Performance Evaluation of Asphalt Mixtures under dry and wet mixing containing Sustainable Silicon Waste Material

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Abstract

Across the worldwide modern infrastructure of transportation is very prominent for social beings in everyday life. With the passage of time gradually surge in growth rate as well as the number of trips. To enhance the performance pavement different agencies are research on the behavior and condition of the pavements. Development of sustainable infrastructure across the globe especially recycling and production by using waste material for road network. The two major predominant factors which relate with construction for developing of sustainable transportation network. Globally, a huge amount is produced of basic HMA and being utilized to produce a handsome volume of the finalization of road materials. This study relates with method of modification by addition of silicone covers of mobile as a waste material. In this study also present an innovational technique of mixing - by dry mix and wet mix and comparison between the performance of both mixing techniques. In our study, utilizing two different sources of aggregate Margalla crush and Sargodha crush 60/70 grade bitumen and silicone covers and used as a modifier. By using high shear mixer having 1100rpm rotating speed prepared Modified Bitumen (MB). Silicone waste are partially replacement at 5,10,15,20 and 25 respectively with bitumen, in this investigation. Basic test of bitumen (Penetration Softening point ductility flash and five points.) with addition of varying percentages shows variable results up to 20% replacement of silicone. Furthermore, for evaluation of pavement performance, Indirect tensile strength (ITS), Moisture Susceptibility Analyses and Rutting Depth resistance test perform on virgin HMA and Modified HMA with 20 % partial replacement of silicone. The result based on performance testing are promising and utilization of silicone waste material consequent impact on the life cycle cost of road infrastructure for sustainable development by reducing the quantity of bitumen which is cost effective. In mixing techniques, dry mixing yield better perform in rutting in term of stability, flow as well as moisture susceptibility. The test results showed that the evaluated quarry aggregates were suitable for use in road

paving. Each aggregate sample has different properties, which are very important from a design, economic and environmental point of view. Margalla aggregate was observed to provide superior mechanical properties compared to Sargodha crush. It is found that modified HMA having 20% silicone. To be economical for huge volume sustainable road construction as well as maintenance. Except having more other significant advantages like reduction in waste and increase sustainability.

Table of Contents

List of Figure

List of Table

Chapter: 1 Introduction

1.1 Background

With time, there is a tremendous increase in the generation and use of Silicone mobile trash. Due to the fact that silicone trash is not biodegradable, it becomes problematic when it is disposed of. This suggests that waste, when placed at disposal sites, does not break down or reduce and instead persists in the ground, negatively harming the natural ecosystem[1-4]. Consuming silicone waste also harms the environment since it releases dangerous dioxins that are harmful and unsafe for humans. Consuming silicone mobile coverings in such big quantities has a negative impact on our drainage systems and the climate. As a crucial greenhouse gas, the release of CO2 is a notable act of pity for all who live on this planet. Due to its large population and lack of a viable recycling industry, Pakistan faces the problem of silicone waste littering. An efficient transportation system is the foundation of any nation's economy. There are around 264000 km of roads in Pakistan, of which approximately 12000 km are under NHA supervision (http://nha.gov.pk). The flexible pavement system, which has multiple layers, is the world's most used paving technology for creating roads and highways. Flexible pavement is subject to a variety of maintenance and rehabilitation charges in order to keep it functioning at a satisfactory level. Rutting, cracking, and moisture damage over time are the primary problems with pavement. Numerous investigations and tests have been conducted worldwide by various researchers in an effort to lower the cost of constructing and maintaining pavement and to increase its performance[5, 6]. The research on incorporating waste materials into the asphalt mix and assessing its performance against various flexible pavement distresses as well as the safe disposal of waste materials that do not decompose readily in landfills caught the attention of researchers and agencies and was the topic of most interest.

1.2 Problem Statement

Static and dynamic traffic loads, climatic fluctuations, and a number of other elements are all continuously and repeatedly having an impact on the pavement[7, 8]. A number of factors, including overloading and permanent deformation (rutting) brought on by temperature, contribute to the functional failure of HMA pavements. HMA pavement loses its use and stability due to a number of failure scenarios. All around the nation, it is now customary to carry silicone as a mobile cover to hold a variety of things. These plastics are burned to produce dioxin, a highly toxic toxin with detrimental effects on human health[9-11]. Dioxins are carcinogenic substances that can harm the human immune and reproductive systems as well as the endocrine glands that produce hormones. As a result of this waste's disposal, residue pollutes the soil and groundwater. Unburned Silicone product flakes end up as obvious litter on the ground as well as in seepage structures, lakes, and streams. Along with harming marine life, this waste is Pakistan's primary cause of drainage system failure. Between 2000 and 2010, the number of mobile cellular subscribers in Pakistan increased significantly, rising from roughly 0.31 million to approximately 100 million subscriptions. In 2021, there will be a peak of about 188.7 million mobile subscribers registered in the nation. The figure has been rising ever since. Our project aims to test the effectiveness of using old and waste silicone products as a modifier of bitumen, the most vital and expensive component of asphalt mixture, rather than disposing of them**.**

1.3 Scope of Research

A proper method of disposal or utilization of this garbage is required due to Pakistan's rapidly expanding population and growing Silicone consumption. If not addressed, it might become a major problem for our nation and have disastrous consequences for public health[12, 13]. There has been extensive research on the use of various waste kinds in asphalt mixes in many nations, including Australia and India,[14, 15] but there hasn't been much done on the impacts of Silicone debris on the physical qualities of asphalt mixes in Pakistan. Currently, Pakistan is seeing a revolution in transportation. Huge quantities of money have been spent developing underpasses, overhead scaffolds, and repairing and widening existing constructed roadways under the current administration. The moment would be right to use silicone waste in roads and maximize its potential if silicone is genuinely improving the qualities of the roads constructed in Pakistan. According to a recent agreement, a 1100 km long road between Lahore and Karachi would be built, while the Karakoram Highway between Rawalpindi and the Chinese border will be renovated and widened. In Pakistan, there are numerous other local roads and highways that are being built and maintained. In my project, silicone waste is going to be used in place of bitumen. This will improve the performance of HMA pavements, lower costs, and have a beneficial environmental impact.

1.4 Research Objectives

The research objectives are as follows:

1. To Evaluate the effect of silicon waste on the Marshall stability.
2. To Evaluate the effect of dry and wet mixing on the asphalt mixtures using silicon waste material.
3. To Evaluate the performance testing by utilize the silicone waste.
4. Life cycle cost assessment of the modified mixtures with conventional mixtures.

1.5 Organization of Report

The five chapters that make up this thesis are briefly outlined below:

The problem statement, study aims, and challenges related to the formation of silicone waste are briefly described in **Chapter 1**.

In **Chapter 2** the literature research on the inclusion of silicone cover in asphalt mixture is explained, along with any relevant issues. It also contains literature on several test procedures used to gauge rut resistance and moisture susceptibility.

The creation of HMA samples for performance testing is covered in **Chapter 3** along with the tools and methods used to characterize asphalt binders with silicone.

The findings of the asphalt mixture testing are reported in full in **Chapter 4** along with their analysis.

The key research study conclusions are reported in **Chapter 5** of this book.

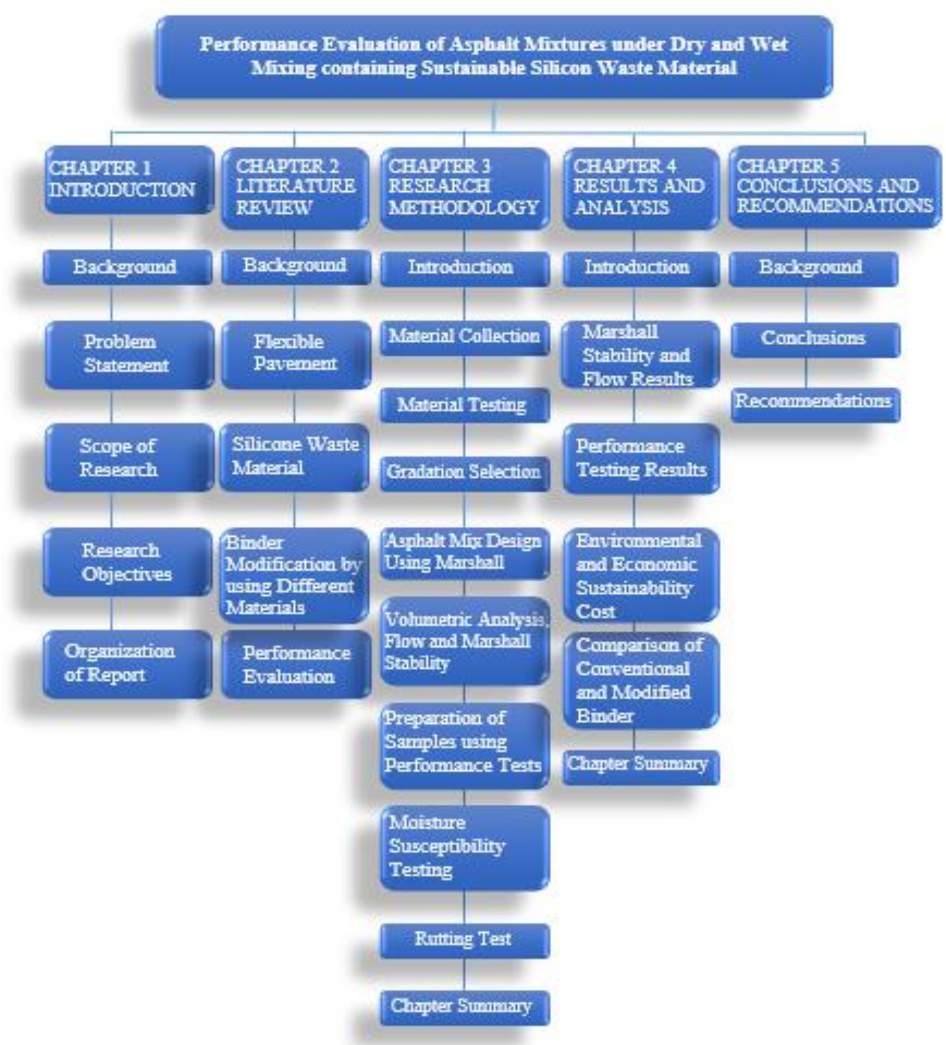

Figure 1.1 Organization Report Chart

Chapter 2 Literature review

2.1 Background

This chapter provides a thorough analysis of the principles and literature around the significance of using silicone in HMA and performance testing. A brief introduction to waste, its effects on the environment, and earlier efforts to include various wastes into pavement and their outcomes. A reliable transportation system is crucial for an enhanced economy and for growth that is acceptable. According to various studies, a road owner can lower maintenance costs if he maintains an appropriate quality of service. According to a World Bank study, increasing $1 at a first 40% reduction in pavement quality will result in savings of $3 to $4 compared to expenditures that would otherwise be necessary at a 75–80% drop in road quality.

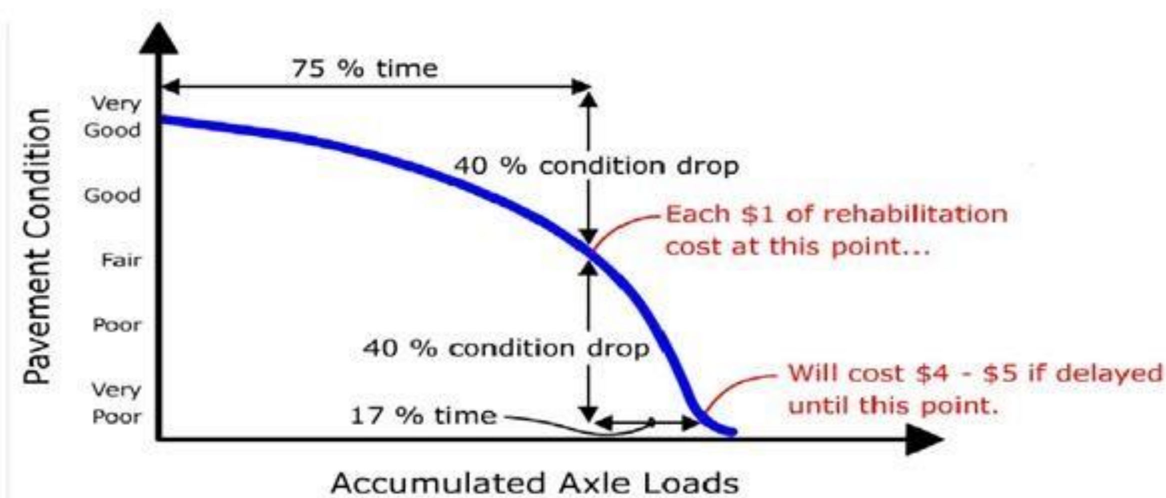

Figure 2.1 Pavement Deterioration Time

The rate of pavement deterioration increases with rising vehicular traffic and pavement age,[16] which causes a sharp increase in rehabilitation and maintenance costs[7, 17]. The pavements will quickly deteriorate to the point where expensive reconstruction will be the only choice left if we don't do rehabilitation or any other preventative maintenance actions at the proper times. To avoid costly constructions, it is more economical to use cost-effective maintenance and restoration measures when necessary. Plastic, steel, and other waste materials can now be recycled thanks to economic and environmental considerations. Waste plastic is one of these waste products that can be effectively employed as an asphalt binder modifier and as a partial replacement for bitumen content, therefore silicone will be studied and used in this research.

