear low density (0.915–0.940 g/cm3), and high density (0.940–0.965 g/cm3) are the three major types in which polyethylene is made. Since the molecules of high-density polyethylene (HDPE) can fit closer together due to its linear polymer chains' limited branches, strong intermolecular interactions are created. Low-density polyethylene (LDPE) is less stiff and denser than HDPE. HDPE waste is frequently used to modify asphalt, usually via a wet technique. Remove flake-shaped waste PE plastic from silo bags with a high-speed stirrer at 11,000 rpm and 170 C for 20 minutes. However, the temperature susceptibility and storage stability of asphalt both declined with the addition of PE(Angelone et al. 2016). A high-shearing mixer with a high shearing rate at a high temperature is used to mix HDPE-modified asphalt more uniformly (Costa et al 2019). It is well-accepted that adding HDPE to asphalt increases stiffness, viscosity, and moisture resistance; however, it is less clear how this alters fatigue resistance.

2.3.3 Low-density polyethylene (LDPE)

In terms of specific gravity, strength, and temperature resistance, LDPE's long, flexible, linear polyethylene chain, with a density of 0.92 to 0.93 g/cm3, is less than HDPE and is hence better able to withstand external forces (Fang et al., 2014b). LDPE must be blended at a high shear rate and temperature to thoroughly melt into the asphalt. The network structure of the base asphalt and the LDPE swelling both affect how the base asphalt behaves. The FTIR measurements revealed that a sizable portion of the methyl and methylene groups in the altered asphalt match the absorption peaks of the asphalt prior to modification causing the absorption peaks at 2925 cm1 and 2856 cm1 to significantly rise (Fang et al. 2014b). It is commonly acknowledged that adding recycled LDPE to asphalt can increase its resilience to rutting, fatigue, and moisture. However, there is disagreement on thermal cracking resistance. Used oil or polyphosphoric acid could be added as a facilitator to improve fatigue cracking resistance and decrease shearing during mixing (Maharaj and Maharaj, 2015;Nu~nez et al., 2014).

2.3.4 Polypropylene (PP)

Wet and dry methods are used to integrate PP into the asphalt mixture. It is widely acknowledged that the inclusion of PP can stiffen the asphalt, as evidenced by an elevated softening point and a decreased penetration, which contribute to increased resistance to rutting. However, PP made asphalt less ductile. PP fibers produced a higher air void in asphalt compositions. While the majority of research concluded that adding PP increased Marshall stability and improved rutting resistance, one study reported that rutting resistance was impaired by increasing air vacancy (Otuoze et al., 2015). Asphalt with a combination modification effect employing organic rectorite and waste packaging PP. A nanomaterial called organic rectorite has a specific surface area of 87 g/m2 and an average diameter of 180 nm (Cheng et al. 2019). To achieve the optimum ductility and plasticity, asphalt at 4% and 1.5% by weight of waste PP is combined with the nanomaterial (Souza et al. 2018).

2.3.5 Polystyrene (PS)

The polymer polystyrene, often known as PS (polystyrene), is frequently used in packaging applications. PS varieties include expanded PS, high-impact PS, and syndiotactic PS. The superior mechanical and insulating qualities of expanded PS and high-impact PS make them ideal for use in resin-molded products like TV cabinets and PS forms for packing electrical goods. Hasan et al. (2016) observed that the asphalt becomes stiffer and has fewer low-temperature qualities with the addition of high-impact PS. The dry approach was employed for the alteration of the asphalt mixture. (Lastra-Gonz_alez et al., 2016; Vila-Cortavitarte et al., 2018). adding PS stiffens asphalt mixtures and increases their resilience to moisture damage, but it is unclear how this will affect their resistance to rutting and fatigue cracking.

2.4 Waste Plastic Pollution in Pakistan

Pakistan has been struggling with the improper disposal of plastic waste for a long time. It is common for single-use plastic products to end up as trash in the streets, waterways, and open spaces, harming wildlife and adding to environmental pollution. These products include plastic bags, packaging, used diapers, and other single-use plastic items.

In Pakistan, non-biodegradable waste diapers pose a significant challenge to garbage management. The improper disposal of diapers in landfills results in the release of hazardous compounds and greenhouse gases. Additionally, the presence of diapers may impact land and water resources.

During the COVID-19 pandemic, the usage of face masks increased as a means of containing the virus. However, the issue of plastic waste has gotten worse as the quantity of disposable face masks has increased. To prevent contributing to environmental pollution or causing health hazards, masks must be disposed of properly.

The Pakistani government and localities must put comprehensive waste management plans into place to address these problems.

2.5 Polymer modification of Asphalt

With the introduction of polymer modification, asphalt, a commonly utilized building material for road surfaces, has made enormous improvements recently. To improve asphalt's characteristics and overall performance, this ground-breaking method involves combining polymers like styrene-butadiene-styrene (SBS) or ethylene-vinyl acetate (EVA) with the material. Attention has been drawn to polymer-modified asphalt for its capacity to increase pavement toughness, resistance to rutting, cracking, and aging, as well as its contribution to environmentally friendly building methods.

Polymer modification procedures frequently involve combining polymer particles with the asphalt binder. As the polymer particles spread throughout the binder matrix, a more cohesive and flexible material is created. When compared to conventional asphalt, the resulting mixture has better mechanical qualities, making it particularly appropriate for locations with high traffic, large loads, and harsh environmental conditions.

2.6 Waste Baby diapers and face mask

Baby diapers are a crucial component of contemporary parenting since they offer convenience, hygiene, and comfort to both parents and infants. Baby diapers are made using a precise and intricate process that combines state-of-the-art technology with premium materials to produce a product that satisfies the highest requirements for comfort, safety, and absorption. This article goes into the numerous steps of manufacturing, illuminating the complex processes that turn raw ingredients into the well-known, dependable newborn diapers we know today.

To stop the spread of bacteria, viruses, and other particles, people often wear face masks over their mouths and noses. In hospital settings, during illness outbreaks, and as a preventative measure against airborne contaminants, they are frequently utilized. Face masks come in a variety of varieties, each with a distinct function and degree of protection, surgical, N95 respirator, cloth mask, and KN95 masks.

2.7 Use of WD and SFM as a Bitumen and Asphalt Mix Modifier

Rutting or continuous distortion of asphalt pavement is one of its most troublesome features. Since the SFM behaves as a semi-liquid between 115.5 and 160 °C—the range of HMA mixing and paving temperature—it can serve as a binding agent to bond the aggregates. After cooling to normal temperature, the hardened SFM can impart rigidity and solidity to the pavement. The results of the investigation demonstrated that the modified mixes had exceptional resistance to permanent deformation under the Asphalt Pavement Analyzer (APA), with the rutting depth values decreasing from 3.0 mm to 0.93 mm by increasing the SFM concentration from 0% to 1.5%. The results of the rutting test and the research on premature distress mechanisms suggest that the appropriate addition of SFM modifiers may improve the high-temperature properties of HMA, which can be utilized to reinforce high-compression and shearing zones in the pavement construction. George (Wang 2022).

Consequently, binders with more than 2% waste mask are found to perform better than binders containing 3% SBS in terms of physical and rheological properties. After adding waste mask ratios and the single styrene–butadiene–styrene (SBS) ratio to the pure binder, the modified binders' rheological, physical, and chemical characteristics were studied. The outcome shown that the addition of SBS and a waste mask to the pure bitumen increased the viscosity and softening point of the binders while decreasing the penetration value. With rising temperatures, waste mask improvements were better able to preserve its elastic qualities at both low- and high-stress levels. The binder most impacted by temperature rise was 3% SBS. Therefore, it has been found that, in terms of physical and rheological qualities, binders containing more than 2% waste mask perform better than binders containing 3% SBS. (Erkut Yalcin).

The thesis aims to advance the field of transportation infrastructure by evaluating the performance of flexible pavement using shredded face masks (SFM) as a modifier of HMA mixture and by developing a cost estimator calculator to determine the cost of constructing asphalt pavement with a mask. To create modified HMA mixes with SFM levels ranging from 0% to 1.5% and test them for rutting, the Asphalt Pavement Analyzer (APA) was utilized. It was shown that by increasing the SFM concentration from 0% to 1.5%, the modified samples demonstrated excellent resistance to permanent deformation as the rutting depth values decreased from 3.0 mm to 0.93 mm. But the samples' resistance to rutting has increased as a result of this study's usage of shredded face masks (SFM) as a modifier of hot mix asphalt (HMA). One illustration of a particular contribution is the evaluation of face masks in hot mix asphalt (HMA). (Hasibul Hasan Rahat 2022).

In order to enhance the asphalt mixtures, the face mask and its numerous layers are applied in two different sizes and four distinct weight percentages. Following that, the samples were put through the Marshall test, resilient modulus, indirect tensile, moisture damage, rutting, and fatigue test. According to the trial's results, these substances improve asphalt's performance, and 12 mm long fibers outperformed 8 mm long fibers in terms of performance. (Ahmad Goli 2023).

Several experiments were conducted in this study for the first time on mixes including different percentages of shredded face mask (SFM) mixed to recycled concrete aggregate (RCA) for use as subbase and road base. Tests for resilient modulus, unconfined compression strength, and modified compaction were all part of these investigations. The results of the testing showed that RCA combined with three different SFM percentages (1%, 2%, and 3%), satisfied the requirements for strength and stiffness for pavement bases and subbases. In addition to boosting the strength and stiffness of the RCA/SFM mixtures, the addition of the shredded face mask also increased their ductility and flexibility. When 1% SFM was added to RCA, the unconfined compressive strength (216 kPa) and resilient modulus (314.35 MP) reached their maximum values. However, adding more SFM above 2% led to a loss of strength and stiffness. (Mohammad Saberian 2021).

