A COMPARISON OF CHARACTERISTICS OF WASTE PLASTIC, CRUMB RUBBER AND POLYMER MODIFIED BITUMEN BASED ON PREVIOUS STUDIES.

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Declaration

The thesis titled **"A comparison of characteristics of Waste plastic, Crumb rubber and Polymer modified bitumen based on previous studies."** was performed for the course completion of CE-400, Titled - Project & Thesis.

The whole work is carried out by the authors under strict and friendly supervision of Dr. Mohammad Hannan Mahmud Khan, Assistant Professor and Associate Head, Department of Civil Engineering, Daffodil International University (DIU), Dhaka, Bangladesh.

It is hereby declared that, the thesis or any part of it has not been submitted elsewhere for award of any degree or diploma or publication.

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Dedications

This thesis dedicated to all of our parents and teachers who inspired us for made this effort possible.

Abstract

Transportation plays an important role in the rapid economic development of a nation. Transportation increases the quality and variety of consumer goods, thereby stimulating the demand and development of trade and economy of the nation. Transport provides various employment opportunities and boosts up the economy of the country. Roads make a crucial contribution to economic development and growth and bring important social benefits. They are of vital importance in order to make a nation grow and develop. In addition, providing access to employment, social, health, and education services make a road network crucial in fighting against poverty. Roads open up more areas and stimulate economic and social development. Every year more and more roads are being constructed which needs a huge collection of bitumen. The primary objective of this thesis is to Comparison on Specific gravity, Ductility, Softening Point, of bitumen modified by waste plastic, crumb rubber & polymer. Comparison of Optimum binder content on each case of modification. Environmental impact assessment for each case. Recommendation for the best modifier of Bitumen Among these three materials. The data of the previous research are collected to determine the best modifiers of bitumen. Finally, considering the optimum point, we recommend the best bituminous modifier for decreasing the cost and quality improvement of bitumen.

List of Abbreviations

RHD	Roads and Highways Department
LGED	Local Government Engineering Department
BPC	Bangladesh Petroleum Corporation
DRM	Disaster Risk Management
CRMB	Crumb Rubber Modified Bitumen
PMB	Polymer Modified Bitumen
AASHTO	American Association of State Highway Officials
ASTM	American Society for Testing and Materials
LDPE	Low-density polyethylene

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Introduction

1.1 Introduction

Bangladesh has moved out through a vast advancement process from the past 2000. There are many expansion projects are added to cope with the needs and crisis. To attach outmost places to develop a decent transportation network for booming passengers and good the road construction project is the most vital among them.) National highways, regional highways (R numbers), and Zilla or district roads (Z numbers) are included in our road network. “The over-all distance is more than 21,000 km. Since then, RHD has expanded the network which at present stands to a total of 21,500 km” [1]. RHD is answerable for the development and repairs of major roads of Bangladesh. Another Government Department, LGED, is taking care of rustic roads.

1.1.1 Bitumen

All over the place, more and More Roads Are Being Built Who Needs an Age Collection of Materials like Aggregate, Bituminous It. Bitumen is the most significant material. Currently, bitumen in Bangladesh is mostly used in road construction and roofing applications. The current

Figure 1.1 Bitumen

claim for bitumen is 4, 10,000 ton but the supply of bitumen is only 2, 60,000 ton. The lack of bitumen is 1, 70,000 ton, which is more than one-third of the total demands. In the South Asian

Region, two types of Bitumen, Grade 60-100 or Soft Bitumen and Grade 60-70 or Hard Bitumen is produced. The recent price of a ton of 60/70 grade smuggled bitumen is about Tk39, 000. “However, Bangladesh Petroleum Corporation (BPC) officials said that native bitumen per ton prices are around Taka 59,330 for 60/70 grade and Taka 56,660 for 80/100 grade’’ [3]. For reducing the cost of bitumen at the present here we will know some complemental materials. Waste plastic, Crumb rubber, the polymer is good to compliment the material.