2.2 Flexible Pavement

Flexible pavements are built with a surface course a bituminous treated surface or an asphaltic surface over one or more layers of unbound base courses or sub-base courses—natural or processed aggregates resting on a subgrade a bed of compacted natural granular material. In order to preserve or protect each underlying pavement layer and the subgrade from compressive shear failure as the intensity of load decreases as it is transferred from the surface deep into the ground through the succeeding layers, with better weather resistant and those resistant to environmental action, flexible pavement relies on the load distributing mechanism of a layered pavement system. When pavement surface temperatures rise to 150^{o}F, materials employed in the top bituminous layer are designed to be stable under strong traffic loads and resistant to fatigue damage and moisture damage.

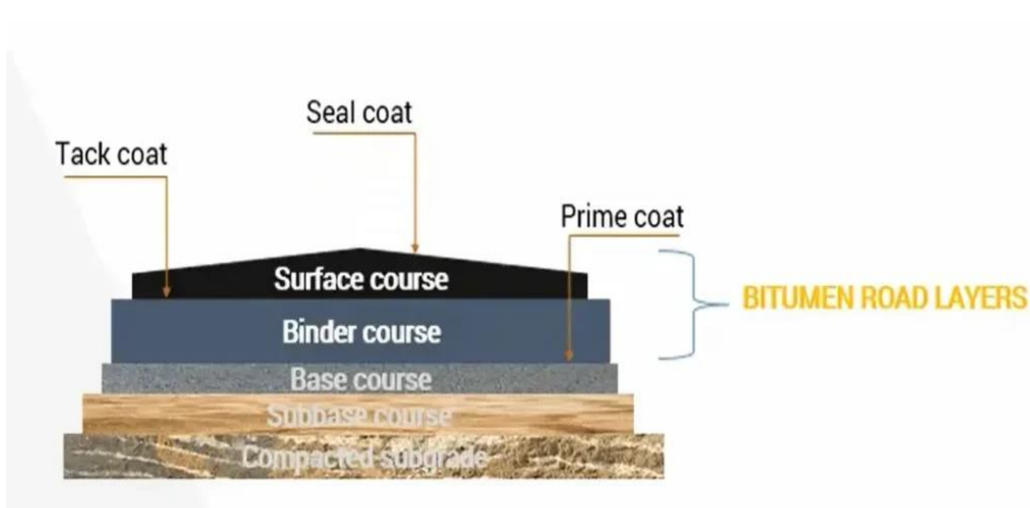

Figure 2.2 Flexible Pavement

2.3 Silicone Waste Material

Here, globally available, untreated waste before disposal served as a modifier. The waste consisting of silicone covers and mobile phone pouch needed to be disposed of and shredded with mechanical shredders. This shredded Silicone particle was melted by heating directly mix with asphalt in a burner and added and mixed as an asphalt substitute.

2.3.1 Impact of waste on Environment

Due to the sudden rise in global population, there has been an increase in industry across a number of sectors, and there has been a clear increase in the production of waste materials of many different forms. Some waste materials, such as slag, scraped tires, plastic, rubber, fly ash, etc., are not biodegradable and remain in the environment and atmosphere for countless generations, making it difficult to dispose of garbage and causing environmental issues. Today, a great deal of items is made of plastic or incorporate plastic in some way. Plastics are present in many everyday items that we use. But as its drawbacks start to materialize, government organizations have curtailed its use. Plastic bags (low density polythene) are one of the primary plastic materials whose use has been outlawed by the government. Its recycling is now under effect. (historyofplastic.com)

2.3.2 Internationally use of Silicone.

A survey report of the cell phone business states that in 2007, there were almost 700 million cell phones in the US alone, of which 36.8% were stashed away in cabinets and drawers. 9.4% were recycled, whereas 10.2% were discarded outside. These are businesses involved in recycling who have chosen the environmentally responsible method of recycling and reusing mobile, phone accessory industry silicone cases. Being an expert in silicone recycling, the business not only efficiently recycles silicon products but also gathers broken components from each client[18]. Making phone cases has grown into a significant industry as mobile phones have gained popularity across the globe. A poll indicates that 75%

of people use a protection pouch for their smartphone. In 2014, approximately 1 billion mobile phones were sold out. Assuming each case is purchased one at a time, this translates to 750 million smartphones sold, or $81.2 million, or $2.6 billion in United States trading sales last year, excluding locations such market stalls and malls[19]. When these cases or cases have served their purpose, they are abandoned and dumped in landfills, where they remain uncovered and are turned into soil as solid waste. It is believed that 500 million silicone phone cases are wasted annually (i.e., hundreds of tons of cases and covers go untreated), even if 10% of mobile users use them. and it is obvious that they should be recycled) security. These are essentially eco-harmful products made from synthetic materials. These pouches and protection cover are typically burned in economically developing countries, thrown out with trash, or dumped in landfills. However, a number of businesses gather and process mobile cover debris in industrialized nations like the United States. Open burning contributes to air pollution by releasing toxic pollutants into the atmosphere. These materials contaminate soil and groundwater by releasing dangerous chemicals into landfills in the form of leachate.

2.4 Binder Modification by Using Different Materials

Numerous experimental studies using various types of material have been carried out to evaluate the performance of HMA pavement. The following are some significant papers and researches that examine the utilization of various wastes in HMA. Yuetan Ma et al in 2021 A massive production of plastic wastes may cause environmental problems on a global scale if the right ways to treating plastic trash are not used[20]. Plastic wastes are added to asphalt concrete mixtures to increase moisture susceptibility, rutting resistance, and fatigue resistance[21, 22]. However, low-temperature performance issues persisted while using plastic-modified asphalt. To overcome the aforementioned restrictions, various strategies and approaches should be used. The moisture sensitivity, rutting resistance, and fatigue resistance of asphalt mixtures are all improved by the use of plastics with low melting points. The ductility of the mixtures is reduced by plastics with higher melting points. According to Sabzoi Nizamuddin et al. (2020), this research study investigates the usage of recycled linear low-density polythene (R-LLDPE), a very popular and widely accessible soft and thin plastic, for bitumen modification[23]. The base asphalt binder and R-LLDPE modified asphalt binder mixes were compared and assessed through rheological, physical, and chemical evaluation in order to determine the applicability of polythene in pavement. R-LLDPE significantly increase base bitumen's chemical, rheological, and physical properties. By increasing the content of R-LLDPE, the softening point temperature and viscosity were raised but the ductility and penetration values were decreased. It demonstrated that the modified bitumen used in HMA mixes had a greater capacity to withstand permanent deformation at higher temperatures than the base binder. Performance of HMA pavements containing small LDPE flakes obtained from municipal garbage was assessed on aged and unaged samples utilizing rutting resistance, fatigue cracking, and stiffness[24]. Asphalt binder with a 6% LDPE concentration performs better in performance testing. While virgin bitumen used in the samples had a somewhat higher moisture resistance than LDPE, both findings were above 80%, so that's okay. The ITS values were greater in the LDPE blend. The stiffness and rutting resistance of bitumen binder were both improved by the addition of LDPE. Another study claim that using LDPE as an asphalt binder modifier altered the deformability pattern of HMA pavement and increased its elasticity compared to the same blend without LDPE[25]. Yuming Lin et al state that because polythene bags are not biodegradable, the current practices and ways for disposing of waste polythene bags actually contribute to major environmental issues and pollution[26]. This study showed that recycling used express bags by modifying asphalt binder using used polythene bags could be eco-friendly. This study examined the viability of modifying the characteristics of asphalt binder and enhancing the physical performance of binder made from LDPE by adding waste polythene bags. Experimental findings and facts demonstrated that using a shearing machine with a high speed could be an efficient way to change asphalt binder uniformly using used polythene bags. Basic experimental findings show that the LDPE waste polythene bags can enhance the softening point temperature and the viscosity of the binder while decreasing the ductility and penetration values of the binder. The addition of LDPE increased the virgin binder's resistance to rutting; this shift in physical behavior is the result of the influence of used polythene bags. The workability of HMA mixes including LDPE additives as asphalt binder replacements may be somewhat diminished. Therefore, when the LDPE concentration in the binder is less than 8%, LDPE-modified binder may be employed. Despite its limited findings, this study demonstrated that using used polythene bags to modify asphalt seems promising. It has been discovered that adding LDPE to bitumen can somewhat alter and increase HMA performance in low temperature and resistance to rutting. The use of waste polythene bags as bitumen modifiers will likely help to manage garbage since several highways are expected to be built in China. The performance evaluation of LDPE-modified HMA mix in labs and in the field requires more study. According to Research, polythene (LDPE) and water sachets are a significant environmental contaminant and a non-biodegradable substance[27]. By looking at its impacts on a few chosen physical characteristics of Asphalt mixes (HMA), such as stability, flow, density, etc. of mix, it was possible to analyze the advantage of this pollutant (LDPE) in the highway agencies. Using the normal technique for Marshall Mix design, many samples were created. The ideal binder content for conventional mix was discovered to be 5.20%, and three samples were made for each variation of polythene content (2%, 4%, 6%, 8%, and 10% by weight of OBC). As a result of the study, it was discovered that replacing OBC with Silicone increased the density and stability of the asphalt mix while decreasing the penetration and flow values. The ideal modifier content value was 20% of the ideal binder content weight. The physical and technical properties of bitumen that had been modified by the addition of polythene were improved, therefore using LDPE in the asphalt for the construction of pavements is an efficient and cost-effective method of waste management. A Study state that the goal of their research was to assess the usage of waste plastic as a reasonably priced bitumen modifier[28]. For determining

OBC, the Basic Design Standard Procedure was applied. The technique aids in choosing the OBC that must be combined with a specific blend to produce a mix that meets the criteria for strength, workability, and durability. The OBC for traditional HMA mix was first computed, and then different contents of shredded Silicone waste as a percentage of calculated OBC were tested. This was done in order to evaluate the Silicone Waste modified (SWM) HMA mix. The ideal Silicone waste content for modified mixtures was determined by looking at the outcomes of standard mixes and then Using the tensile test, indirect tensile strength was discovered for each sample. The optimal Silicone waste component needed to improve asphalt mix was found to be 20% by weight of OBC, according to the research. Performance. Strength was increased, flow was increased, and stability was also increased. These results suggest that this research will increase the resistance of pavement to permanent deformation and fatigue cracking, resulting in the production of more cost-effective and durable pavement. This enhancement is the result of improved intermolecular adhesion between bitumen and waste plastic coated aggregates, which lengthens the life of the pavement and increases HMA strength. In (2017) Mohd Ezree Abdullah et al study's primary goal was to investigate the physical properties of asphaltic mixtures including plastic waste at different percentages, including 4%, 6%, 8%, and 10% by weight of asphalt binder[29]. Tensile strength, stability, creep modulus, and resilient modulus were all tested in this study. According to experimental findings, HMA mix containing 4% plastic offers the highest level of stability. However, if plastic content rises above a certain proportion, a little decline in stability is seen. In contrast, the highest tensile strength ever measured in modified asphaltic concrete was 152 PSI at 8% plastic content. The most resilient modulus, which was measured at 496029 PSI at 25°C and 71793 PSI at 40°C, was produced by the asphaltic mixture supplemented with an 8% plastic additive. In a combination with a 10631 PSI pressure, the inclusion of 8% plastic component resulted in the highest creep modulus being seen. It was determined that while stability was maximum at 4% of plastic content, adding 8% of plastic content showed the highest value of asphaltic mixture features. Raghad U. Abass et al. in 2014 state that this research focuses on the potential use of waste plastic in asphalt mixes and the search for the most effective safe disposal method in addition to improving the performance of pavement structures through better mix design[30]. The physical properties of the enhanced asphalt mix (dry density) under the ideal additive waste thin plastic (13% weight) are affected by the replacement waste thin plastic content by weight of asphalt in the HMA mix. With more additive waste thin plastic replacement and less change, it appears that dry density values decline, reaching an optimal percent at 13% weight. In order to achieve the best features and performance in terms of (physical, chemical, and thermo-mechanical properties), bitumen binder should only make up 10% of the asphalt mix. Nobinur Rahman and colleagues (2013) Aiming at waste polythene (LDPE) and polyvinyl chloride as the type of polymer to be utilized to determine the potential usage to improve the properties of asphalt mixes and to look at the design criteria of asphaltic mixtures in which these two modifiers are used at OBC[31]. The trials of modified asphalt binder physical characteristics were the focus of the findings, and normal Marshall mix design processes were utilized to first determine the OBC in conventional mix and then to conduct experiments on changed mix to determine its qualities. The parameters of the mix's stability, density, flow, and voids are determined by experimental studies. The properties of the plastic modifier-asphalt concrete mix utilized in this study were within acceptable bounds. Based on the findings of experimental studies, it was concluded that asphalt concrete mixes containing polyvinyl chloride and polythene modifier contents of up to 7.5% and 10%, respectively, might be utilized to construct flexible (HMA) pavements in warmer climates. In this study, it was found that bitumen's softening point rose as the amount of polyvinyl chloride and polythene modifiers increased, while the ductility, penetration grade, and solubility value of modified asphalt mix decreased when compared to conventional asphalt mix. Indira 2022, In contrast to the unmodified asphalt concrete mix, experimental findings from this study showed that the mixture treated with LDPE had a larger proportion of VMA and was more stable[32]. This would result in less permanent deformation, which would improve the rutting resistance of these combinations. The modified asphalt concrete mix's air voids are very similar to those of the original mixture. A 4% air gaps percentage is more than sufficient to allow bitumen to expand without flushing or bleeding, which could weaken flexible pavement's ability to resist slipping. Polythene's use in asphalt concrete mixtures minimizes permanent deformation and improves fatigue resistance overall.