Baby nappy waste makes up a large portion of hygiene waste and is now primarily landfilled or burned.In the current study, the potential use of shred waste diapers (SWDs) as a cutting-edge viscosity-modifying additive for cement grouts and concrete is investigated. A model that creates the chemicals that SWDs contribute to concrete was put forth. The model was used in conjunction with environmental and construction regulations to show the legal framework for the use of SWDs in various types of concrete. The viscosity-modifying abilities of SWDs were tested using cement grouts and self-consolidating concrete. The effectiveness of SWDs in altering viscosity was assessed using a Bingham viscosity model and flow tests. The current findings demonstrate that making highly effective viscosity-modifying admixtures for concrete using SWDs is a sustainable process (H. Karimi 2020).

2.8 Performance Evaluation

The tensile strength, flow, potential for rutting, stability, and resistance to moisture damage of normal and modified bitumen mixtures were all studied in this research. The effectiveness of HMA was also evaluated concerning the effects of WD and SFM components. To figure out the impacts of WD and SFM modification on the overall effectiveness of asphalt mixes, the influence of WD and SFM on the properties of fresh binders was also evaluated.

2.8.1 Moisture Damage of Asphalt Pavements

In the infrastructure of asphalt pavement, moisture damage, also known as moisture-induced damage, is a major concern. It describes the deterioration of asphalt pavement brought on by water or moisture seeping into the pavement layers, resulting in decreased structural integrity and performance over time. Moisture damage can take many different forms and lead to a variety of problems, such as Rutting, Cracking, and Durability.

Figure 2.2 Pavement cracking

2.8.2 Rutting in Asphalt Pavements

Rutting is a typical type of asphalt pavement distress characterized by the development of long-lasting depressions or grooves in the road's wheel path. It happens as the pavement material expands under traffic loads, usually as a result of a combination of variables including traffic volume, load intensity, temperature, and asphalt mix characteristics. Higher degrees of pavement deformation may result from heavier and more frequent traffic loads, particularly in locations with stopping and accelerating vehicles. High temperatures have the potential to weaken the asphalt binder, making it more flexible. In contrast, low temperatures can make the pavement more brittle and cause cracking. Rutting resistance is significantly influenced by the kind and caliber of asphalt binder used in the mix. High-performance grade binders and polymer-modified binders can aid increase deformation resistance.

Figure 2.31 Pavement rutting

2.9 Summary

The chapter offers a thorough analysis of the state of plastic trash in Pakistan and makes suggestions for effective ways to mix plastic waste with asphalt. It defines flexible pavements, explains how loads are distributed on them, and discusses several methods for creating asphalt mixtures. The chapter also discusses study findings on the addition of waste diapers and shredded face masks to bitumen and asphalt mixtures. It concludes by describing the performance characteristics that will be evaluated in this study.

3 CHAPTER 3: MATERIALS COLLECTION

Materials such as aggregates, asphalt binders, face masks, and waste diapers were gathered from appropriate sources. A characterization method was used to evaluate this material's compatibility and acceptability for use in the current study project.

3.1 Materials Collection

3.1.1 Aggregates

The Khanpur quarry in Taxila, Pakistan, provided the aggregates used in the study. Asphalt pavements' mechanical characteristics, including their hardness, toughness, gradation, water absorption, specific gravity, surface roughness, angularity, flakiness, and elongation, are important elements that can significantly affect how well they perform. British Standards and ASTM guidelines were applied in laboratory tests to figure out the viability of the gathered materials.

3.1.2 Asphalt Binder

In this investigation, virgin bitumen of the 60/70 penetration grade was used, which was purchased from Pakistan's Pak Arab Refinery Company Limited (PARCO). This Figure 3.2 Collection of Aggregates from Khanpur Quarry 26 particular bitumen type is well-suited for chilly to mild temperature ranges and is a common choice in Pakistan.

Figure 3.1 Asphalt Binder

3.1.3 Waste diaper

Disposable diapers are made of many polymers. Long-chained molecules known as polymers are created from numerous small, repetitive motifs, which serve as the chain's links. The typical disposable nappy contains at least five different polymers, each of which has a distinct function.

The actual nappies are formed out of numerous layers. Polypropene is frequently used to make the top sheet closest to the baby's skin. To preserve the baby's skin, some manufacturers additionally include a tiny layer of lotion on the top sheet.

The acquisition layer is the layer that lies beneath the top sheet. This layer absorbs the urine, keeping it from the baby's skin, and is often made of cotton and polyester.

This is where our following layer comes in. In addition to cotton, the absorbent layer beneath the acquisition layer also contains sodium polyacrylate.

The water-resistant rear sheet is the last layer of a disposable diaper. This layer, which is often made of polypropene and polyethylene, keeps the baby's sheets and clothes from getting wet from the nappy's moisture.

Figure 3.2 baby diapers

3.1.4 Waste face mask material

face masks are commonly composed of non-woven cloth layered numerous times (usually three times), together with disposable materials such as polystyrene and polyethylene. In the modern world, polyethylene, sometimes known as polythene (PE), is the most extensively used plastic. It's a polymer made mostly of petroleum that's utilized in packaging (plastic films, bags, containers, etc.).. Typically, the outer layer is harder and more colorable and ought to be impermeable to water. PES (polysulfone), melt-blown or spun-bond non-woven propylene, or combinations, make up the middle layer. To provide greater filtering, the middle layer is frothy and has a high fiber density. Spun-bond or thermo-nonwoven propylene, PES, or their mixes make up the inner layer. The individual's skin is in direct contact with the inner layer.

Figure 3.3 face mask

3.2 Material Characterization

Before being used in asphalt mixes, various tests on aggregates, asphalt binder, and RAP were conducted to evaluate their physical traits and characterize them to ensure their suitability and compatibility for use in HMA.

3.2.1 Aggregates

Aggregate is the key component of the asphalt mix. It helps to provide resistance to permanent deformation, stability, and resistance to repetitive load.to determine the quality of aggregates, laboratory tests such as gradation and specific gravity are conducted to determine the strength of stockpiles. Following are the laboratory test.

- Shape Test of Aggregates
- Aggregates Specific Gravity and Water Absorption tests
- Aggregates Impact and Crushing values
- Aggregates Los Angeles Abrasion Test

3.2.1.1 Shape Test of Aggregates

The shape is the essential physical property of aggregate. The shape of the aggregates gives strength to the asphalt mix. The shape test determines the quantity of elongated and flat aggregates particles. According to ASTM d4791, the aggregate particles with dimensions less than 0.6 of their mean sieve size are categorized as flaky aggregates. Aggregated particles with lengths more than 1.8 of their mean sizes will be labeled as elongated.

3.2.1.2 Specific gravity

Specific gravity is used to describe the weight-volume characteristics of aggregate material. Each type of aggregate that is coarse, fine, and filler had its own specific gravities calculated according to the definition, fine aggregates pass through the No. 4 sieve while coarse aggregates are retained on it.

3.2.1.3 Coarse aggregate

The methods and tools described in ASTM C 127 were used to test the specific gravity of coarse aggregate and water absorption. The specific gravity test for coarse aggregate determines the weight of coarse aggregate in three different sample situations, namely oven-dry 29, when no water is present in the sample, submerged in water or underwater, and saturated surface-dry, where water has filled the aggregate pores. The test was completed on the 10-20 mm and 5-10 mm coarse-graded stock heaps, and the results are reported in Table 3.1

3.2.1.4 The specific gravity of Fine Aggregate and Filler

The ASTM C 128 protocols and tools were used to measure the S.G. of fine aggregates. the S.G test that was performed on fine aggregate to establish the values of bulk S.G, Saturated Surface Dry, and apparent specific gravity is shown in Table 3.1

3.2.1.5 Impact Value Test

The aggregate's resistance to breaking is its impact value. Sieves in the sizes 1/2", 3/8", and #8 (2.36mm), a tamping rod, and an impact testing assembly were employed as the equipment for this test. 350 grams of representative aggregate sample, which passed through a 12" sieve and was retained on a 3/8" sieve, were added in three layers, each tamped 25 times, to the impact test apparatus cup. The sample was placed into the machine's larger mould, and 15 blows were delivered with a hammer that weighed 13.5 to 14 kg at the height of 38 cm. Afterward, the aggregate was removed and put through sieve #8. The proportion of material that passed through a 2.36mm sieve was used to calculate the impact value.

Figure 3.4 aggregate impact value test

3.2.1.6 Crushing Value Test

The aggregates must be strong enough to withstand traffic loads to produce superior quality and durable pavement. A steel cylinder with open ends, a base plate, a piston with a 150 mm piston diameter and a hole across it so a rod could be inserted to lift it, a cylindrical measure, a balance, a tamping rod, and a compressive testing machine were the tools utilized for this test. Aggregates were sent through a set of sieves, and those passing through 12" and retaining on 3/8" were chosen. A sample of aggregate was cleaned, oven-dried, weighed (W1), and then put in three layers, each tamped 25 times, to that cylindrical measure. The sample was moved into the base-supported steel cylinder.

3.2.1.7 LOS Angeles Abrasion Test

This test evaluates the road aggregate's hardness. Ideally, aggregate is tough enough to resist wear brought on by high traffic volumes. The Los Angeles Abrasion Machine, a balance, a set of sieves, and steel balls were the equipment utilized for this test. Methodology for testing or grading B was used in this process. 11 steel balls or charges and 5000g (W1) of aggregate, which is the number of aggregates retained on 12" and 3/8" sieves, were added to the aggregates before being placed in the Los Angeles abrasion machine. The machine was turned at 30 to 33 rpm for 500 revolutions. A 1.7mm sieve was then used to sift the material. The sample's weight (W2) after passing through it was noted. Finding the abrasion value required using =w2/w1*100

It is essential to evaluate the acceptability of aggregates in light of ASTM and BS standards and specifications for material characterization while making asphalt mixtures. The tests done on the aggregates are shown in Table 3.1. These studies were conducted using the Khattar Quarry aggregate.