1.1.2 Flexible pavement

“Plastic pollution is harmful to humans, animals, and plants through toxic pollutants. To break down plastics can take about hundreds or even thousands of years, so the environmental damage is long-lasting. It is also responsible for effects all organisms in the food chain from tiny species like plankton through to whales’’ [5]. “Heavy rainfall is characteristic of Bangladesh. Rajshahi is a dry western region with the exception of the relatively, the annual rainfall is about 1600 mm, At least 2000 mm of rainfall receive most parts of the country at per year’’ [6]. So here, Rains is not constant over. “Most of the highways and roads of Bangladesh are constructed with the flexible pavement. For high-temperature susceptibility and lower resistance to moisture, most of the roads get deteriorated induced damage of the conventional bitumen used in Bangladesh’’ [1]. “It is estimated that around 1.0 billion scrap tires are produced every year all over the world, out of which around 150,000 tons are produced by Bangladesh’’ [7]. Due to the large volumes of tires, they are not anticipated at landfills and 75% void space. This 'fizzing' effect can damage landfill inside layers that have been connected to help keep landfill pollutants from contaminating local surface and groundwater. Odor, dust emissions, noise, waste, energy consumption, and solvent emissions are included in (VOC emissions) from tire production. The most significant of these impacts are VOC emissions and, locally, odor. “Each year around 275 million ton of plastic waste

is produced around the world; between 4.8 million and 12.7 million ton is discarded into the sea. About 60% of the plastic waste in the ocean arises from the following top 5 countries'' [8]. The road construction cost in Bangladesh is the maximum in all over the world, quality roads are hardly made for lack of proper monitoring by the authorities concerned and the accountability of construction organizations, said the expert. Administrators at the Road Transport and Highways Division and Local Government Engineering Department (LGED) said over 2,000 km of roads are required for renovation every year only because of burdened vehicles. It is estimated that there are 2.75 lakh km roads under the LGED while some 20.03 km highways and district roads under the Road Transport and Highways Division.

It shows the cost of per kilometer road construction is $2.5 million to $11.9 million in Bangladesh, which is the highest in the world. With economic development at the rate of 6.5% GDP [Finn Road Limited (2014)] on average, the heavy traffic intensity is very increasing which requires heavy-duty roads which cannot be achieved with neat bitumen. In a report on June 20 last, the World Bank presented a list of substructure costs, particularly on the road. In Bangladesh, the waste tire generation each year is about 905000tones. So, modification of conventional bitumen in a cost-effective manner. The recovery of weakened pavements has become one of the main concerns in road engineering. Thus, the improvement of more tough bituminous combinations to be used as external layers is a priority for the sector. Gap graded bituminous combinations manufactured with reformed binders at high dosages have been used with suitable results. However, these materials are liable to temperature, and their performance is at the mercy of climatic conditions. In order to develop the design of these mixtures, this research has concentrated on a better appreciation of their fatigue performance as a function of temperature. Polymer reformed bitumen (PMB) is one of the particularly designed and engineered bitumen grades that are a charity in production

pavement, roads for substantial duty traffic, and home guttering solutions to enduring extreme weather situations. As polymer products take a very long time (say 800 years) to decompose, the dumping of these materials poses a great threat to the environment and make waste management very expensive.so if we can use this waste in pavement then it will very it will be environmentally friendly and reduce construction by decreasing the use of bitumen.

In view of these, the proposed study will be important and useful in the context of Bangladesh. It is expected that the proposed study will help to explore the potential of the modified binder by the characteristics among waste modified bitumen, crumb rubber modified bitumen, and polymer modified bitumen and thereby would encourage the use of modified bitumen in pavement construction in Bangladesh.

1.2 Statement of the Problem

The present trend of road construction in Bangladesh is almost 95% bituminous pavement (RRD, 2006). Like all other countries, in Bangladesh, the scarceness and increasing cost of construction materials along with heavy axle loads, environmental circumstances, poor design, and inappropriate construction technique lead to impulsive failure of flexible pavements and force engineers to consider more economical and durable pavement design methods to build roads using indigenous pavement materials and advanced construction techniques (Hamim, 2017). The situation comes to be even more dangerous in the case of undersized countries. As a high rising urban city with high population density and an increased rate of transportation needs, the Roadway pavement of Dhaka city has to withstand more traffic load than any other cities in Bangladesh. Moreover, the poor drainage system in most of the city roads accelerates the deterioration of the pavements. For these reasons, consistent periodic maintenance has been implemented to retain the