2.5 Performance Evaluation

It is described how several researchers undertake moisture susceptibility and rutting tests in the lab using the prescribed methodologies, and how their performance is evaluated.

2.5.1 Moisture susceptibility

You, Zhanping (2015) When water damages an asphaltic pavement, it causes moisture susceptibility, which can be characterized as a weakening of the link between the aggregates and the asphalt binder and a reduction in the durability of the pavement[33]. Due to the many formations of its physical appearance, which might include raveling, rutting, cracking, or shoving, it can result in complex forms of pavement deterioration and distresses to perceive. The performance of bituminous pavement is now seriously at risk.

Mohd Hasan and Mohd Rosli (2015) The main source of moisture sensitivity is moisture that becomes trapped inside the aggregates of the asphalt mix due to the low compaction temperature produced by HMA, which results in inadequate drying of the aggregate and susceptibility to moisture-induced damage[34]. Two separate types of damage can be attributed to dampness. Reduced asphalt binder bond strength and adhesive failure between bitumen and aggregates are both related to cohesive failure.

If there is an issue with bonding between the asphalt binder and the fine particles in the surface course, moisture induced damage can also be described as a reduction in the strength and durability of asphalt concrete pavement. Less and weaker bonding between the aggregate and binder increases the risk of moisture-induced deterioration. Pavement performance testing with induced moisture can benefit from indirect tensile Strength Tests (ITS). By measuring the tensile strength of asphaltic mix samples (Marshal Samples), both unconditioned and conditioned, moisture sensitivity can be assessed. The sample is loaded in opposite directions until it cracks or can support no more weight; the more loads the sample can withstand, the stronger the pavement will be. Another tool for assessing moisture damage is the Hamburg wheel-tracking system. The outcome of this gadget was influenced by a number of distinct elements. To identify the variables influencing the results from the Hamburg gadget, several investigations were conducted. These were named as aggregate quality, stiffness of the asphalt cement, long- and short-term aging of the cement, characteristics of the crude oil used to extract the asphalt, and compaction temperature.

Indirect tensile test (ITS) was performed to assess moisture susceptibility by calculating indirect tensile strengths ratio (ITSR), according to Arminda Almeida the indirect tensile strength ratio, or ITSR, is the comparison between the ITS of conditioned (wet) specimens and the ITS of unconditioned (dry) specimens. Marshall mix 16 design samples were created in a lab for this experiment's performance[35]. The average value of four different samples per group served as the results for indirect tensile strength. The maximum tensile stress that is computed as a function of the peak load value, the height, and the diameter of the sample is known as the indirect tensile strength, or ITS. They discovered that asphalt mixes containing LDPE had lesser moisture resistance than standard AC, with the first sample showing an ITSR value greater than 80% when compared to asphalt mixes devoid of plastic, and LDPE modified mixes exhibiting higher dry ITS values. According to the Washington State Department of Transportation, an efficient performance test for assessing moisture sensitivity in the pavement sector is the indirect tensile strength ratio. By conducting an indirect tensile test on conditioned and unconditioned fabric specimens, and then calculating their ratio, moisture susceptibility can be calculated for research reasons, the tensile strength ratio (TSR) method is also used to assess the asphalt mix's susceptibility to moisture. Low density polythene (LDPE) and high-density polythene (HDPE) waste plastic materials were employed as a modifier of asphalt by including them in different contents in asphalt mix to determine damage resistance owing to moisture in asphalt concrete mix, according to Safeer Haider et al. High-density polythene (HDPE) is less susceptible to damage from moisture when used as an asphalt modifier[36]. Low-density polythene (LDPE), however, also enhances HMA mix performance by raising the tensile strength of the HMA samples.

2.5.2 Permanent Deformation

Permanent deformation, which mainly happens along the wheel path at high temperatures, is the discomfort in flexible pavements. It is among the most typical types of permanent pavement deformation. Performance tests are conducted using fresh and used (non-biodegradable) materials to assess the performance of the asphalt mix and to develop new and improved design methodologies for better pavement performance under various sorts of loading circumstances. Due to bitumen's viscoelastic characteristic, asphalt mix becomes softer as pavement surface temperature rises. Permanent deformation is a significant issue with Pakistani pavements that transportation agencies need to address due to inadequate guidelines and excessive loads.

Below are some of the primary causes discussed:

- Poor and insufficient pavement layer compaction during construction.
- Inefficient mix design.
- Weak Undergrad.
- Over compaction brought on by heavy loads or recurrent traffic loads that exceed the capacities of the pavement.
- Surface debris is removed by traffic.
- Asphalt mix plastic deformation.

Figure 2.3 Rutting in Pavement

2.5.3 Rutting Depth

Rutting was assessed using an experiment on a Double wheel-tracker, in accordance with standard (EN 12697-22), using DWT equipment and a procedure used for roller-compacted standard samples that were prepared in a laboratory and had dimensions of (370mm 300mm 40mm) (length width thickness). The method was based on moving a normal loaded wheel often to and from a slab constructed of the material being tested (700 5 N or 157 lb). If a rut depth of 20 mm is reached, the test may end before the 18 cycle completions and automatically end after 10,000 load cycles (each cycle representing two passes). The Portuguese Road Administration specified a temperature of 50°C for the test. Recycled low-density polyethylene (LDPE) was added to the asphalt concrete mix, which increased its stiffness and rutting resistance. AASHTO T 32411 standard was followed for conducting the DWT experiment at 50°C. Superpave Gyratory Compactor (SGC) was used to compact cylindrical specimens to a height of 62 mm and a diameter of 150 mm. Two samples were merged to form a single test sample, which was then run through a steel rolling roller 52 times per minute. After each run through the linear variable differential transformer (LVDT), vertical deformation was measured. The test ends once there have been

5000 cycles, or 12 mm of vertical deformation, whichever comes first. The Double Wheel Tracker (DWT) instrument, made by the CONTROLS firm, was used to conduct tests. Following the completion of the wheel tracker testing, a deformation data curve was constructed in software for each sample, and the asphalt mix's resistance to stripping and deformation (rutting) was measured and assessed based on the slope curve. Both excessive and insufficient amounts of asphalt binder will have a negative impact on the mix's ability to prevent rutting. In order to aid compaction or obtain the appropriate density, the asphalt content of a paving mix shouldn't be raised because we risk performance problems. Aggregate fine fraction with a finer gradient.

Chapter 3 Research Methodology

3.1 Introduction

This chapter describes the entire methodology used to accomplish the research goals, including obtaining all the necessary materials from various local sources, performing initial physical material testing on aggregates and bitumen in accordance with predetermined standards, preparing samples, and evaluating performance. In accordance with predetermined standards, several performance test processes are also presented. A controlled sample set as well as samples containing Silicone waste at various weight ratios of asphalt binder were used in the research investigation. Silicone waste was combined with binder using a wet and dry mixing technique, in which bitumen and crushed silicone particles are combined at 120°C for 30 minutes while being spun by a rotary machine at 30-33 rpm. The changed binder's physical test findings were contrasted with those of the unmodified binder. This chapter goes into great length on calculations for the determination of OBC at various percentages of asphalt binder using a simple bitumen test procedure. Based on OBC specimens prepared with and without Silicone addition for performance testing that includes moisture susceptibility and rut resistance, the Silicone percentage used is 20%, which was determined to be the ideal additive content through preliminary physical testing of asphalt binder. Additionally, performance testing was done on a sample that contained 20% silicone waste. Hamburg Double Wheel Tracker HDWT was utilized for the rutting test, and deformation was noted. On a universal testing machine (UTM), a moisture susceptibility test was conducted to measure the indirect tensile strength of conditioned and unconditioned HMA samples and to compute the tensile strength ratio. This chapter will cover the methods used for sample preparation as well as all the necessary input data used during various testing on the specimens. Figure describes the full intended study process.

3.2 Methodology

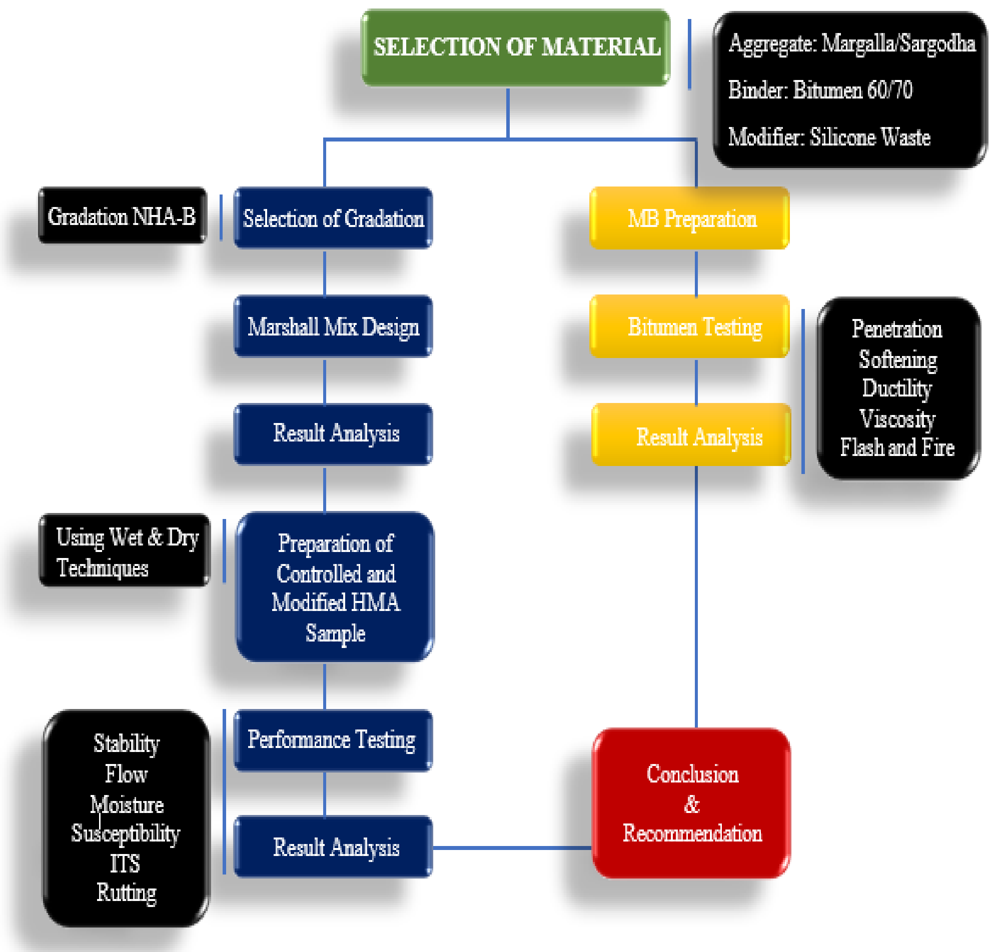

Figure 3.1 Methodology Chart

3.3 Material Collection

Materials such as aggregates from the Taxila Crushing Plant and from Sargodha Crusher in Sargodha, Pakistan asphalt binder from PARCO, and silicone waste from several Markets Sites were collected.

3.3.1 Aggregates

Aggregates were collected from two different sources. The strength and durability of flexible pavements are significantly influenced by the quality of the aggregates. It supports the greatest weight of HMA pavements. The shape and texture of the aggregates have a significant impact on the strength and other technical qualities. The gradation of aggregates has an impact on HMA characteristics as well. In general, angular and rough-textured aggregates are better able to resist pressures that could lead to pavement irreversible deformation from repeated traffic loads. To verify the engineering qualities of aggregates, mandatory tests are carried out in accordance with ASTM and BS.

3.3.2 Margalla Crush

Margalla (Limestone) aggregate was sourced from Taxila (Rawalpindi district).

Used in present research. Margalla high-quality limestone is considered the best stone (gravel) and is often used in the construction of roads and airfields[37]. These stones were used in the construction of Many highways and motorways and also Gwadar airfield[38]. Because of this, the Margalla Hills are rapidly depleting. Sections over Six miles have already been excavated by miners, crushers, cement manufacturers and realtors

3.3.3 Sargodha Crush

Secondly, Sargodha Crush sourced from District Sargodha. Coarse aggregate of size 20 mm, medium aggregate of size 10 mm and fine aggregate of size <4.75 mm were used for the preparation of the asphalt mixture. Extensive mechanical evaluations and tests were performed on all selected units.

Figure 3.2 Sample Collection

3.3.4 Asphalt Binder

In Pakistan, 60/70 penetration grade bitumen is typically used, depending on the weather. So, 60/70 grade asphalt binder (bitumen) was purchased from PARCO.