Figure 3.5 LOS abrasion value test

Table 3.1: Test results of Aggregates

Test	Specification		Result	Limits
Elongation Index (EI)	ASTM D 4791		5.67%	≤ 15 %
Flakiness Index (FI)	ASTM D 4791		9.79%	≤ 15 %
Aggregate Absorption	Fine	ASTM C 128	1.43%	≤ 3 %
	Coarse	ASTM C 127	0.77%	≤ 3 %
Crushing Value	BS 812		24.70%	≤ 30 %
Impact Value	BS 812		17.00%	≤ 30 %
Los Angeles Abrasion	ASTM C 131		22.40%	≤ 45 %
Specific Gravity	Fine Agg	ASTM C 128	2.57	_
	Coarse	ASTM C 127	2.61	_

3.2.2 Tests on Asphalt Binder

Consistency, safety, and purity are the three characteristics of a binder that must be considered for engineering and building applications. As the temperature varies, the asphalt binder's consistency alters. As a result, a constant temperature is needed to verify the consistency of the asphalt binder. A penetration or viscosity test is typically used to determine the bitumen binder's consistency. The softening point test and the binder ductility test are two additional tests that increase data consistency and confidence. As a result, the following laboratory tests were performed to describe the asphalt binder

- Softening Point Test
- Flash and Fire Point Test
- Viscosity Test
- Penetration Test
- Ductility Test

3.2.2.1 Penetration Test

Penetration tests can be used to determine how well asphaltic compounds penetrate. Containers containing specimens and needles are used in the penetration test. When the binder is softer, penetration levels are greater. Unless otherwise stated, the temperature used, the load, and the test duration were all by AASHTO T 49-03. After completing penetration tests on PARCO 60/70 specimens, three values from each sample were collected. All values contained met the necessary penetration criteria.

Figure 3.6 Penetration Test

3.2.2.2 Softening Point Test

Bitumen is a visco-elastic material that gradually loses its elasticity and viscosity as the temperature rises. The bitumen's softening point is the temperature at which a sample of standard size can no longer hold the weight of a 3.5-gram steel ball. Therefore, the bitumen softening point is the average temperature at which the two binder rings become sufficiently pliable for the 3.5 grams of steel balls to drop 25 mm and contact the bottom of the jar. As recommended in AASHTO-T-53, the ring and ball apparatus was utilized to find the asphalt's softening point.

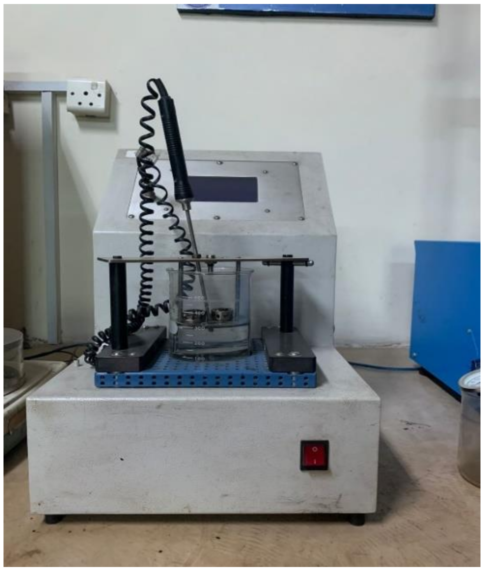

Figure 3.7 Softening point test

3.2.2.3 Ductility of Asphalt

An important aspect to consider while characterizing the HMA mixture's performance is ductility, which is a crucial attribute of asphalt binder. The degree of ductility shows how bitumen responds to temperature changes. AASHTO T 51-00 states that it is "the length in cm at which a standard sample of the asphaltic material will be stretched without breaking at the specific speed of 5 cm per minute and at the specified temperature of 25+ 0.5°C.The typical circumstances and outcomes for bitumen ductility tests are shown in Table 3.2. Each specimen met the minimum 100 cm ductility requirement.

Figure 3.8 ductility

3.2.2.4 Flash and Fire Point Test of Bitumen

The lowest temperature at which bitumen suddenly flashes in specific circumstances is known as the flash point of bitumen.

The fire point is the temperature at which a substance ignites and burns under specific circumstances. The D3143/D3143M-13 standards performed the flash and fire point tests.

Figure 3.9 flash and fire point test

3.2.2.5 Viscosity Test of Asphalt Binder

Viscosity is defined as the relationship between applied shear stress and shear rate. It measures flow resistance. This test establishes the procedure for measuring the viscosity of bitumen at high temperatures ranging from 60 °C to more than 2000 °C. Rotational Viscometer uses the notion of torque. It calculates the torque needed to rotate an object immersed in a liquid (in this case, bitumen) and correlates that torque with the fluid's viscosity. This test is carried out in line with ASTM D 4402 - 06, a test standard. Table 3.2 displays the results In light of ASTM material characterization criteria and specifications, it is vital to assess bitumen's applicability while preparing asphalt mixes. The experiments indicated above were performed in a lab to evaluate the asphalt binder (PARCO 60/70). The outcomes of the tests are displayed in Table 3.2.

Table 3.2: Tests results on Bitumen

S.NO	Test Description	Result	Specifications	Standards
1	Penetration at 25 C	62.5	60-70	ASTM D5
2	flash point (C)	357	>232	ASTM D 92
3	fire point (C)	381	-	ASTM D 92
4	softening point (C)	51.5	49-56	ASTM D 36-06
5	Viscosity (cm)	0.24 pa. sec	0.22-0.44 pa. sec	ASTM D 4402
6	Ductility (Pa-sec)	124cm	>100	ASTM D 113-99
7	Specific gravity	1.01	D70	0.97-1.02

3.2.3 Bitumen Modification with Waste baby diapers

The results were then contrasted with bitumen samples that had not been treated. Samples of WD-modified bitumen were created using a high-shear mixer running at a speed of about 1100 rpm. In the region of 155 to 160 °C, the base bitumen was heated until it achieved a liquid form. The heated bitumen was then gradually blended with WD, and the mixing process was continued for two hours. Then, for use in future testing, WD-modified samples at concentrations of 2%, 4%, and 6% were put in different vessels and sealed with aluminum foil. The ductility, softening point, and penetration of WD-modified bitumen were examined to determine the ideal WD content that can be used for bitumen modification in subsequent tests.

3.2.3.1 Penetration Test on WBD Modified Bitumen

As shown in Figure 3.18, when bitumen was altered using various concentrations of WD (2%, 4%, and 6%), the Penetration value decreased. This reduction was more pronounced at higher WD concentrations, indicating a tougher texture in the modified bitumen. Therefore, it was determined that the bitumen underwent a process of hardening as a result of the integration of WD.

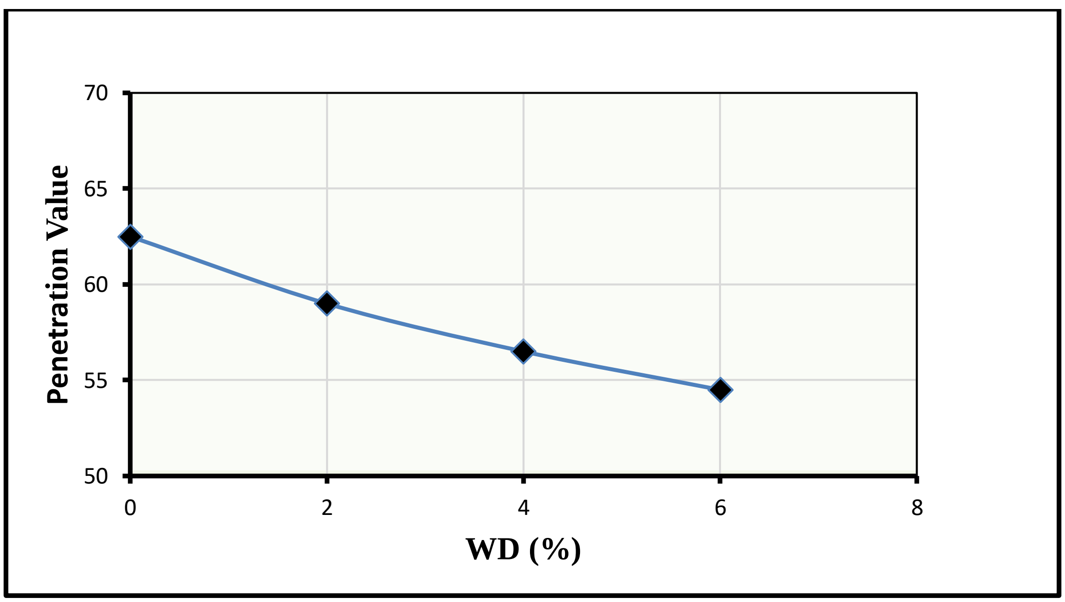

Figure 3.10 Penetration test

3.2.3.2 Softening Point Test on WBD Modified Bitumen

The Softening Point value increased as a result of the alteration of bitumen using various concentrations of WD (2%, 4%, and 6%), as shown in Figure 3.20. As the quantity of WD grew, this increase became more significant, indicating that the modified bitumen had a tougher texture. It was concluded that the bitumen went through a hardening process as a result of the addition of WD.

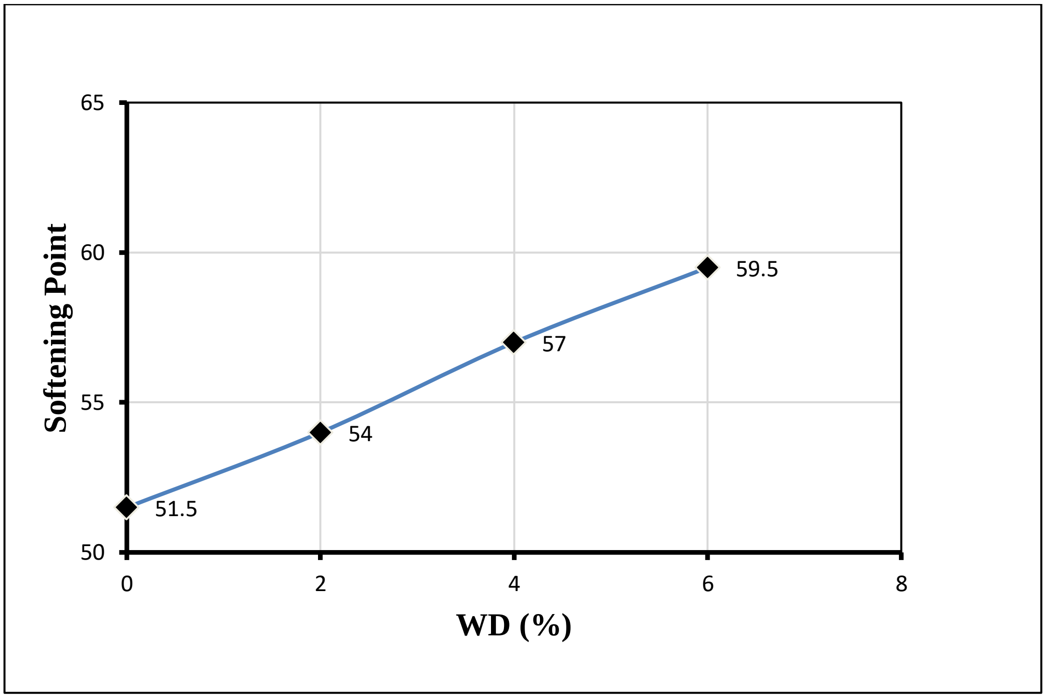

Figure 3.11 Softening point test

3.2.3.3 Ductility Test on Modified Bitumen

Different percentages of WD were used to modify bitumen, and the modified bitumen's corresponding ductility value was noted. The findings indicated a decrease in Ductility value with a rise in the percentage of WD, as presented in Figure 3.22

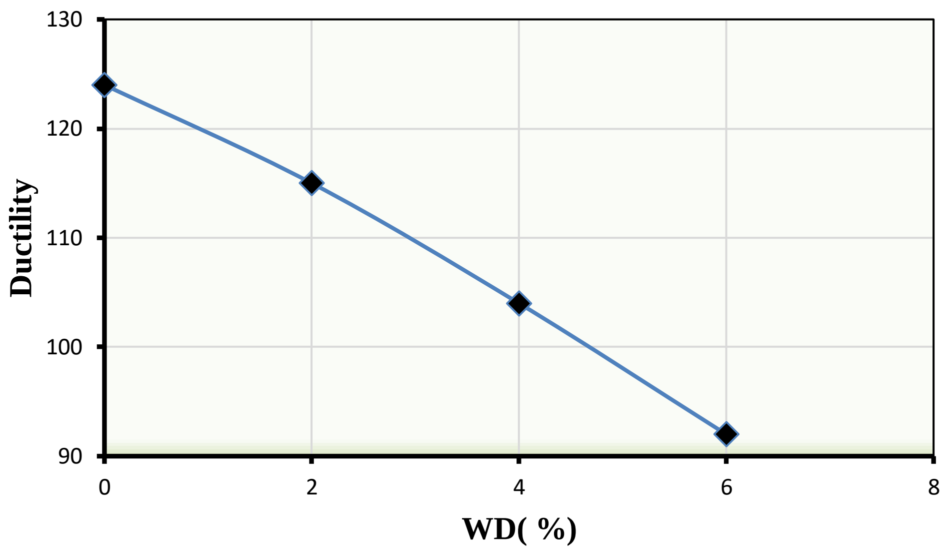

Figure 3.12 Ductility test

3.3 Selection of Optimum WBD Content

Table 3.3: Test result on modified bitumen

WD %	Penetration	Softening	Ductility ()
0	62.5	51.5	124
2	59	54	115
4	56.5	57	104
6	54.5	59.5	92

3.4 Gradation Selection

According to the NHA (1998) requirements for dense graded surface course mixtures, the aggregate gradation employed was NHA class B. According to MS-2, the nominal maximum size for this gradation was (3/4") or 19mm. The chosen gradation is displayed in Table 3.4, along with the percentage of material passing through each sieve, and the associated gradation curve is plotted in Figure 3.13.

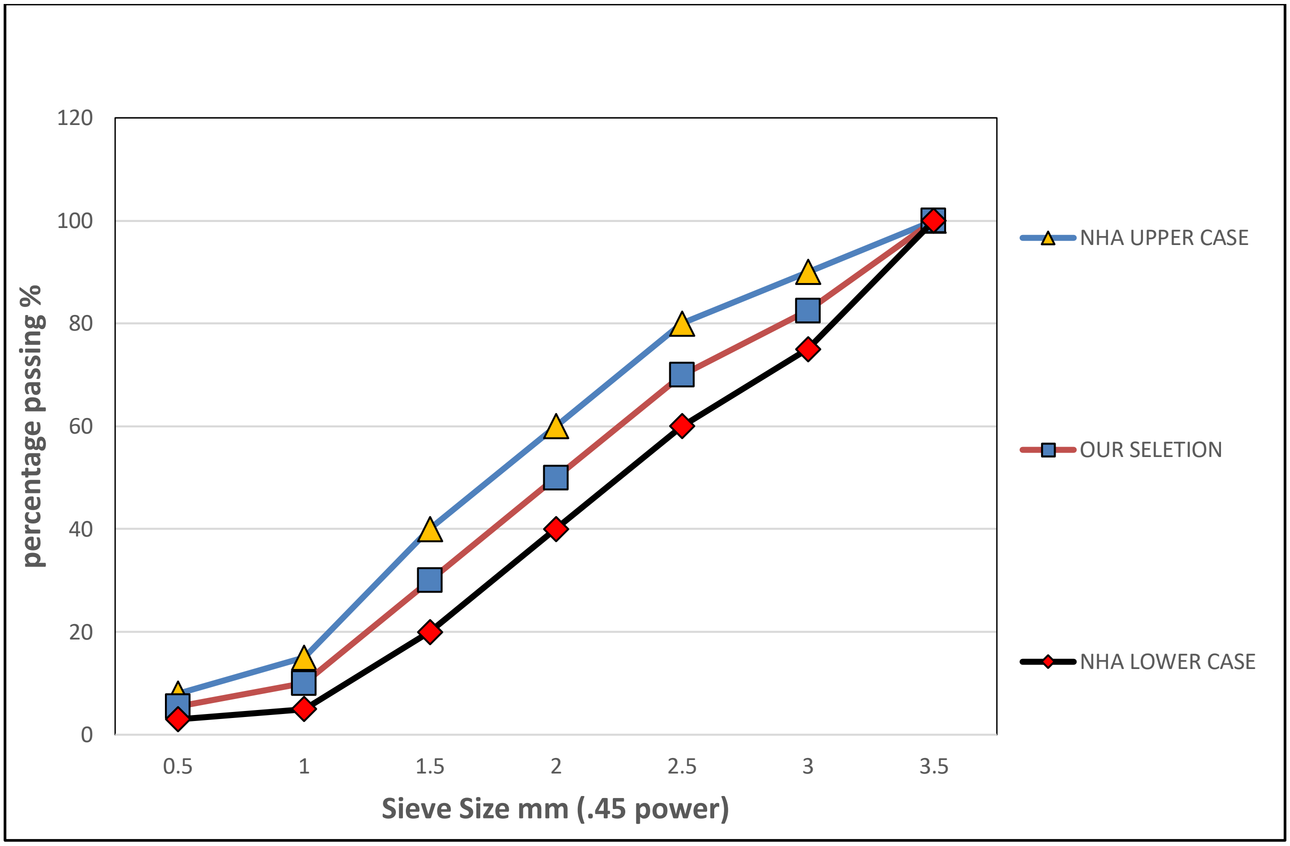

Figure 3.13 NHA Class-B Gradation plot with Specified limit

Table 3.4 NHA Gradation B

S.NO	Sieve size (mm)	NHA Specification range (% passing)	Our selectin	Retained (%)
1	19	100	100	0
2	12.5	75-90	82.5	17.5
3	9.5	60-80	70	12.5
4	4.75	40-60	50	20
5	2.36	20-40	30	20
6	1.18	5-15	10	20
7	0.075	3-8	5.5	4.5
8	Pan	…	…	5.5

3.5 Asphalt Mixtures Preparation

Different bitumen percentages by weight of aggregates are used to create different asphalt mixtures. These samples were made following the Marshall Mix Design Procedure. Samples were prepared for Performance Testing after OBC determination.

3.5.1 Preparation of Bituminous Mixes for Marshall Mix Design

The Marshall Test evaluated the optimal bitumen content (OBC) for virgin bitumen using various bitumen percentages (3.5%, 4%, 4.5%, 5%, 5.5%). The aggregates were then 110 °C oven dried after being sieved into the various sizes needed for the project. Marshall Mix samples weigh 1200gm in total. The proportion of asphalt in the mix, which ranges from 3.5% to 5.5% by weight, caused weight variations. The aggregate utilized after that comprises various sizes according to the gradation employed. To determine OBC, Marshall Stability, Flow, and Volumetric Properties were measured.