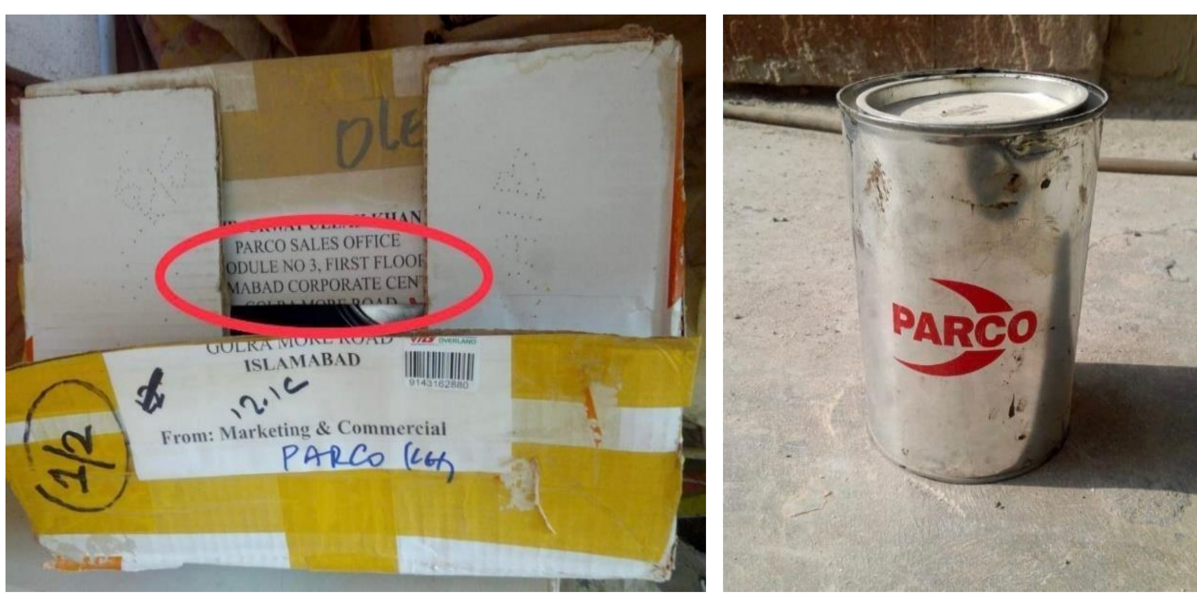

Figure 3.3 60/70 Grade Bitumen

3.3.5 Silicone Waste

Silicone trash was collected from many Markets locations. These were utilized in place of the OBC content discovered by a bitumen basic test. This composite bitumen, which contains both bitumen and silicone, was then used to prepare samples for various performance tests. Collection of silicone cellphone covers from market sites.

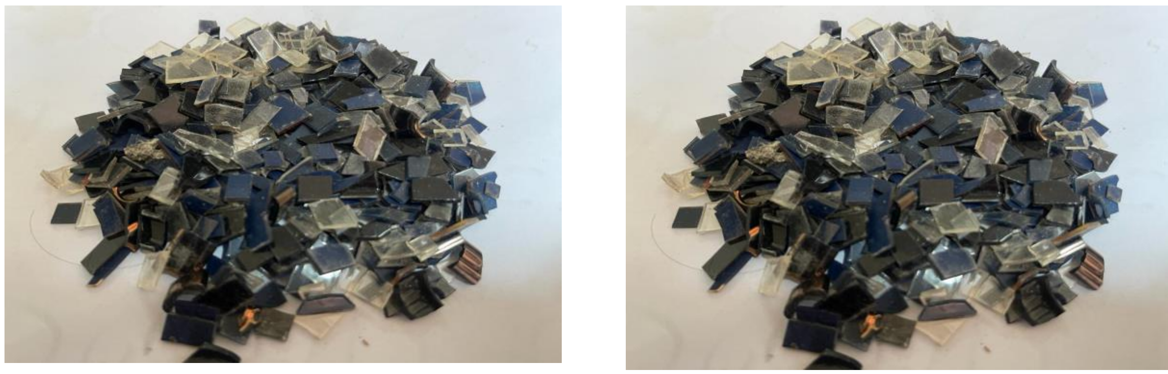

Figure 3.4 Shredded Silicone Waste

3.4 Material Testing

Initial physical tests were carried out on bitumen and aggregates in accordance with the established standards to determine whether the materials meet the criteria needed to be employed in an asphalt mix or not

3.4.1 Aggregate Tests

Since aggregate serves as the primary structural component of HMA pavement and resists deformation, it must be robust and long-lasting to provide its intended function. On aggregate, the following experiments were run in a lab.

- Shape Test (flakiness and elongation index).
- Tests for water absorption and aggregate specific gravity.
- Impact and crushing values for aggregates.
- Los Angeles Abrasion Test aggregates

3.4.2 Shape test of Aggregates (ASTM D 4791-99)

The proportions of flaky and elongated particles in aggregate stockpiles are identified using the shape test of aggregates. Flaky particles are aggregate particles whose smallest diameter is less than 0.6 times the average dimension of the sample aggregates. Elongated particles are defined as aggregates with a bigger diameter greater than 1.8 times the average aggregate dimension of the sample. Shape Test Apparatus in Figure 3.5 The flakiness and elongation indices must both be under 15%. Aggregates with an angular shape work best for interlocking**.**

Figure 3.5 Flakiness & Elongation Test

3.4.3 Specific Gravity Test (ASTM C 127 & ASTM C 128)

The weight of a certain volume of aggregates divided by the weight of a comparable volume of water at 24°C is known as the specific gravity of aggregates. The following test, which was carried out solely on coarse aggregate in accordance with ASTM C 127-88, yielded three different weights for specific gravity calculations: the weight of oven-dried aggregates, the weight of aggregates completely submerged in water, and the weight of aggregates at their saturated surface when dry. According to ASTM C 128 standards, a water absorption test and specific gravity of fine aggregates were conducted. In table 3.1, the specific gravity results are enumerated. Specific Gravity Test for Coarse Aggregates, Figure 3.6 26 Specific Gravity Test for Fine Aggregates, Figure

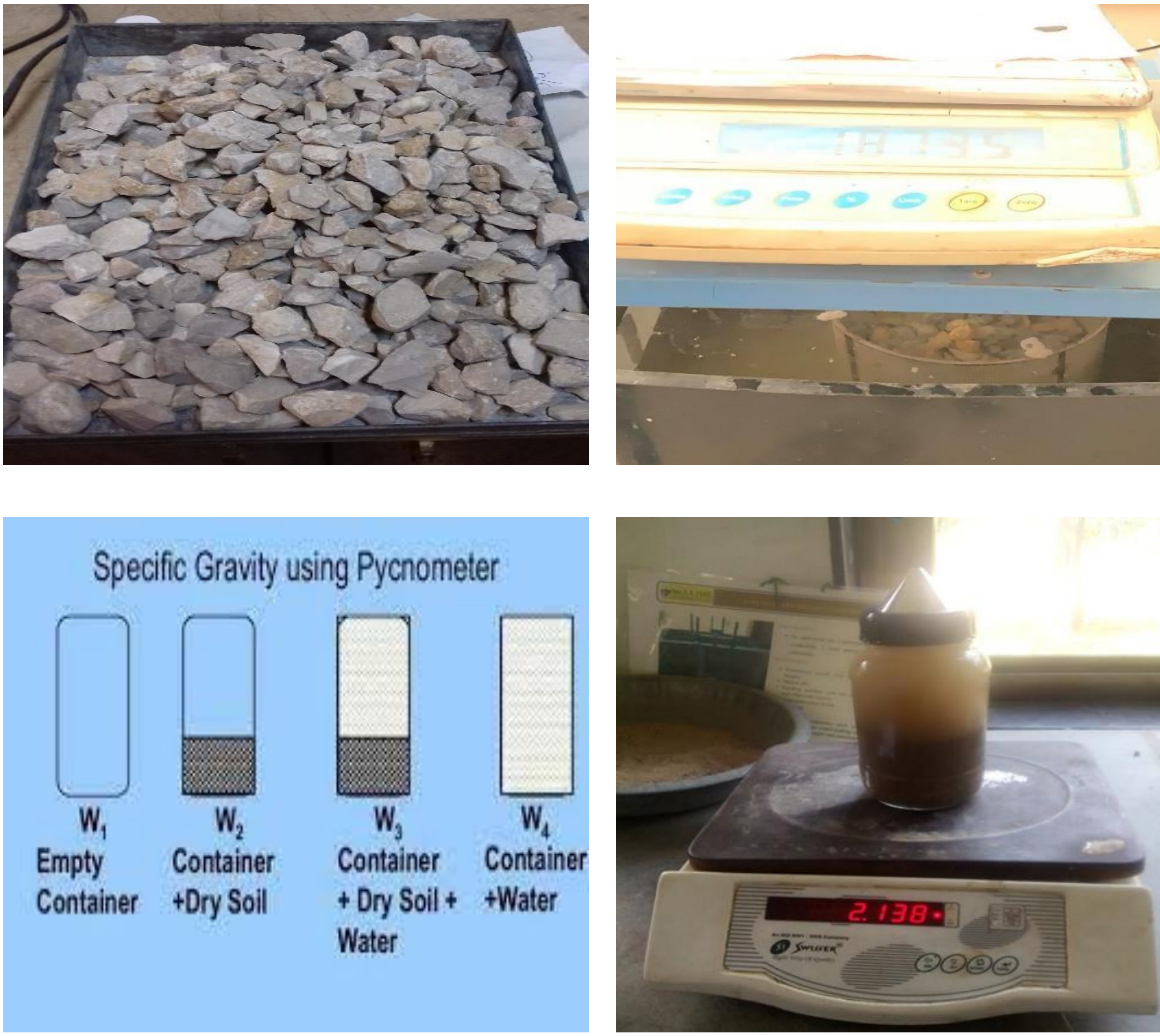

Figure 3.6 Specific Gravity Test

3.4.4 Impact Value of Aggregates (BS 812)

The relative strength of aggregates against abrupt impact loading is revealed by the impact value test of aggregates. Sieves in the sizes 1/2", 3/8" and #8 (2.36mm), a temping rod, and an impact testing assembly were employed in the performance of this test. Three layers of 350 grams of representative aggregate samples that passed through a 12" sieve and were retained on a 3/8" sieve were placed in an impact test apparatus cup, and each layer was given 25 blows with a temping rod before the aggregates in the cup received 25 blows from a rammer that was suspended 38 cm in the air and weighed 14 kg. Following that, the material was sent through sieve #8. The percentage of the material that passes through filter #8 represents the impact value of the aggregates. Table 3.1 provides a summary of the results. Impact Value Test Apparatus, Figure

Figure 3.7 Impact Value Test

3.4.5 Los Angeles Abrasion Test (ASTM C 535)

This test was run to evaluate the aggregates' resistance to damage brought on by traffic loads. The efficiency of a pavement will suffer the higher the abrasion value of the particles. A LOS ANGELES machine, a set of sieves, steel balls, and a balance were the testing equipment. A representative aggregate sample of about 5000g was placed in the Los Angeles Machine along with 11 steel balls, of which 2500g were retained on a 12" sieve and 2500g were retained on a 3/8" sieve. After 500 revolutions, the material from the machine was removed and passed through a 1.7mm sieve, and the weight (W2) of the passing sample was recorded. W2 and W1 were divided to determine the abrasion value, which was then multiplied by 100. Los Angeles Abrasion Machine, Figure 3.9 Aggregate Crushing Value (3.3.1.5) The aggregates must be robust enough to support traffic loads in order to build a long-lasting pavement with adequate resistance to deformation. The equipment used for the crushing value test was made up of a steel cylinder with open ends, a base plate, a piston plunger with a 150 mm diameter and a hole across it for raising a rod, a cylindrical measure, a balance, a tamping rod, and 28 compressive testing machines. The aggregates that made it through a 12" sieve and stayed on a 3/8" sieve were chosen. A sample of aggregate was properly cleaned, oven dried, weighed (W1), and placed into a cylindrical measure in three layers, each of which was tamped 25 times. The sample was then placed in the cylinder's base plate in three layers before the plunger was installed. Crushed aggregate was then removed from the steel cylinder and put through a 2.36mm screen after being placed in the compression testing machine, where load was then applied uniformly at a rate of 4 tons per minute until the total load reached 40 tons. This sieve's output was gathered, and the weight (W2) of the material was recorded. The formula for determining an aggregate's crushing value is W2/W1 x 100. Results are listed in a table.

Figure 3.8 Los Angeles Test

Table 3.1 Properties of Margalla Aggregate

Margalla Aggregate				
Aggregate Test	**Specification of test**		**Results**	**Limits**
Impact Value	BS- 812		14%	≤30%
Los Angles	ASTM- C131		20.82%	≤45%
Specific Gravity	ASTM C 128	Fine agg	2.28	_
	ASTM C 127	Coarse agg	2.726	_
Aggregate Absorption	ASTM C 127		0.71%	≤3%
Elongation Index (EI)	ASTM D 4791		2.17%	≤15%
Flakiness Index (FI)	ASTM D 4791		11.26%	≤15%

Table 3.2 Properties of Sargodha Aggregate

Sargodha Aggregate				
Aggregate Test	**Specification of test**		**Results**	**Limits**
Impact Value	BS- 812		17.55%	≤30%
Los Angles	ASTM- C131		26.50%	≤45%
Specific Gravity	ASTM C 128	Fine agg	2.12	_
	ASTM C 127	Coarse agg	2.658	_
Aggregate Absorption	ASTM C 127		1.00%	≤3%
Elongation Index (EI)	ASTM D 4791		3.78%	≤15%
Flakiness Index (FI)	ASTM D 4791		12.81%	≤15%

3.4.6 Binder Charactertics

For construction of pavements and different engineering purposes it is important to have knowledge about important physical properties of asphalt binder. Consistency and safety of bitumen need to be considered. As the consistency changes with temperature so standard temperature is important for comparing consistencies of bitumen.

The tests made on the binder are as follows:

- Asphalt binder penetration value test
- Asphalt binder Softening point temperature test.
- Asphalt binder ductility test.

- Flash and Fire Point of asphalt binder.

3.4.7 Penetration Test (AASHTO T 49-03)

The depth of a standard loaded needle that would vertically penetrate a sample of asphalt binder under specified parameters of temperature, loading, and duration was measured using an asphalt binder penetration test to determine the penetration grade of the binder. Smaller penetration levels are shown by hard binder, and vice versa. According to AASHTO T 49-03, the following conditions were used: 100gm of load was applied, 25°C of temperature was maintained, and a 0.14mm to 0.16mm needle was used for the test. The test time was 5 seconds. Five values from each specimen of the two PARCO samples were collected after penetration tests. All results collected met the requirements of the penetration test standard in accordance with the specifications.