Table 1.5: Test Matrix for Determination of OBC

Bitumen Content (%)	No of Samples
3,5%	3
4%	3
4.5%	3
5%	3
5.5%	3
Total	**15**

3.5.2 Preparation of Bituminous Mixes

After sieve inspection, aggregates were dried at 105°C to 110°C to a consistent weight. For the Marshall Mix design method (ASTM D6926), 1200 grams of aggregate are needed to prepare a compacted 4-inch diameter sample. Equation 3.2 was used to determine the amount of bitumen needed for each specimen as a proportion of the mix's overall weight:

$$M_T = M_A + M_B \quad (3.1)$$

$$M_B = X/100(M_T) \quad (3.2)$$

Where,

M_T = Total mix Mass

M_A = Aggregate Mass

M_B = Bitumen Mass

X = Bitumen Percentage

3.5.3 Mixing of Aggregates and Asphalt

ASTM D6926 suggests using a mechanical mixer for efficient bitumen and aggregate mixing. The dried, heated aggregates and heated bitumen were taken out of the oven and put right into the mechanical mixing apparatus. Figure 3.14 displays the schematic design of a mechanical mixing apparatus. The mixing temperature ranged from 160°C to 165°C, matching the temperature at which bituminous mixes are produced in Pakistan (per NHA Specifications). Additionally, the Superpave mix design (SP-2) specifies that this mixing temperature corresponds to the binder viscosity range of 0.22 to 0.45 Pa.sec.

Figure 3.14 mixing of aggregates

3.5.4 Conditioning of Mixture

According to ASTM D6926, bituminous mixes must be conditioned for two hours before compacting. Each bituminous blend created by the mixing device was afterward put into a metal container.

3.5.5 Specimen Compaction

According to Marshall Mix design, there are three criteria for compaction, depending on whether the surface is ready for light, medium, or heavy traffic. 75 strikes are administered to each side of the samples to accomplish compaction since, for design purposes, we are assuming pavement for high traffic. The loose mixture created by heating aggregate with bitumen is then put into a base-plate-equipped mould. The specimen was positioned with filter paper above and below it. After administering 75 strikes to one side of the specimen, it was turned over, and another 75 blows were administered. This compacting was done by hand.

3.5.6 Volumetric, Marshall Stability, and Flow determination

After measuring the bulk specific gravity (Gmb) and theoretical maximum specific gravity (Gmm), volumetric characteristics, including Voids Filled with Asphalt (VFA), Voids in Mineral Aggregates (VMA), unit weight, and Air Voids (VA), were analyzed using formulae. The Marshall Mix design criterion is displayed in Table 3.5. To calculate the Gmm and Gmb of bituminous pavement mixtures, ASTM D2041 and D2726 were employed. Following the Gmb determination, the samples were evaluated for flow and stability using Marshall Test equipment after being submerged in a water bath at 60°C for an hour.

The sample was fed into the Marshall apparatus at a continuous deformation rate of 5 mm per minute until it could no longer withstand the stress. The maximum load in KN was used to determine Marshall Stability. The stability value is the maximum load a mixed sample can support before failing, and the flow number in millimeters represents the strain experienced by the sample under this load. Marshall Mix design standards state that a pavement surface intended for heavy traffic must have a stability value lower than 8.007 KN and a flow value between 2 and 3.5 mm. The specimen was taken out of the water bath and tested right away.

Figure 3.15 marshal stability and flow

3.6 Volumetric Properties of HMA

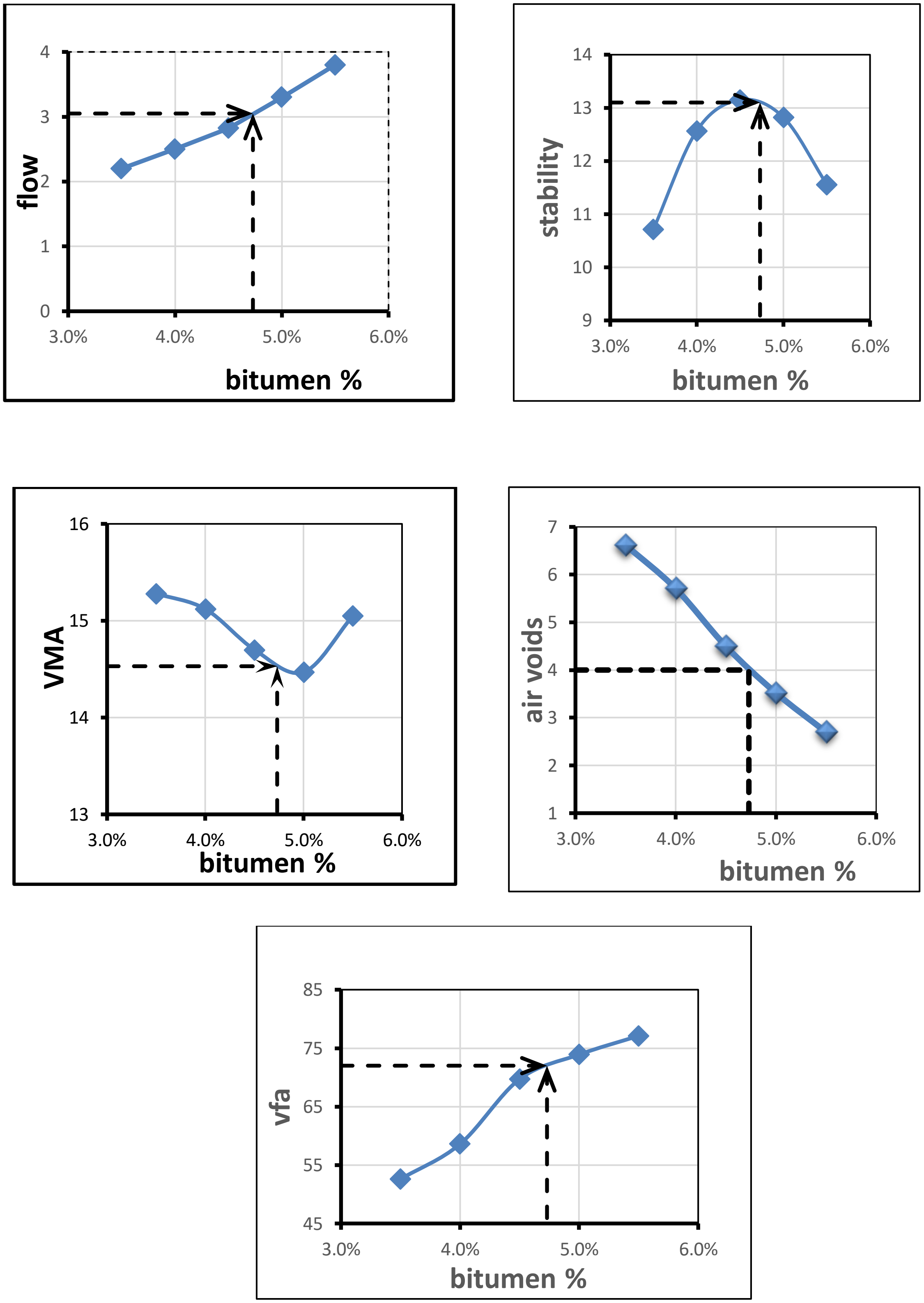

Figure 3.16 Volumetric Properties of Marshall Sample

3.7 Performance Testing of Asphalt Mixtures

Performance tests, such as the Hamburg Double Wheel Tracker test, Marshall Stability and Flow test, and the Moisture susceptibility and Indirect tensile strength test, were carried out to examine the indirect tensile strength and moisture damage, rutting resistance, stability, and flow of controlled and modified asphalt mixes. As illustrated in Table 3.11, an assessment matrix for performance testing was put together for five distinct types of mixtures, each of which had been modified for a certain level of ideal WD and SFM content. For the other four blends, one served as a control.

Table 3.6: Test Matrix for Performance Tests

S.NO	WD % OF BITUMEN	SFM %	Samples for DWT	Samples for moisture susceptibility	Samples for flow and stability
1	o	0	3	6	3
2	Optimum WD bitumen content	0	3	6	3
3	Optimum WD bitumen content	0.5	3	6	3
4	Optimum WD bitumen content	1.0	3	6	3
5	Optimum WD bitumen content	1.5	3	6	3
Total			15	30	15

3.7.1 Preparation of Sample for Performance Tests

The Marshall method for moisture damage preparation was employed to prepare samples for UTM testing, while the Superpave mix design was used to make specimens for double-wheel tracker testing. At 105°C to 110°C, the aggregates were heated to a consistent weight. The mixing and compaction temperatures for HMA were each 135°C. The preparation of 6-inch diameter gyratory compacted specimens required 6000gm of aggregates. After mechanically combining aggregates and asphalt binder, samples were heated for two hours to condition. Samples were put in the gyratory mould after conditioning, and 125 rotations were employed to compact the specimens. Using a saw cutter on each specimen, a standard sample of 2.5 inches in height and 6 inches in diameter was carved out for the wheel tracker test. Figure 3.18 depicts the cutting of test specimens with a saw.

3.7.2 RUTTING INVESTIGATION OF SAMPLES

Rutting is one of the most common permanent pavement deformations brought on by cyclic traffic loads. Along the tyre paths, the pavement material accumulates small deformations. To analyze rutting propensity, the specimens were assessed utilizing a Double wheel tracker to ascertain their resistance to persistent deformation. The electrically powered DWT can move a steel wheel with a diameter of 203.2mm and a width of 47mm across a test specimen. With a contact area of 970 mm2 and a weight of 1581.0 lbs on the steel wheel, the average contact stress generated by the wheel contact is 0.73 MPa. Similar to how the contact pressure of a steel wheel creates the influence of the rear tire of a double axle. The contact area grows larger, and the contact stresses change as the rut depth rises. The steel wheel moves backward and forwards over the thing. The DWT steel wheel must pass the sample about 60 times per minute. The center of the sample is where the wheel travels over the specimen at a speed of almost 1 foot per second. Rutting tests can be performed in dry, wet, and air modes with the aid of DWT. This study employed dry mode to assess the asphalt mixtures' rutting susceptibility. Modifying the DWT under the anticipated test conditions can utilize these three modes. The Double Wheel-41 tracking equipment used to conduct rutting tests is depicted in Figure 3.35. Two 2.5-inch-thick specimens were created by sawing the samples from the top and bottom surfaces before the test. The silicon mould from the wheel tracker tray was used to cut these specimens.