Figure 3.9 Penetration Test

3.4.8 Softening Point Test (AASHTO-T-53)

The temperature at which an asphalt binder reaches a specific level of softening under typical test settings is referred to as the asphalt binder softening point. The Ring and Ball device was used to calculate the softening point of bitumen. The average temperature at which the two rings of asphalt binder become sufficiently pliable to for the 3.5 grams of steel balls to drop 25 mm and contact the base of the jar is known as the asphalt binder's softening point. The test's findings are displayed in table.

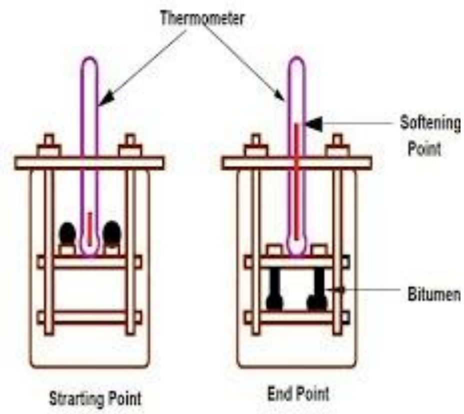

Figure 3.10 Softening Point Test

3.4.9 Ductility Test (AASHTO T 51-00)

Ductility is an important property of asphalt binder that allow bituminous material to bear great elongation or deformation without breaking. Ductility of an asphalt binder can be defined as the length in cm that a standard sample of the asphaltic material will be stretched without breaking at specific speed that is 5 cm per minute and at specified temperature of 25 ± 0.5°C defined by (AASHTO T 51-00). Different samples of virgin (non-modified) asphalt were tested and the average of all shows the ductility value more than specified least limit that is 100 cm.

Figure 3.11 Ductility Test

3.4.10 Flash and Fire Point Test (ASTM D 92-12)

This test is carried out to ensure the highest level of safety is upheld while using HMA on the job site. The lowest temperature at which the asphalt binder will momentarily flash when exposed to flame under certain circumstances is referred to as the flash point. According to certain sources, the asphalt binder can sustain fire for three seconds and burn at a certain temperature, which is known as the "fire point." According to D3143/D3143M-13 standards, a flash and fire point test was performed. The outcomes are listed in table.

Figure 3.12 Flash & Fire Pont Test

3.4.11 Rotational Viscosity Test.

The ratio of the induced shear stress to the shear rate, as determined by the rotational viscosity test, is the coefficient of viscosity. This coefficient represents the viscosity, a measure of flow resistance. This test method describes how to measure bitumen viscosity at high temperatures between 60 and over 200 °C. Torque is a notion that is used in rotating viscometers. It calculates the bitumen's viscosity and the torque needed to rotate the bitumen.

In accordance with ASTM D 4402, a rotational viscometer was utilized to determine the viscosity of bitumen. First, the container, spindle, and the environment chamber of the viscometer were brought up to 135 °C. Next, bitumen was heated until it was in a flowable state. Sample was subsequently poured in chamber and put into temperature control unit. Sample was then heated to 135 °C and calibrated to test temperature for ten minutes.

Figure 3.13 Rotational Viscosity Test

3.4.12 Specific Gravity Test of Bitumen

According to ASTM D 70, the pycnometer approach was adopted to calculate the specific gravity of bitumen. A standardized pycnometer was used to hold the sample. Weighing the pycnometer and specimen was followed by filling the empty space with water. The entire pycnometer was weighed after being brought to the test temperature. Equation 13 was used to calculate the mass of the bitumen specimen and the amount of water it evacuated in order to determine the specific gravity of bitumen.

A = the pycnometer's weight

B = Pycnometer weight along with Distilled water weight.

C = weight of the pycnometer plus the weight of the half-full bottle of bitumen.

D = the sum of the weights of the pycnometer, the bitumen that has been poured to half the bottle, and the water that has been added to the leftover half.

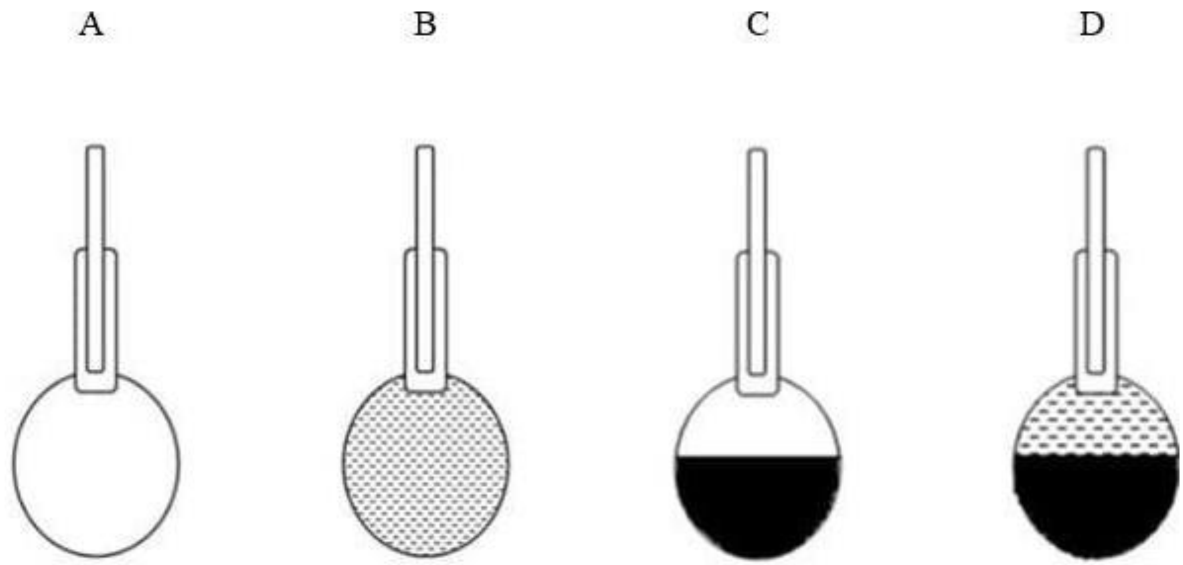

Figure 3.14 Specific Gravity of Bitumen

The outcomes of thorough testing of bitumen's elastic characteristics are described in Table together with their acceptable limitations in accordance with testing and standards.

Table 3.3 Results of Standrad Testing of Bitumen

S. No.	Test Description	Specification	Result	Limit
1.	Penetration Test @ 25 °C	ASTM D 5-06	67	60 – 70
2.	Ductility Test (cm)	ASTM 113-99	109	> 100
3.	Flash Point (°C)	ASTM D 92	273	> 232
4.	Fire Point (°C)	ASTM D 92	375	> 320
5.	Softening Point (°C)	ASTM D 36-95	49	48 - 58
6.	Rotational Viscosity (Pa-sec)	ASTM D 4402	2.97	≤ 3
7.	Specific Gravity	ASTM D 70	1.03	-

3.4.13 Binder Modification with Silicone.

3.4.13.1 Penetration Test on Modified Bitumen

When virgin asphalt was blended with various silicone contents in percent by weight of bitumen binder, penetrations were measured. Based on the findings, it was determined that bitumen becomes harder and its penetration value drops as silicon level in asphalt binder increases. In figure 3.17, penetration levels are displayed as follows:

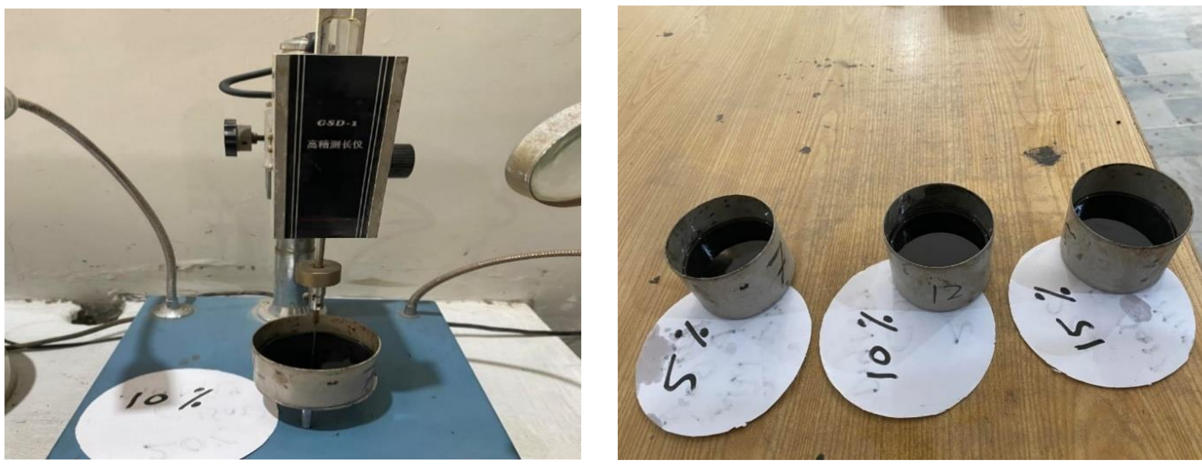

Figure 3.15 Penetration Test

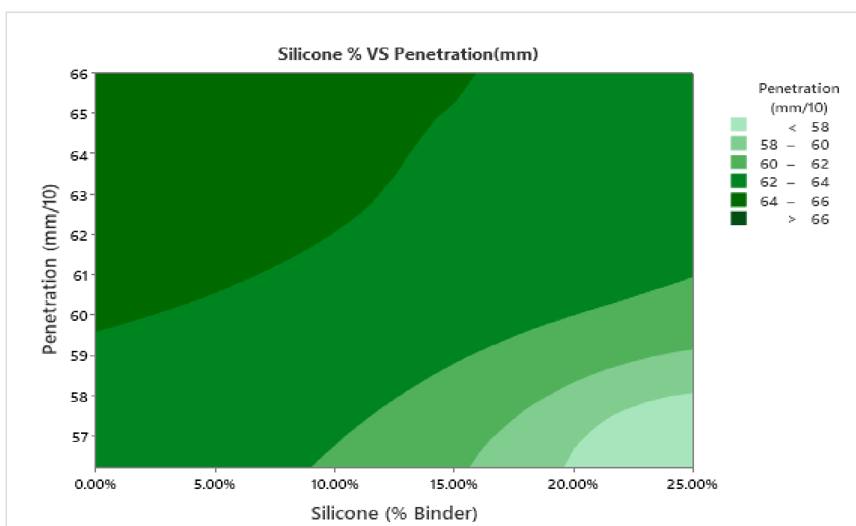

Figure 3.16 Penetration (mm/10) vs Binder (%)

3.4.13.2 Softening Point test on Modified Bitumen

Different contents in order to test the softening point, virgin asphalt was combined with silicone waste at a ratio of 10% by weight of bitumen binder. The findings showed that raising the LDPE component in asphalt binder raised bitumen's softening point temperature. Figure 3.19 displays the softening point results for each silicone content percentage in the binder.

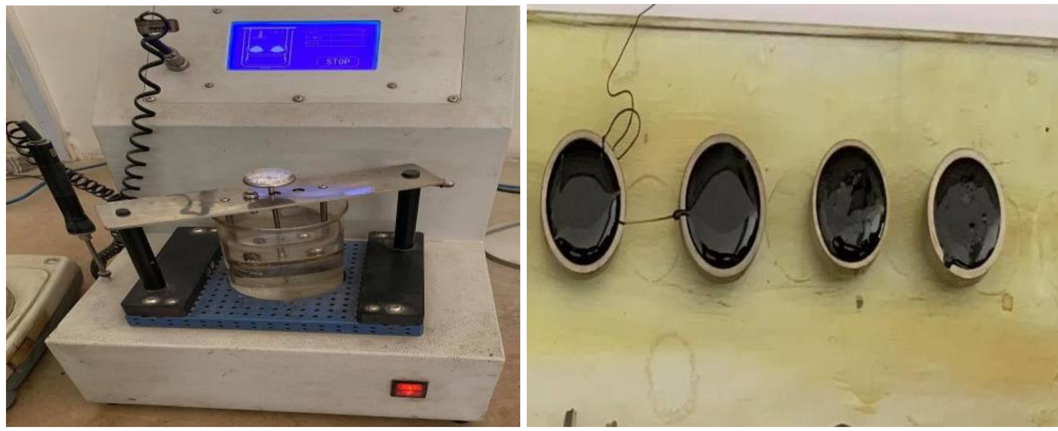

Figure 3.17 Softening Point

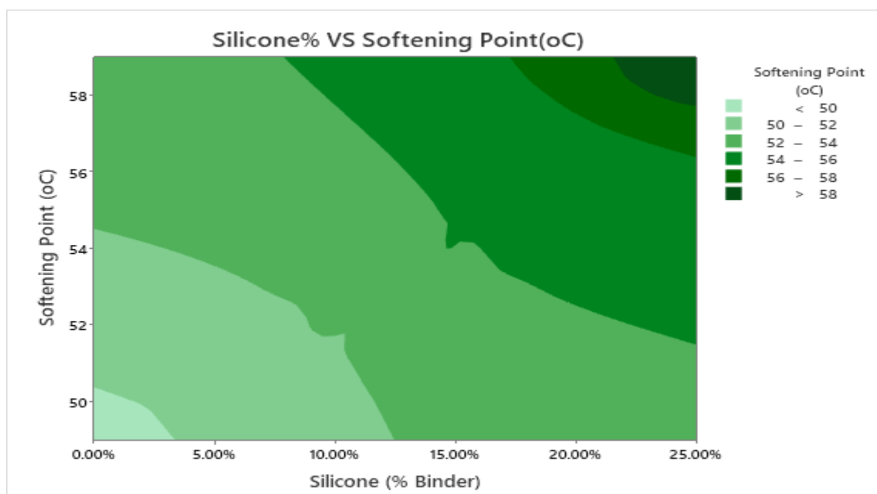

Figure 3.18 Softening Point vs Binder

3.4.13.3 Ductility Test on Modified Bitumen.

A ductility test was carried out after various amounts of Silicone waste material were mixed with virgin asphalt at various percentages by weight of the bitumen binder. Based on the findings, it was determined that bitumen ductility diminishes as silicon level in asphalt binder rises. Figure 3.21 displays the ductility values for each % of bitumen

Figure 3.19 Ductility Test

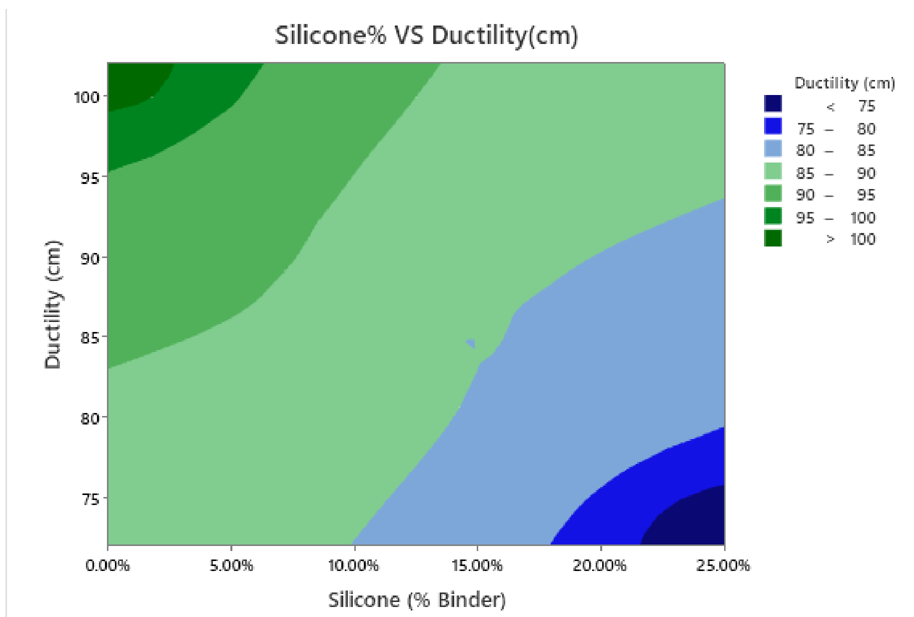

Figure 3.20 Ductility VS Binder

3.4.13.4 Optimum Binder Selection.

For the purpose of choosing the ideal modifier content, the results of several physical tests on asphalt binder modified with various Silicone waste contents are summarized in table 3.3

Different tests on the asphalt binder with various Silicone content levels—which limit the Silicone content to 20% by weight of bitumen—were conducted, and the results demonstrated that using 20% Silicone as a replacement for asphalt binder by weight won't alter the binder's grade or other properties.

Table.3.4 Physical Properties of Binder

Physical Properties of Binder with different % of Modifier (Silicon)				
Units	Silicon (% Binder)	Penetration (mm/10)	Ductility (cm)	Softening Point (°C)
M1	0%	66	109	49
M2	5%	65.3	92	51
M3	10%	64.7	89	52
M4	15%	63.8	85	54
M5	20%	62.3	83	55
M6	25%	56.2	72	59

3.5 Gradation Selection

For the creation of the asphalt mix, NHA grade B was chosen. According to MS-2, the nominal maximum size for this gradation was (3/4") or 19mm. According to the percent passing through each sieve, the chosen gradation is displayed in table 3.4, and the associated gradation curve is plotted in figure

Figure 3.21 Aggregate Gradation

Table 3.5 NHA Aggregate Gradation

S.No	Sieve Size (mm)	NHA Specification (% Passing)	Our Selection	% Retained	Wt Retained (gm)
1	19	100	100	0	0
2	12.5	75-90	82.5	17.5	1002.12
3	9.5	60-80	70	12.5	715.8
4	4.75	40-60	50	20	1145.28
5	2.38	20-40	30	20	1145.28
6	1.18	5-15	10	20	1145.28
7	0.075	3-8	5.5	4.5	257.69
		8	Pan	5.5	314.95

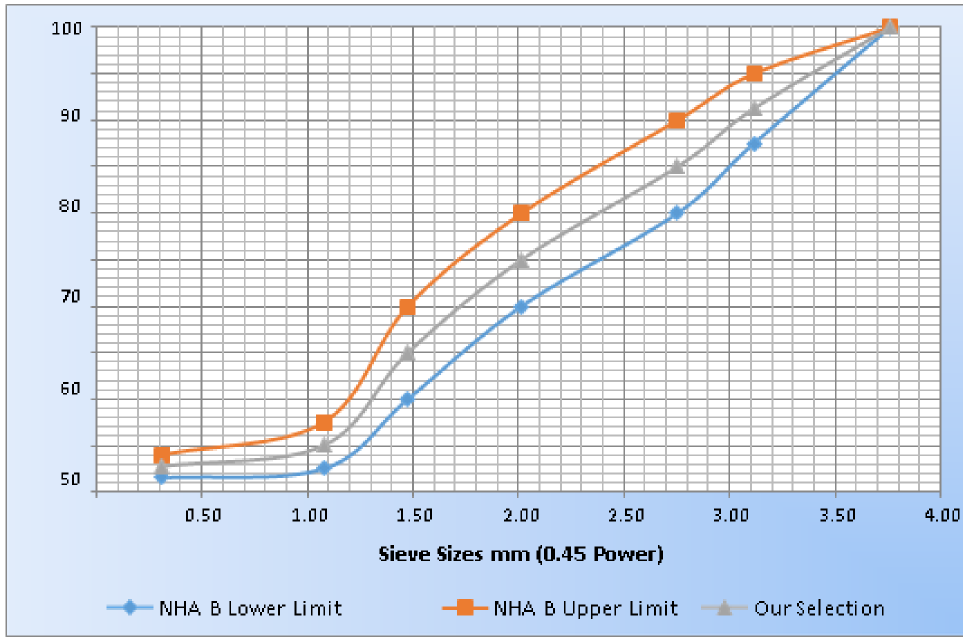

Figure 3.22 NHA Gradation Chart

3.6 Asphalt Mix Design Using Marshall

In line with the Marshall Mix Design process (AASHTO T 245), asphalt mix sample were created. Dry and wet mixing techniques were used to prepare these samples.

3.6.1 Dry Mixing Process

Due to the higher melting point of silicone, the dry-mix design technique was also suitable to be observed. At start higher temperature of 260◦C aggregates were heated further on Shredded pieces of silicone having size having <2.36mm were added into aggregates and mix well to ensure that the aggregates were Homogeneously mix with Silicone and also coated on aggregates. Homogenous mixture was cooled to 160°C after mixing well. The asphalt was heated in an oven at 110°C and then pour it into the already heated aggregate-silicone mixture at 160°C. After that mixing of aggregate silicon, with bitumen the mixture was compressed into cylindrical specimens at 135°C with 75 blows on every side.

Figure 3.23 Dry Mixing Process

3.6.2 Wet Mixing Process

In wet mix process first heated the aggregates and Silicone Modified Bitumen in an oven before mixed with aggregate at 110◦C. After that mix Aggregate with Modified Bitumen (% of OBC) At 160◦C Later on mix was compacted in standard size Mould at 135◦C and giving 75 blows on both sides of the Marshall Cake

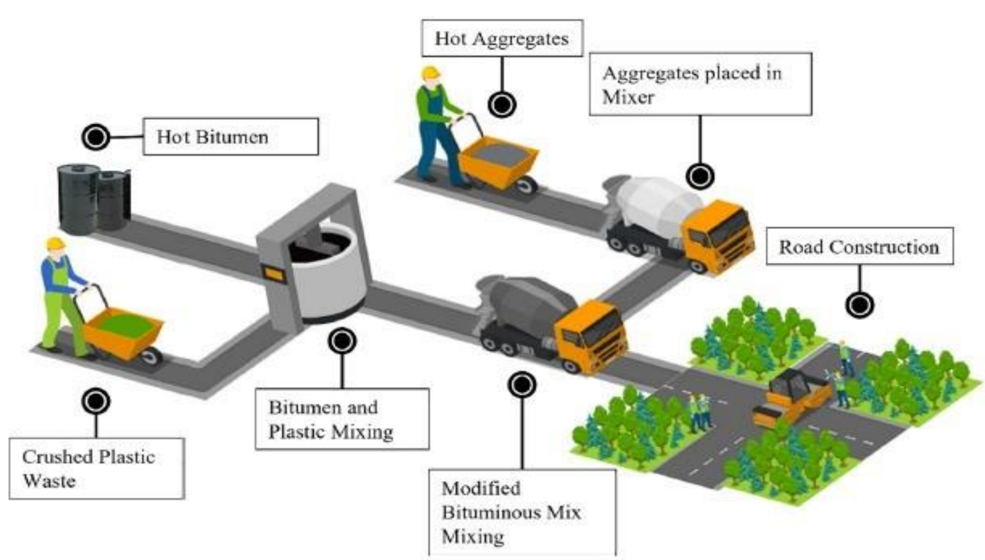

Figure 3.24 Wet Mixing Process

3.6.3 Mixing of Asphalt and Aggregate.

For the creation of traditional Marshall specimens, asphalt binder was heated to a temperature of around 160°C before being combined with oven-dried aggregate in a mechanical mixer at the same temperature until a homogeneous mixture was achieved.

Figure 3.25 Mixing of Asphalt

3.6.4 Compaction of Asphalt Concrete

Sample Three criteria for sample compaction are based on the Marshall Mix design technique, depending on whether the pavement surface is being prepared for light, medium, or heavy traffic loading. In order to accomplish the necessary compaction, 75 blows on each side of the mix sample are applied in a Marshall compactor, presuming that the pavement is being designed for heavy traffic loading. The Marshall compactor's cylindrical mold, extension collar, and base plate make up the compaction apparatus. The mold had a 4-inch interior diameter and a height of around 3-inches. A filter was put at the bottom of a mixture before it was put into a mold. The loose mixture made by heating aggregate with bitumen is transferred to a mold, which has a base plate with a spatula and filter paper on top. After that, the hammer was placed over the mold assembly, and 75 blows were given to the mixture. When the required number of blows had been given to one side of the sample, the sample was then turned over, and another 75 blows were given to that side. Figure 3.25: Samples from Marshall

Figure 3.26 Marshall Sample Preparation

3.7 Volumetric Analysis, Flow and Marshall Stability

Determination After preparing the sample, it was cooled to room temperature for roughly 24 hours by being left in the laboratory's open air. By figuring out the values of Gmb and Gmm, the volumetric characteristics of the specimen were computed. Gmb and Gmm testing were conducted in accordance with ASTM D2726 and D2041 standards, respectively. Prior to determining the sample's weight in water and SSD, the weight of the sample in air was calculated for the purpose of determining Gmb. Marshall Samples' Gmb Calculation is shown in Figure 3.26. Following the measurement of Gmb, the sample was transferred to a water bath and heated to 60 °C for 60 minutes before being tested for Marshall stability and flow using Marshall equipment. The sample was put into the Marshal apparatus at a continuous rate of 5 mm/minute until it could no longer withstand the load. The stability value represents the maximum load that a mixture of samples can withstand before failing, and the flow number in millimeters represents the strain experienced by the sample at this load. According to the MS-2 Marshal mix design standards, the stability value for the pavement surface cannot be less than 8.007 KN, and the flow value must be between 2- and 3.5-mm. Conditioning of Marshall Samples, Figure 3.27 Marshall Stability and Flow Test, Figure 3.28 Weight the loose mixture for the Gmm calculation, then determine the calibration weight of the apparatus before adding the mixture to it and applying vacuum. Weigh the apparatus containing the mixture once more after the air that was trapped in it has been released**.**

3.8 Preparation of Samples for Performance Tests

After Determination of optimum bitumen content, samples for performance testing were prepared i.e. for moisture susceptibility and rutting resistance tests.

3.8.1 Moisture Susceptibility

The preparation of specimens for moisture susceptibility testing was done in compliance with ALDOT 361, which specifies that a Marshall sample for the test have 50 2.5" height and 4" diameter. The samples that were produced for moisture susceptibility testing were separated into two categories, one of which had just virgin asphalt binder and the other of which had a 20 percentage of Silicone waste material that was substituted with Bitumen. Samples were created by substituting of Bitumen with the 20% of silicone waste material. In the form of shredded asphalt binder, Silicone was added. Only virgin bitumen was present at maximum bitumen concentration. At 160 °C, Silicone and bitumen were combined. Following oven drying at 110°C, bitumen containing LDPE was then blended with the aggregate at 160°C. At 130°C, the compaction was completed.