The sample was placed on a steel tray, tucked under the wheel, and fastened. It was time to turn on the wheel tracking system. The software was then updated with the example data. The wheel's pass-per-minute (ppm) setting was 25. As needed to assess the rutting potential of asphalt mixtures incorporating grade 58 bitumen (PARCO 60/70), the number of passes was set to 10,000 (5000 cycles). The wheel tracker was employed while in the dry mode to determine rut damage at a temperature of 40°C. Finally, the test was conducted, and the mounted specimen's wheel began to move forward and backward. The number of passes was displayed on the laptop linked to the machine. The wheel's whole back-and-forth motion was counted as two passes. The LVDT (Linear Variable Differential Transformer) simultaneously monitors the wheel motion and the imprint of the rut in millimeters of the unit. The machine automatically shuts off when the required number of passes were completed. The outcomes were kept for later use.

Figure 3.17 Hamburg Double Wheel Tracker Testing

3.7.3 MOISTURE SUSCEPTIBILITY TESTING

ASTM D 6931-07 performed the moisture susceptibility test (Moisture-Induced Damage Resistance of Compacted Hot-Mix Asphalt). Three unconditioned samples of each blend were examined. Before testing, these unconditioned samples were immersed in a water bath with a temperature of 25°C (77.8°F) for an hour. In a different batch, three conditional samples for every blend were analyzed. According to ALDOT-361, samples were saturated, then placed in a water bath for 24 hours at 60 °C (140.8 °F), then for an hour at 25 °C (77.8 °F). At a rate of 50 mm per minute, 42 diametrically loaded specimens—both unconditioned and conditioned—were loaded. Then, using the specimen's measurements and failure load, the tensile strength for each specimen was calculated. The average conditioned tensile strength was divided by the average unconditioned tensile strength to get the tensile strength ratios. To be considered acceptable, the employed tensile strength ratio has to be at least 80%. The tensile strength of each subgroup was determined using Equation 3.3.

$$St = 2000P/\pi Dt \qquad (3.3)$$

Where:

St = Tensile strength, kPa

P = Maximum load, N

t = Specimen height before the tensile test, mm

D = Specimen diameter, mm

subset indicates the possibility of moisture damage. Equation 3.4 is used to compute the TSR for each blend.

$$TSR = [S2/S1] \qquad (3.4)$$

Where:

S1 = Average tensile strength of unconditioned subset, and

S2 = Average tensile strength of conditioned subset.

Figure 3.18 Indirect Tensile Strength (IDT) and Moisture Susceptibility Testing

3.8 Summary

This chapter provides a thorough analysis of the sources used in the study's research and their characterization. It goes over the many tests run on these materials, as well as the methods and techniques employed. In this chapter, we also discuss the tests conducted on modified bitumen samples to determine the Optimum Modifier Content and the use of the Marshall mix design approach to find the Optimum Bitumen Content (OBC). Additionally, it provides a thorough explanation of the performance testing procedure as well as the technique for creating samples and carrying out performance testing.

4 CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Introduction

Rutting is the form of pavement wear and tear that tends to occur on HMA pavements around the world, especially in Pakistan. It is brought on by higher axle loads and higher pavement surface temperatures. Therefore, performing the Hamburg double wheel tracker test is a recommended method for determining rutting susceptibility that is both technically and practically appropriate. Rutting and moisture that have been trapped in the pavement both have the potential to harm HMA pavements and cause early deterioration. The Universal Testing Machine (UTM) is a well-liked and straightforward technique that is frequently utilized to evaluate the harm brought on by moisture.

This study evaluated the effects of varying the proportions of WD and SFM on the characteristics of both controlled and modified asphalt mixtures. The optimum concentration of WEPS was determined through the Marshall mix design process, while the most suitable bitumen content was determined by conducting physical tests on WEPS-modified bitumen with varying levels of concentration. The samples were ready for performance testing after the ideal bitumen and modifier content had been established. The study looked into many characteristics, including flow, rutting, stability, tensile strength, and moisture damage.

Topics including moisture damage, stability and flow, and rutting susceptibility have already been examined in this thesis's literature review part. The Materials and Methods section already provided a full description of the procedures and guidelines utilized in this study to carry out the tests and accomplish the research goals. The outcomes from several tests will be presented and examined in this chapter.

4.2 Waste Baby Diaper Modified Bitumen Testing Results

in order to compare the behavior of WD-modified bitumen to unmodified bitumen in terms of penetration, softening point, and ductility, several tests were conducted on it. With the addition of WD, modified bitumen's penetration value was reduced and its softening point increased, as shown in Figure 4.1. The minimal ductility value of 100 cm at 25°C suggested by ASTM D113 was not met by WD-modified bitumen at 6%; rather, it fell below it when WD was increased. The ductility values at various WD modifier proportions are shown in Figure 4.2.

As WD content was added, the modified bitumen's penetration value decreased, and at 6% WD content, the bitumen grade changed. Additionally, the bitumen's ductility value was below the required level for WD concentration values higher than 4%. Based on the results of these preliminary testing, 4% was determined to be the ideal WD modifier level for the best bitumen performance. An improvement in the modified bitumen's resistance to deformations is shown by an increase in the softening point and a drop in the penetration values.