3.8.2 Rutting Depth

The process for preparing samples for rut resistance testing, AASHTO T 312, specifies that gyratory samples with a diameter of 5.9" and a height of 2.4" should be used. The NHA B gradation was followed while batching roughly 6kg of aggregates for mix design, and oven drying at 110°C was done on the aggregates. The ideal amount of asphalt binder was heated to roughly 160°C and combined with the aggregates in a mechanical mixer at that temperature. After the aggregates and asphalt mix had been mixed, the sample was transported to a gyratory compactor mold. Plates and filter paper were then placed on the upside and bottom of the sample, and the mold was then placed inside the gyratory compactor. Compaction was then done by setting 125 gyrations at roughly 135°C. After the sample had been compressed, the mold containing it was removed from the gyratory compactor, and the sample was then expelled using a mechanical ejector. The sample was cut with a saw cutter to a height of 2.4" and a diameter of 5.9" after being allowed to cool for about 24 hours at room temperature. Sample 51 was initially around 6" in diameter and 6" in height. The specimens that were created for the rutting resistance tests were separated into two categories: one had samples that simply had virgin asphalt binder, and the other had samples that contained 20% silicone. These samples were created using the dry-mix method, which involves mixing the silicone content with the asphalt binder first at 140°C and then mixing the aggregates with the ideal binder content including the ideal modifier content at 160°C. Figure 3.31: Preparing and Cutting Gyratory Samples Figure 3.32: Sample Ready for Rutting Test 52

3.9 Moisture Susceptibility Testing

The ASTM D 6931-07 moisture susceptibility test was carried out. Eight sets of samples, each set having two samples (four sets modified and four sets unaltered), were evaluated. The remaining four sets of samples were conditioned. Two sets of unconditioned samples were changed with 0% and 20% Silicone waste. Only after that test was completed were these samples put in a water bath at 25°C for 60 minutes. The remaining four sets were conditioning samples, which were saturated and submerged for one day (24 hours) in a water bath heated to 60°C before spending an hour in a water bath heated to 25°C. Table 3.8's testing matrix is displayed. The UTM machine was then loaded with all of the samples at a rate of 50mm per minute. The maximum load at failure was examined, recorded, and the tensile strength was calculated using the following formula (equation 3.3). Then, to determine moisture susceptibility or to check for moisture-induced deterioration, the ratio of the average tensile strength of the conditioned sample to the mean tensile strength of the unconditioned sample was calculated. For this ratio to meet the criteria for performance, it must be at least 80%. The most used technique for assessing moisture susceptibility is this one.

Figure 3.27 Moisture Susceptibility Sample

The tensile strength of each subset was calculated by Equation 3.3.

$$P\ S_t\ = 3.3\ D\ t$$

Where:

St = Tensile strength of sample, kPa

P = Maximum load,

N t = Sample height before tensile test, mm

D = Sample diameter, mm

TSR indicates the possibility of damage caused by moisture to pavement. TSR is the ratio of tensile strength of conditioned sample to unconditioned sample. TSR for each subset of specimen is determined by the equation 3.4.

$$TSR = [S_2] \text{ (3.4) } 53\ S_1$$

Where:

S_1 = Mean tensile strength of unconditioned sample

S_2 = Mean tensile strength of conditioned sample.

3.10 Rutting Test

The Hamburg Double Wheel Tracker (HDWT) is a device that simulates the situation of a roadway by repeatedly cycling a 157-lb wheel over a sample of asphalt mix inside a chamber while maintaining a constant temperature. AASHTO T 324 is followed when conducting the test. Four gyratory samples were created, two of which were left unaltered and included solely virgin asphalt binder, while the other two had 20% of Silicone in place of bitumen. Table 3.9's testing matrix is displayed. The first four unaltered portions of the mix sample were introduced and fixed inside the apparatus after these four samples were divided into eight pieces. The test was carried out in a chamber with a constant temperature of 40°C and dry air. The 12.5mm rut depth was chosen as the failure threshold. Samples were put through wheel passes totaling 5000 cycles at a pace of 25 cycles per minute. Additionally, sample information was added to the software that displays deformation data. The test was designed to end after either 5000 cycles were finished or a 12.5-millimeter rut depth was reached, whichever came first. Rut depth grows as the number of cycles increases. No sample failed under these circumstances. After the test was over, the samples were taken out and the silicone-modified samples were fixed in the HDWT device's molds. Information was then loaded into the software, and the test was run under the identical loading, cycle, and temperature conditions.

Figure 3.28 DWT Sample

3.11 Chapter Summary

The lab evaluation of aggregates and the asphalt binder used to create asphalt mixes is covered in this chapter. For the preparation of the asphalt mix, the materials that indicated the standard criteria and standards were employed. The volumetric characteristics of prepared samples of asphalt mix were calculated. The techniques for preparing samples for performance tests, such as moisture susceptibility as well as rutting resistance tests, were described at the final section of the chapter, along with methods for carrying out tests.

CHAPTER 4: RESULTS AND ANALYSIS

4.1 Introduction

Rutting is the most typical type of pavement distress that is seen on HMA pavements all around the world, but particularly in Pakistan. Rutting is typically caused by hotter pavement surfaces and larger axle loads. Therefore, it is technically sound and desirable to do the Hamburg double wheel tracker tests to investigate rutting susceptibility. In addition to rutting, moisture trapped by the pavement acts as a destructor that mostly causes HMA pavement to fail early. Determining moisture-induced damage by UTM is a straightforward, popular, and common method. This study examines the effects of substituting waste Silicone mobile covers (20% of bitumen) for asphalt binder in the HMA mixture on the rut resistance and moisture susceptibility of the paving mix. Incorporating the ideal additive content, specimens for performance testing were created. NHA class B was utilized as the grade. Moisture susceptibility along with rutting susceptibility have been extensively thoroughly examined and explained in chapter two of the literature study. Different parameters selected for experimental testing in accordance with standards have been examined and commented upon in Chapter 3 of the Testing Methodology. In this chapter, specific findings from two experiments—moisture susceptibility (ITS) and rut resistance—are discussed in depth. Test results from conventional samples and Silicone-modified samples are analyzed and compared, and the results are discussed. Microsoft Excel was used to analyze the findings of the various HMA mix laboratory trials. One of the most crucial goals of this research is to conduct a cost analysis at the conclusion of the study, after which the findings will be compared, after determining the best method for the safe disposal or efficient utilization of Silicone waste. Results of Performance Testing to compare the performance of an asphalt mix containing virgin binder and a binder modified with Silicone content, moisture susceptibility and rutting tests were performed on sample asphalt mixes.

4.2 Marshall Stability and Flow Results.

In the investigation of marshal stability and flow value four different types of mix are prepared by involve two different source of crush Margalla and Sargodha and mixing was done by wet mix and dry mix Table 10 below shows the stability (KN) and flow rate (mm) for both HMA Marshall Mix and Silicone Modified samples for both aggregate type by wet mixing and dry mixing procedure. Studies have shown that the addition of Silicone Cover waste improves the stability of asphalt mixtures. The stability of Silicone modified HMA is superior compared to his controlled HMA samples due to the improved adhesion between aggregate, binder and shredded silicone waste. Graph show the dry mixing having better results in the form of stability and flow if it differentiates with the wet mixing results same as for the aggregates it is analyzed that Margalla based Marshall specimen having better stability and Flow values as compared to Sargodha based Specimen which are shown in Figure 6(a)(b). In general, high flow values an index for a mix which is susceptible to permanent Deformation due to traffic load. Mixtures with low flow values are therefore indicative values There may be air voids above normal levels that the pavement faces. Premature cracking due to brittleness that occurs during pavement service life.

Table 4.1 Stability and flow analysis of asphalt mix samples with Sargodha & Margalla

Aggregate Source: Sargodha								
Mixing Method	**Modifier**	**Stability**	**Flow**	**Gmm**	**Gmb**	**Air voids**	**VMA**	**VFA**
Unit	**%**	**KN**	**Mm**	**g/cm^3**	**g/cm^3**	**Vv**	**%**	**%**
CM **(Control)**	0	10.177	2.337	2.471	2.335	5.517	16.775	67.109
WM	20	11.75	2.553	2.471	2.35	4.883	15.649	68.796
DM	20	12.34	2.623	2.471	2.358	4.56	15.043	69.69
Aggregate Source: Margalla								
CM **(Control)**	0	11.183	2.44	2.521	2.389	5.21	16.356	68.144
WM	20	12.927	2.773	2.521	2.412	4.298	14.421	70.199
DM	20	13.923	2.987	2.52133	2.416	4.178	14.323	70.832

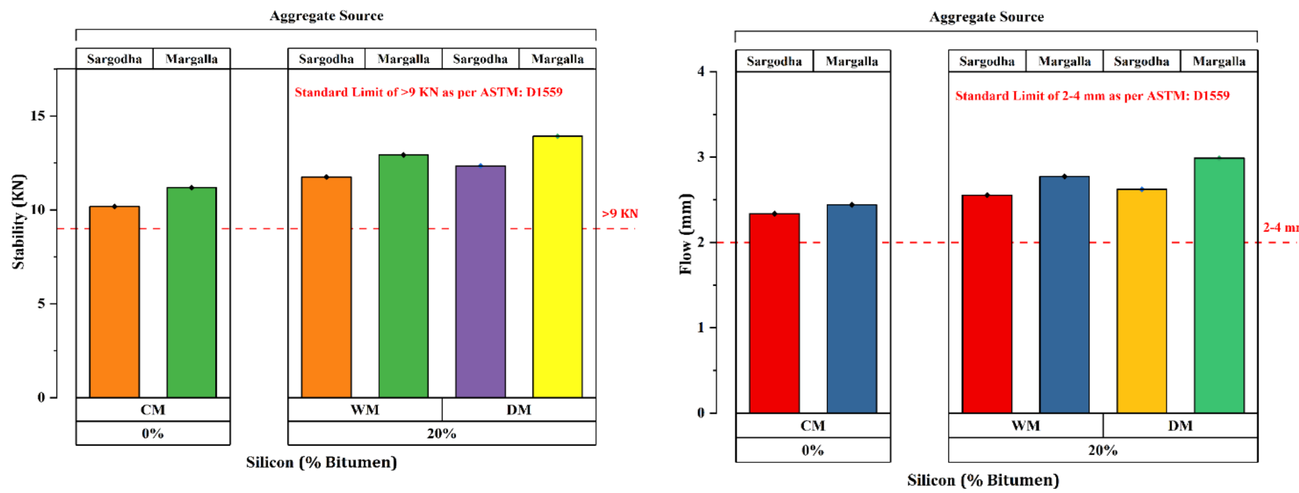

Figure 4.1 Result of Stability & Flow

4.3 Performance Testing Results.

An assessment was conducted to evaluate the performance of an asphalt mix sample by the implementation of moisture susceptibility and rutting tests. The purpose of this evaluation was to examine the performance of the asphalt mix, which consisted of both virgin binder and binder modified with a 20% addition of Silicone components.

4.3.1 Moisture Susceptibility

As per ASTM D6931-07, experimental testing was conducted. To be tested for ITS, specimens were produced in accordance with the Marshall mix design standard. Two samples for the unconditioned indirect tensile strength test plus two samples for the conditioned indirect tensile strength test were generated for HMA that only contained virgin asphalt binder. Sample conditioning was done in line with ALDOT 361. After allowing the sample cooling at room temperature for 24 hours, the requirement for unconditioned testing was to keep it at 25°C in a water bath for an hour before performing the test in a UTM, whereas the the need for conditioned samples after letting the sample cool at room temperature involved warm soaking for the following 24 hours at a temperature of 60°C in a water bath and then kept at 25°C for an hour just before the test happened. The same number of samples were also made for the

HMA mixture that substituted 20% silicone for the ideal amount of binder. After running the test in the UTM machine, the sample's maximum load before failing is documented, and the tensile strength of the sample is calculated using the method already discussed in chapter 3. The formula is used to calculate the tensile strength ratio, which is then used to determine whether or not samples made with LDPE modified binder meet the required tensile strength ratio requirement (above 80%) as suggested by the standard. Tensile strength of all samples, both conditioned and unconditioned, is found using this method. Tables 4.1 and 4.2 provide a summary of the tensile strength along with tensile strength ratio results. As viscous samples perform better under tension, the majority of researches came to the conclusion that ITS readings for unconditioned and modified samples are better over unconditioned and unmodified samples. Due to moisture-induced degradation, the ITS values of conditioned samples are lower than those of unconditioned samples. TSR value marginally reduces as the amount of plastic in the HMA mixture increases. Indirect tensile strength comparison results for conditional and unconditioned samples are shown graphically in figure 4.1, and tensile strength ratio comparison results are shown graphically in figure 4.2. Figure 4.3 displays the sample evaluated for moisture susceptibility evaluation.

It was found that the ITS of the HMA mix increases as the silicon content does. All HMA samples meet the required minimum TSR value of 80%. Since samples with more viscous materials perform better under strain, they will retain more of their tensile strength when subjected to high temperatures and moisture levels. The ITS of the silicone-modified HMA mixture is higher in the dry samples than it is in the traditional (unmodified) mixture. While still within acceptable bounds, modified mix moisture resistance as measured by TSR was somewhat lower than that of traditional mix.