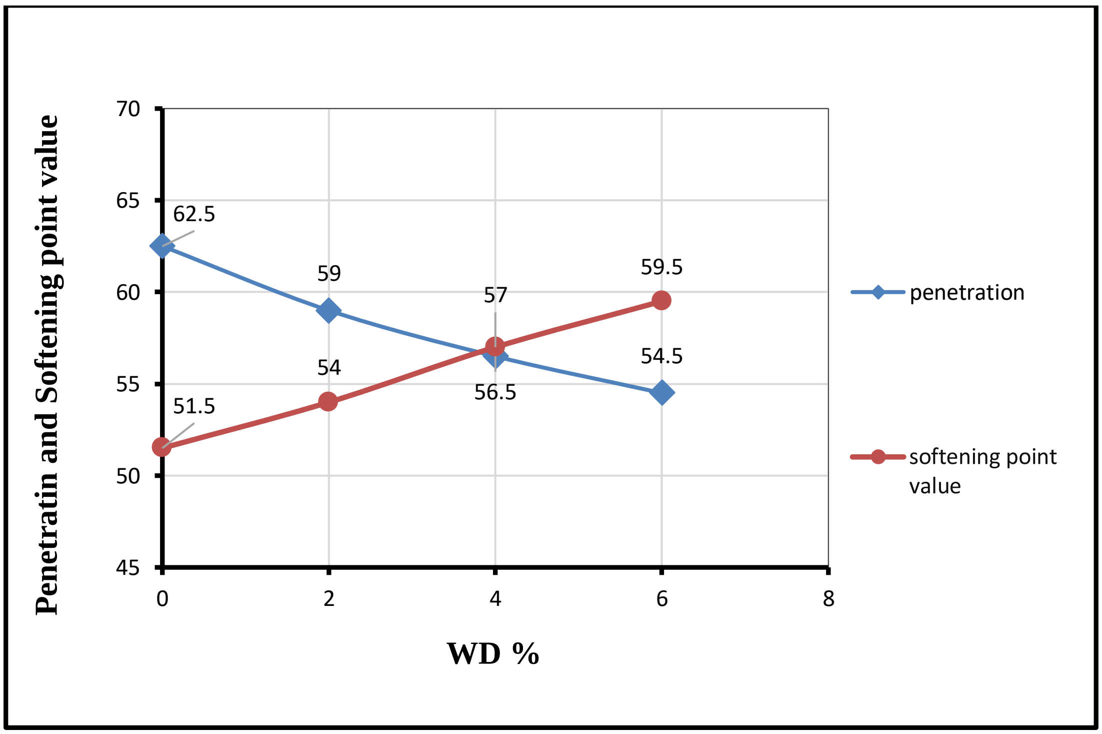

Figure 4.1 Penetration and Softening Point of WBD Modified Bitumen

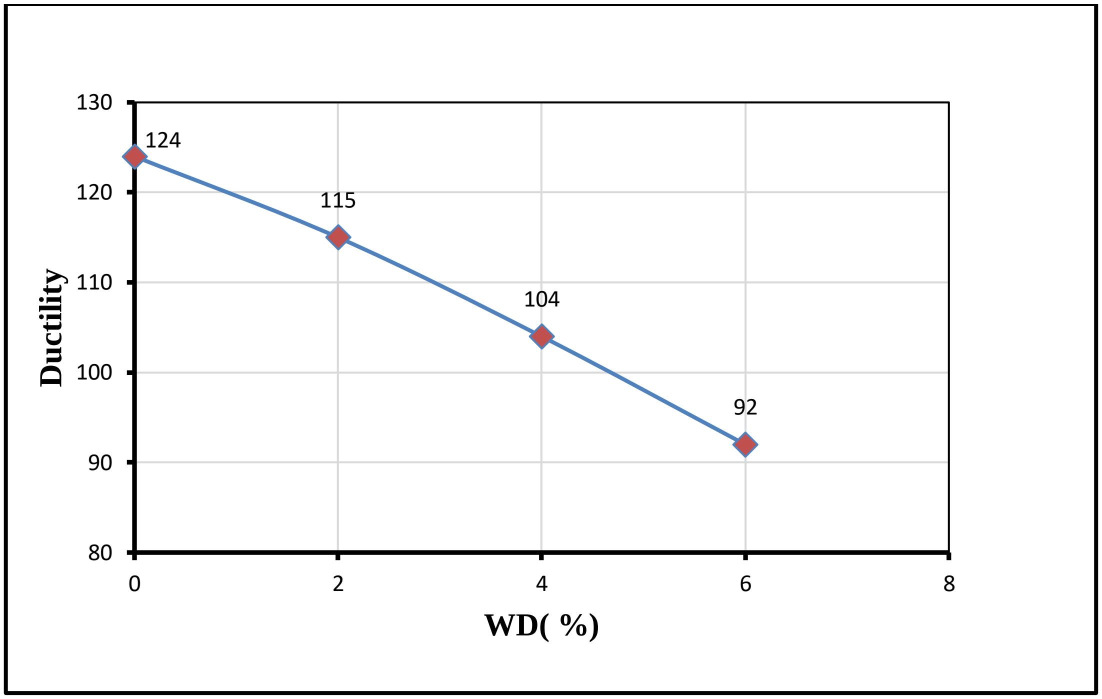

Figure 4.2 ductility of modified bitumen

4.3 Moisture Susceptibility and Indirect Tensile Strength Results

The ITS test is an essential indicator of the durability and durability of asphalt pavements. The test demonstrates the pavement's resistance to tensile stress-induced cracking and other forms of strain. After conducting some empirical tests on modified HMA, it was discovered that the bitumen grew tougher and its resistance to deformation improved with the inclusion of waste diapers, which ultimately led to the construction of a stronger link between aggregates. Following the incorporation of virgin HMA with the optimum WD concentration, the indirect tensile strength of the unconditioned and conditioned samples increased by 3.78% and 6.14%, respectively, and as a result, it demonstrated improved resistance to cracking and deformation. With the addition of 0.5% SFM and the ideal WEPS content in comparison to controlled HMA, indirect tensile strength was increased by 5.63% and 11.02% for unconditioned and conditioned samples, respectively. The ITS value increased by 6.98% for unconditioned samples and by 11.73 percent for conditioned samples at 1% SFM and the optimal WEPS level, respectively. Similarly for 1.5% SFM and optimum WD content the ITS value for unconditioned and conditioned samples increased by 7.73% and 12.73%. Overall, it was discovered that the SFM materials are stiffer, which causes a stronger link between aggregates and a higher indirect tensile strength value of the SFM-modified mixes compared to controlled mixes. The stiffness of the WD modifier improved the moisture damage resistance of modified HMA, and it outperformed the controlled mix in terms of moisture susceptibility. As illustrated in Figure 4.4, when the ideal WD content was added to virgin HMA, the tensile strength ratio increased by 2.26%. When SFM material and Optimum WD content were combined, the TSR value was increased. the TSR value for 0.5%,1%, and 1.5% was increased by 3.13%,4.43%, and 4.55% as compared to the controlled mix. All the mixture containing SFM and the ideal WD concentration meets these criteria, as shown in Figure 4.4, all of the mixes, modified and unaltered, fulfilled ALDOT-361's minimum TSR requirement of 80%.

Table 4.1: Indirect Tensile (IDT) Strength of conditioned Samples

Tensile Strength results for HMA containing WD-modified bitumen and SFM (Conditioned Samples)				
WD and SFM %	**Height (mm)**	**Diameter (mm)**	**load**	**tensile strength**
Virgin	64.5	101	4.3321	422.32
OWD and 0% SFM	64.25	101	4.567	448.26
0.5 % SFM	64.75	101	4.732	468.87
1 % SFM	64.75	101	4.845	471.88

Table 4.2: Indirect Tensile (IDT) Strength of Unconditioned Samples

Tensile strength results for HMA containing WD-modified bitumen and SFM (unconditioned)				
WD and SFM %	**Height (mm)**	**Diameter (mm)**	**Load (KN)**	**tensile strength (kpa)**
Virgin	64.4	101	4.851	474.29
OWD and 0% SFM	64.3	101	5.015	492.23
0.5 % SFM	64.6	101	5.153	501.87
1 % SFM	65	101	5.21	507.43
1.5 % SFM	65	101	5.278	511.29

Table 4.3: Tensile Strength Ratio of Virgin and Modified Mixes

Sample	unconditioned strength kpa	conditioned strength kpa	TSR value
Virgin	474.29	422.32	89.04%
OWD and 0% SFM	492.23	448.26	91.06%
OWD and 0.50% SFM	501.87	468.87	91.83%
OWD and 1% SFM	507.43	471.88	92.99%
OWD and 1.50% SFM	511.29	476.02	93.1%

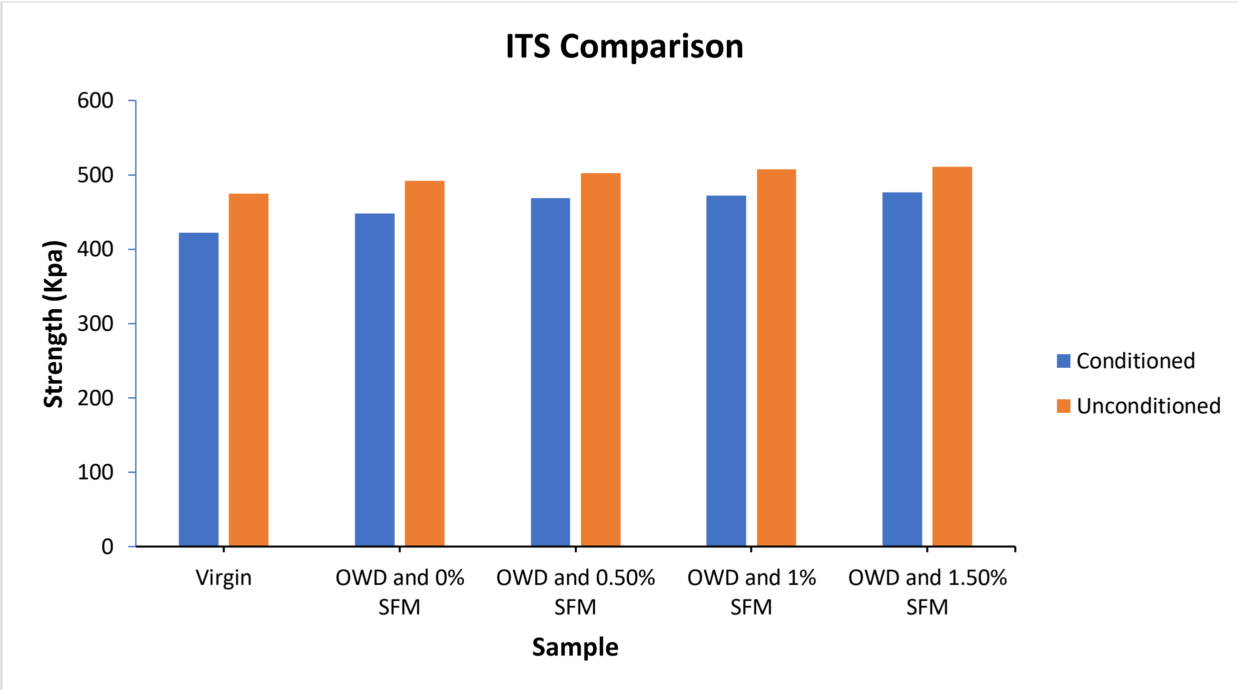

Figure 4.3 Indirect tensile strength of controlled and modified HMA mixes

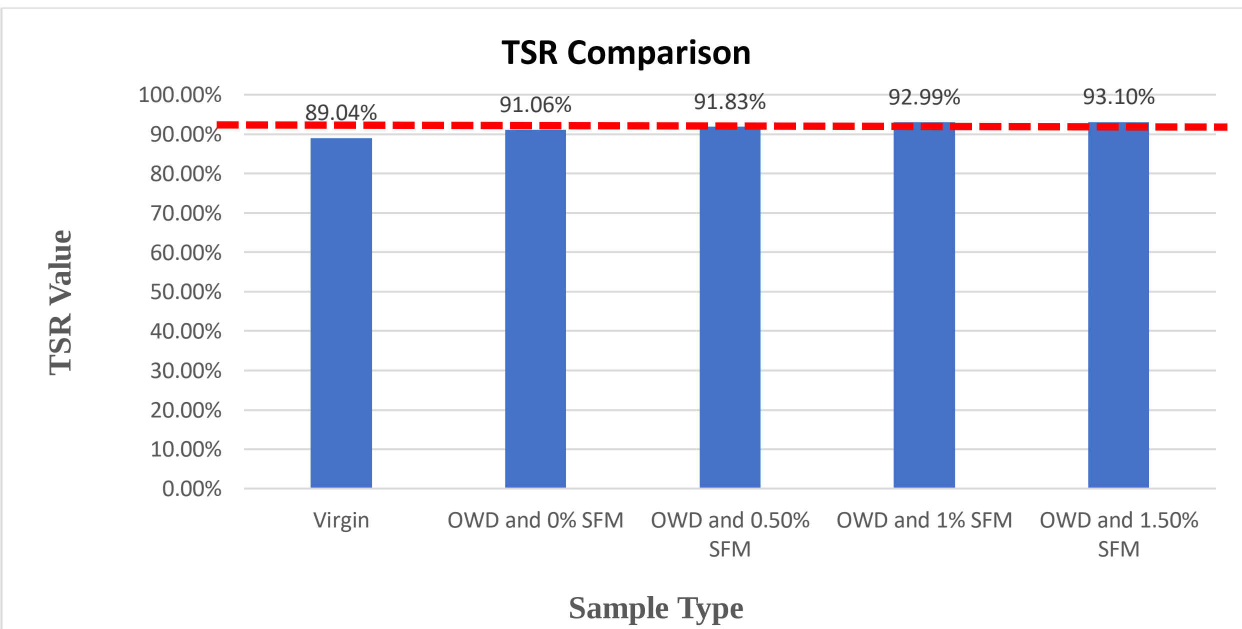

Figure 4.4 Indirect tensile strength of controlled and modified HMA mixes

4.4 Rutting Resistance of Control and Modified Mixes

The addition of WD-modified bitumen increased the HMA mixture's rut resistance by 8.11% because these particles are less temperature-sensitive than virgin bitumen and experience less stiffness loss. These types of mixtures enable the final product to perform better in terms of resistance to plastic deformation, making them appropriate for use in warm regions where plastic deformation is a frequent problem in road networks. The rutting resistance of the modified asphalt mix was greatly increased by the inclusion of 0.5% SFM and the ideal WD concentration. When compared to the virgin mix and the modified mix with the optimal WD content, the modified mix's rutting resistance improved by 31.59% and 25.55%, respectively. Using 1% SFM and optimum WD amount greatly improved the modified asphalt mix's resistance to rutting. The adjusted mix displayed an improvement in rutting resistance of 42.60 and 37.50%, respectively, over the virgin mix and the mix with 0.5% and the optimum WD concentration. By addition of 1.5% SFM and optimumWD the rutting resistance increased by 48.69% and 44.16% as compared to virgin mix and mix with o.5% and optimum WD.