Table 4.2 Indirect Tensile Strength of Virgin & Modified HMA

Indirect Tensile Strength of Virgin and Modified Bitumen HMA Samples							
Modifier (%)	**Conditioned Samples S1**			**Unconditioned Samples S2**			**TSR S1/S2**
	Load (KN)	**Mean**	**ITS**	**Load (KN)**	**Mean**	**ITS**	**TSR S1/S2**
0%	8.52 8.46	8.49	0.881	8.66 8.76	8.71	0.943	93%
20%	8.31 8.41	8.36	0.868	8.94 8.98	8.98	0.967	90%

Table 4.3 Tensile Strength Ratio of Virgin & Modified HMA

Tensile Strength Ratio (TSR) of Virgin and Modified Bitumen HMA Samples			
Modifier (%)	**Conditioned Strength (KN)**	**Unconditioned Strength (KN)**	**TSR (%)**
0%	881	943	93%
20%	868	967	90%

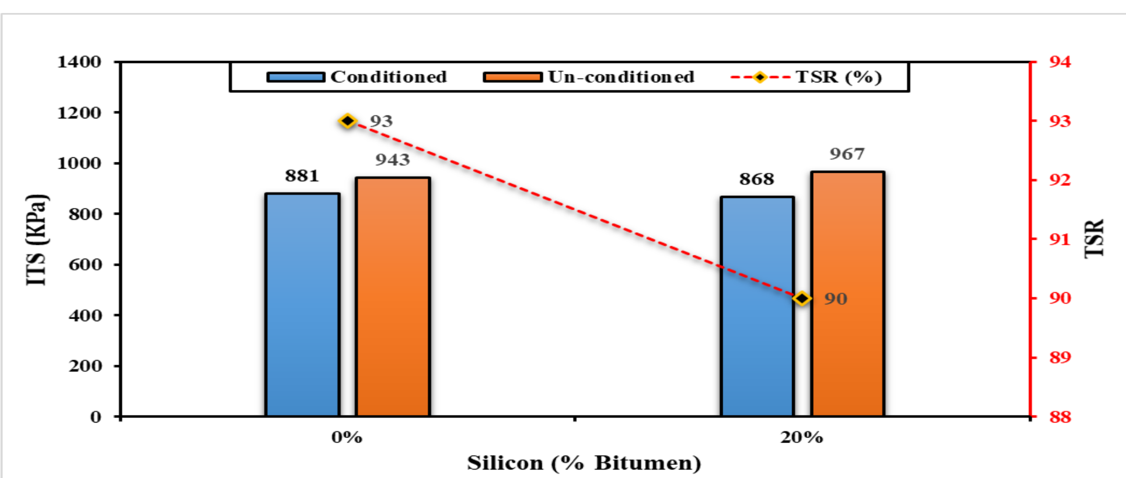

Figure 4.2 Tensile Strength Ratio Result

4.3.2 Rutting Depth Test.

The test was conducted in accordance with AASHTO T 324 standard. Four samples in all were created using a gyratory compactor for the rutting test, of which two were unaltered and following one day of cool to room temperature, two samples were saw-cut to the appropriate sizes of 2.4 inches in height and 5.9 inches in diameter to fit within molds, resulting in the formation of four samples. Two samples were modified using 20% Silicone, having a height of 6 inches and a diameter of 6 inches. Four of the eight components, which were put in two molds of the HDWT testing machine, were left unchanged. The test was then conducted using software on a laptop with the temperature and speed set to 40°C and 25 cycles per minute, respectively. After 5000 cycles, samples were withdrawn from the machine, modified samples were put within the machine's molds, and the procedure was repeated. When the test was concluded, results were acquired. Following that, findings were compared in order to determine how differently original asphalt and silicone-modified asphalt paving mix were susceptible to rutting. Figures 4.4 and 4.5 display the full results as well as a comparison of the outcomes. Rutting Test Results, Table 4.3

Table 4.4 Rutting Depth of Virgin & Modified HMA Sample

Loading Cycles	**Rutting Depth of Virgin(mm)**	**Rutting depth of modified(mm)**
0	0	0
500	1.75	1
1000	2.16	1.29
1500	2.4	1.49
2000	2.69	1.71
3000	3.02	1.99
4000	3.29	2.24
5000	3.51	2.43

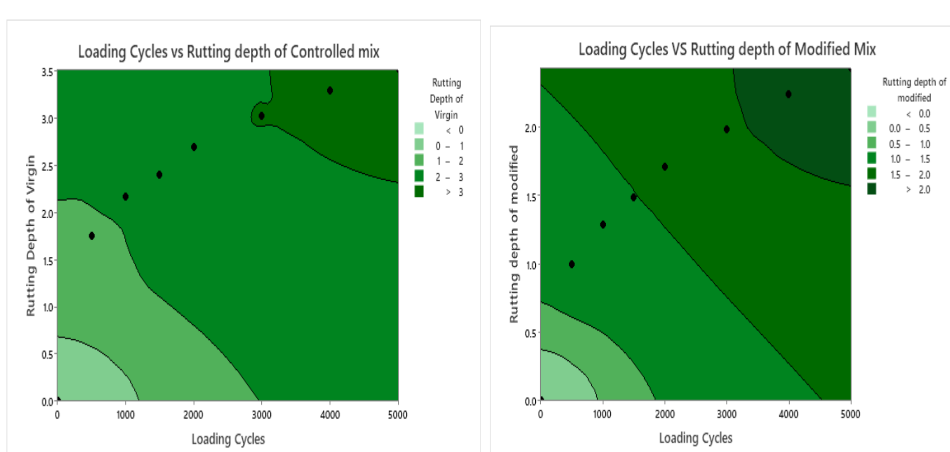

Figure 4.3 Rutting Result

4.4 Environmental and Economic Sustainability

The use of Silicone Mobile covers is gradually increase across the globe. Silicone Waste continues to rise despite efforts to reduce, reuse and recycle Silicone waste every day. According to research, the total 187.9 million Mobile phones are registered in 2022 and more studies shows that 75% people use silicone case for their cell phone to avoid overheating and scratches pollution by Silicone is a serious problem and its increasing consumption is alarming and its long declination time of almost 300 years. In addition, rising oil prices on annual bases,[39] devour of natural resources, a ban on limestone mining in the Margalla Hills[40] negative environmental pollution, Urban flooding, depletion of aquifers, construction costs and loss of funds are all caused by road moisture loads. Excessive and frequent vehicle loading is just one of many challenges facing the road construction industry. Continuing with findings, it was concluded that using Silicone waste to improve road quality makes sense. There is value in improving the longevity and maintainability of roads while it also prevents silicone waste from polluting the air and environment. Many studies results are terminated that the addition of alternative in road construction should be buck up[41, 42] That minimize the overuse of raw materials and provide to sustainable engineering projects. A cost comparison was performed to assess the cost savings from using Silicone waste HMA blends and also for unmodified HMA. A road with 3.6m wide with heavy traffic was assumed with a Course thickness (ACWC) 50mm. It was assumed that preparation and compaction both costs were almost similar for HMA mix including asphalt concrete subbase (ACBC), granular subbase (GBC) and granular subbase (GSBC) therefore Its cost was completely neglected. The Marshall mix design resulted in an HMA mix asphalt density of 2327 kg/m3.

4.5 Cost Comparison of Conventional and Modified Binder

The cost of the materials is the most crucial aspect among all those that influence the cost of constructing a pavement. Asphalt binder is primarily the more inexpensively variable material as compared to all other components. It is possible to reduce the amount of virgin asphalt binder used to make HMA pavements, hence lowering the total cost of pavement construction. Silicone waste content can be used as a replacement for asphalt binder modifier at a level that does not impair overall pavement performance. This study compares the costs of standard asphalt binder with Silicone-modified asphalt binder (which uses silicone component in place of bitumen). A one-kilometer pavement stretches with one lane (3.6m) and a thickness of two inches (50mm) is compared. Asphalt wearing course standard compacted density is taken to be 2350 kg/m3. Figure 4.7 illustrates the cost analysis graphically.

4.5.1 Calculations of the Material Cost

Table 4.5 Description of road section

Sr. No	Design Parameter	Values
1	length of Pavement Section	1 KM
2	No of Lanes	1
3	Width of pavement section	3.5m
4	Bitumen Percentage	7%
5	Surface Course thickness	50mm

Volume of asphalt mix = length × width × thickness

= 1000 m × 3.6 m × 0.05 m = 180 m^3

Density = 2327 kg/m^3

Quantity of asphalt mix = length × width × thickness × density

= 1000 × 3.5 × 0.05 × 2327 = 418860 kg.

Total quantity of bitumen at 4.5% = 418860 kg × 0.045 = 18848 kg / 1000

= 18.84 tons.

4.5.2 Cost Analysis of Road Section.

Table 4.6 Description of Cost Saving

Description	Calculation	Results
Total Volume of Mixture	1 × 3.6m × 50mm	180 m3
Density of Bitumen		2327 kg/m3
Weight of Mix For 1 KM Section	2327 × 180	418.86 Tons
OBC	4.50%	
Required weight of Asphalt Binder	418.86 × 0.045	18.84 Tons
Cost of Asphalt Binder		97000 PKR / Tons
Cost of Virgin Bitumen	18.84 × 97000	1827480
For 20% of OBC replacement with Silicone waste.		
Required weight of Silicone waste	18.84 × 0.2	3.768
Required Asphalt Binder with 20% Silicone	19.44 - 3.768	15.672
Cost of Bitumen Modified with 20% of Silicone	15.672 × 97000	1520184 PKR
Total Cost Saving	1827480-15020184	307296 PKR

Table 4.7 Description of bitumen saving per m3 of asphalt mix

Description of Bitumen saving per m^3 of asphalt mix				
Sr. No	**Binder**	**Quantity of Bitumen**	**Quantity Saving Bitumen**	**Cost Saving/m^3**
Unit	**%**	**Tons**	**%**	**PKR**
1	0%	0.1046	0	0
2	20%	0.0837	19.98	2027.3

Quantity of bitumen/m^3 of asphalt mix = total quantity of bitumen / total volume of asphalt mix

= 18.84 / 180 = 0.1046 tons and

Rate used for bitumen = 97,000. Saving cost/m^3 = (0.1046–0.0837) × 97000 = 2027.3 PKR.

4.6 Chapter Summary

This chapter goes into great length in its study of the outcomes of various laboratory performance tests. The outcomes of the UTM machine are reviewed in relation to the rise in ITS values, and TSR values are also calculated to ascertain moisture susceptibility. To assess the data gathered from performance testing, tables and graphs are displayed. Comparing the results of the moisture susceptibility test with and without the integration of silicone revealed that, under stress-controlled conditions, the incorporation of silicone can be linked to a reduction in the amount of virgin bitumen utilized. In the format of bar charts and graphs, the outcomes of the wheel tracker test, the ITS test for controlled specimens, and the specimen comprising silicone were displayed. The cost comparison for the Control mix and the mix including 20% Silicone waste is then completed. In a kilometer-long segment with an average thickness of 50mm, virgin asphalt binder cost $20. One kilometer of silicone modified binder was decreased from 1.596 million to 1.532 million, a 4% cost savings, and the trash was safely disposed of.

Chapter: 5 CONCLUSION AND RECOMMENDATIONS

5.1 Background

This project aimed on determination of the effectiveness of Silicone, as replacement of virgin asphalt binder, in HMA mixes. Moisture induced damage and rutting are the serious issues and major problems of HMA pavement. Hamburg double wheel tracker is a device that is used for determination of rutting susceptibility of hot paving mix. HDWT can also be used for long term performance evaluation. UTM is one of testing equipment also used for performance evaluation of pavement especially used for determination of indirect tensile strength that can be further used to calculate moisture susceptibility. NHA Class-B wearing course gradation, PARCO bitumen of grade 60/70, and Aggregate was brought from Hattar crush plant were used in this project. Silicone Mobile Covers were collected from different Mobile Centers. After determination of OBC, samples for performance testing were prepared with virgin asphalt binder and with addition of Silicone waste, as replacement of Bitumen. Marshall mix design samples for moisture susceptibility and super pave gyratory samples for rutting susceptibility testing. The key findings of performance testing and conclusions are as follows.

5.2 Conclusion

From this research it concludes that such synthetic solid waste is used in road construction. Industries in growing countries must not only impart a green and inexpensive road infrastructure, but also solutions for the sustainable treatment of this particular waste. We believed that putting this idea into practice would allow us to build roads in a low-cost, based on sustainability and ecofriendly way of urbanization. The increasing graph of mobile phone users leads to this waste Production in millions of tons of waste cases and mobile phone cases. Asphalt is therefore a continuing and major source of material used for the road construction, and providing an alternative binder when preparing asphalt mixtures in road construction can minimize material requirements, Asphalt production costs are reduced. This study provides evidence for collection mechanisms and the use of silicon cover waste for economical road construction processes and waste discarding. This study accesses the moisture damage Susceptibility, rutting depth, stability, and flow properties of HMA modified with the addition of Silicone waste by wet and dry mix procedure to improve quality Pavement serviceability and weather condition due to heavy traffic loads usability of the road surface due to heavy traffic and also Control the growing environmental pollution. Material properties of bitumen as a binder have been shown to remain within the Acceptable range used according to ASTM standards. Silicone modification of asphalt improved softening point and penetration. This suggests that the Silicone-modified pavement is less likely to deform. Anyway, the ductility of Silicone-modified asphalt decreases gradually As Silicone % increases. Adding and increasing the Silicone % content to an optimal level improved the results of moisture damage, Rutting depth as well as stability and flow test results. Dry-mix technology gave better results in stability and flow therefore, further performance test analyses done by dry mixing.

5.3 Recommendations.

- The research conducted rutting susceptibility and moisture susceptibility tests to assess performance. Additional tests such as fatigue cracking, creep testing, workability assessment, dynamic modulus analysis, flow number determination, and flow time measurement were not conducted.
- It is recommended to assess the efficacy of using Silicone waste as a substitute for asphalt binder in Hot Mix Asphalt (HMA) through the construction of a trial section in order to determine its compatibility with the prevailing temperature and traffic conditions in Pakistan.
- It is advisable to investigate the chemical characteristics of silicone waste when combined with asphalt binder in order to assess the potential for enhancing its properties. This assessment would identify if any rejuvenating agent could be employed to improve the properties of silicone waste, hence enabling its incorporation into hot mix asphalt (HMA) with silicone waste. By implementing this approach, a larger quantity of silicone waste might potentially be employed, resulting in a reduction of virgin bitumen content.

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