The face mask layer stabilizes the binder on the surface of the aggregate particles in the asphalt mixture by forming a high-viscosity composite network. This action improves the ability of the mixture containing the face mask to prevent rutting.

Table 4.4: Rut depth values after every 1000 cycles

No of Cycles	Rut Depth (mm) for Virgin HMA	Rut Depth (mm) for Optimum WD Content and 0% SFM	Rut Depth (mm) for Optimum WD Content and 0.5% SFM	Rut Depth (mm) for Optimum WD Content and 1% SFM	Rut Depth(mm) for optimum WD content and 1.5% SFM
0	0	0	0	0	0
1000	1.8	1.68	1.17	0.87	0.77
2000	2.57	2.35	1.53	1,15	1.04
3000	2.98	2.47	1.71	1.37	1.25
4000	3.25	2.84	1.92	1.60	1.47
5000	3.45	3.17	2.36	1.98	1.77

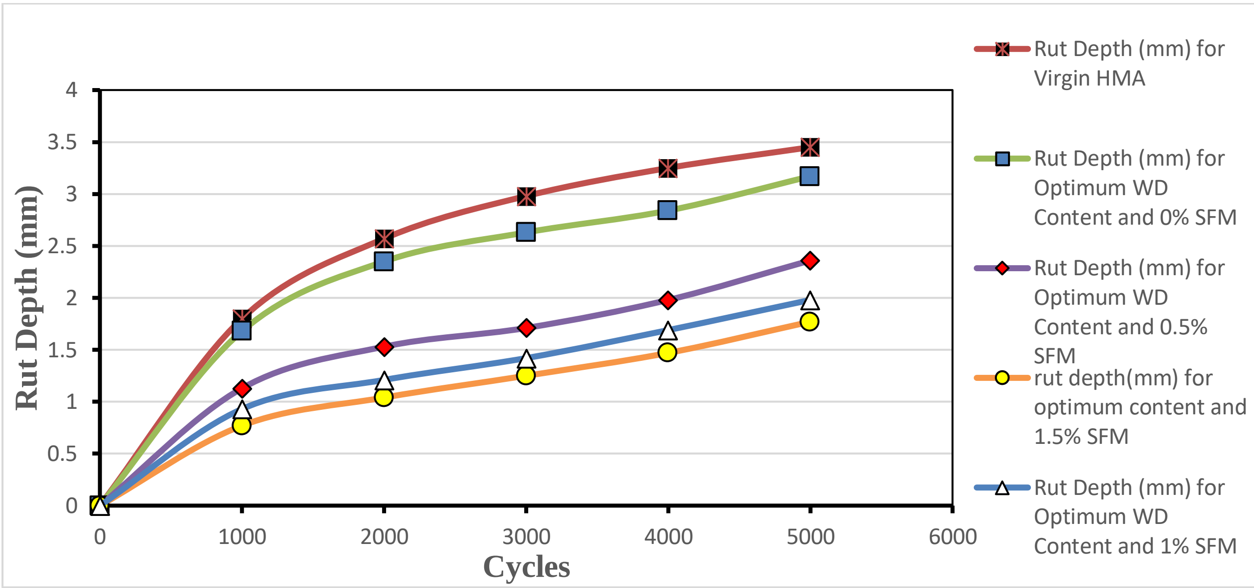

Figure 4.5 Rut Resistance of Control and Modified Asphalt Mixes

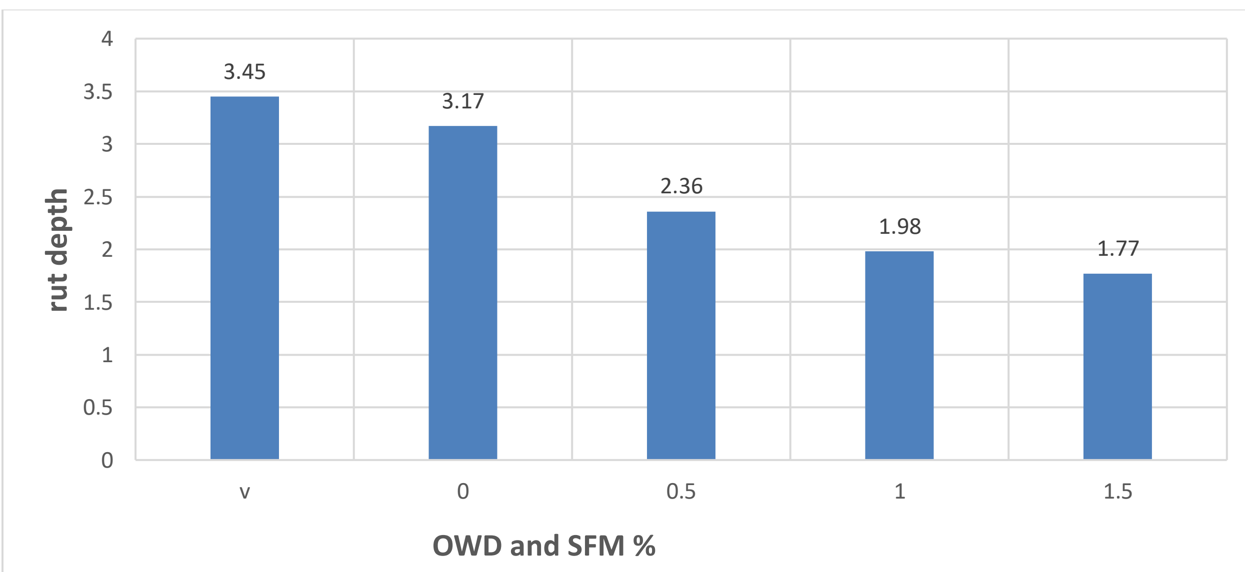

Figure 4.6 Rut Depth

4.5 Summary

This chapter has described the thorough analysis of the outcomes of laboratory tests. Regarding the rise in RUT potential, ITS values, and TSRs, the results of the DWT and UTM are discussed. The results reveal that in terms of tensile strength and resistance to rutting, using WD and SFM perform better than the controlled mix.

5 CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Background

The purpose of this study was to evaluate the performance of HMA modified with baby diapers and face mask utilising the Superpave mix design and to ascertain whether the HMA's original qualities had changed. To evaluate the performance of asphalt mixtures, the results of a conventional performance test and a general testing system were employed. WBD was use as bitumen modifier. SFM was used as a modifier to describe the performance of asphalt mixtures. What the ideal binder and polymer content need to be was established. Double wheel tracker and UTM were employed to evaluate the performance of the pavement. It was imported from Khattar with NHA Class B wearing course gradation, PARCO Bitumen of grade 60/70, and aggregate. baby diapers and face mask from local store was used. The Marshall Method was used to calculate OBC. Samples were prepared for performance testing after identifying OBC. Gyratory compactors were used to prepare the samples for rutting. Marshall compactor was used to prepare samples for ITS and moisture susceptibility. The following are the main outcomes, conclusions, and results of performance testing.

5.2 Conclusions

This innovative research outlines a strategy for reducing the environmental effects of infectious and pathogenic waste by the use of waste BD and FM as modifiers in asphalt mixtures for road surface. The following conclusions are reached as a result of the experimental results:

- As a modifier, adding 4% shredded BD to conventional bitumen caused the bitumen grade to decrease while concurrently raising the softening, flash, and fire point temperatures. This provides evidence in support of the idea that adding BD to bitumen improves rut resistance and reduces permanent deformation. Notably, the set threshold limitations specified by ASTM recommendations were violated when the proportion of BD inclusion rose above 4%.
- With an increasing amount of FM addition, improvements in the modified aggregates' mechanical and physical properties were seen. Notably, considerable improvements were seen in all parameters when the aggregates were treated with 1.5% shredded FM: the

values for absorption, crushing, impact, and abrasion were increased by 33%, 11%, 11%, and 14%, respectively, in comparison to virgin aggregates.

- When compared to the reference mix, Mix 5 showed a significant 18% increase in the ITS and an even more amazing 39% improvement in stability, along with a 27% reduction in the flow. These results convincingly support the increased binding strength between aggregates and asphalt paste as a result of BD and FM inclusion.
- Internal densification caused by the modified aggregate surface, improved bitumen properties, and a stronger bond between the modified aggregate and bitumen all worked together to increase mix 5's moisture resistance and elastic performance by 8% and 33%, respectively, while significantly reducing rut depth by 53% when compared to mix 1. This provides substantial support for the idea that after-melting BD and FM results in a stronger connection.
- Finally, a rough evaluation of the potential use of waste BD and FM in road pavement, using the recipe for mix 5 on an annual basis, showed a significant reduction in the waste materials of 36% and 61%, respectively. It is crucial to remember that employing BD and FM to handle and prepare asphalt mixtures has dangers for infectious and pathogenic diseases in real-world settings. As a result, it is highly advised that necessary precautions and careful disinfecting measures be carefully followed throughout such surgeries.

5.3 Recommendations

- In this investigation, increasing the FM doses for aggregate coating improved the characteristics of the asphalt mix. Therefore, it is advised to research how FM-modified aggregates affect the road surface at dosages higher than 1.5.
- Furthermore, it is strongly encouraged to undertake a thorough investigation to determine the environmental advantages of adding FM and BD into road pavement. To determine the level of environmental improvement obtained, this analysis should use the methodology described in Section 5 of this study.

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