highways functional. This learning deals with the exploration and documentation of road surface burdens and cracks before and after reappearing and compare the outcomes to calculate the effectiveness of the resurfacing. The pavements are visually measured and four valuation methods: RHD, DRM, Indian Congress Method, and Texas Innovation Group Method are used. Ten roads are certain throughout Dhaka city to calculate the effectiveness of resurfacing and increase of life span of the pavements. Before resurfacing, most of the roads were in underprivileged to fair to humble condition. But in the future a periodic resurfacing after a specific interval, most of them stimulated into a fair or good situation. Finally, it can be said that this research may prove itself advantageous for future planning and application to ensure effective, comfortable, safe, and efficient traffic movement which may lead to a better transportation system throughout the country. Frequent heavy rain during the monsoon inundates the roadway pavement in cities and towns. A large portion of roadways pavement undergoes water due to recurrent high flood. The void in the bituminous pavement is filled with water under submerged conditions. At this condition, pore pressure is developed by the action of the wheel load. This pore pressure creates a tremendous uplift force that eventually breaks the bond between aggregate and binder. Thus, aggregate is loosened and lifted by the action of the wheel. As a result, striping of aggregate initiated, and "pothole" occurred in the pavement. Plastic is a viscous material having a good adhesive quality. Plastic modified Bitumen has a higher viscosity than conventional bitumen. It adheres to the aggregate and makes a thick coating that helps the aggregate to prevent stripping.

Another problem of flexible pavement made with conventional bitumen is temperature susceptibility. Normal bitumen is hard and brittle at low temperatures and soft like mud at high temperatures. In hot temperatures, especially in the summer season the temperature reaches the softening point of bitumen and accumulates on the pavement surface. This phenomenon is

commonly known as bleeding. Because of bleeding the road surface becomes slippery. Waste plastic modified bitumen has less temperature susceptibility. It is functional during a wide range of temperature variance as plastic increases the softening point of bitumen.

Rutting is a vertical depression on the pavement surface caused by the vehicle wheel load and is another cause of pavement failure. It results from permanent deformation of any layer on the subgrade usually caused by consolidation or displacement of the pavement edge due to traffic loading. Lack of sufficient on the binder may cause permanent deformation. Cracking is another problem that results when the binder is not capable of sustaining the pressure due to temperature variance. A pothole is a final result of cracking.

In Bangladesh, a huge amount of money is spent due to the restoration and maintenance of flexible pavement. The national highway, regional highway, and all kinds of pavement need conventional repair work every year. Delay on the repair work may cause total structural failure of the pavement. This extra money can be saved using Plastic modified Bitumen. This will also provide plastic waste disposal solution eventually protect the environmental pollution

1.3 Objectives of the Research

The objectives of this thesis are

- Comparison on Specific gravity, Ductility, Softening Point, Penetration of bitumen modified by waste plastic, crumb rubber & LDPE.
- Comparison of Optimum binder content on each case of modification.
- Recommendation for the best modifier of Bitumen Among these three materials.

1.4 Scope of the Study

There are different types of materials used as binders. In this study, we will describe only three types of binders with pure bitumen. Because all of them are not capable of making a well-blended mix with virgin bitumen.

1) this study investigates the properties of Waste Plastic Modified Bitumen, Crumb Rubber Modified Bitumen, and Polymer Modified Bitumen with non-modified bitumen and Characteristics Comparison among them. Economic aspects were discussed in detail.

This is done by showing bituminous tests of Penetration tests, the Ductility Test, Softening Point Test, and the Specific Gravity Test.

Plastic is of the different types found as a waste form but all of them are not capable of making a well-blended mix with virgin bitumen. Only thermostatic plastic-like polythene, Pet bottles are used to make a good homogenous mixture. Only heat is enough for melting this type of plastic. A mechanically and thermostatically controlled blender would be used for blending waste plastic.

2) The crumb rubber material was obtained from the exhausted truck tires.

3) The study consists of the preparation of 25 samples for the Bituminous Test and 30 samples For Marshall Test.

4) Economical aspects were discussed in detail.

1.5 Thesis outline

In this research project work carried out is divided into different topics and presented in five Chapters.

A brief introduction to the statement of the problem is presented in the first chapter with special emphasis on the objectives of the proposed study.

Chapter 2 of this thesis covers a review of recent studies on the polymer, waste plastic, crumb rubber modified bitumen conducted home and abroad. It includes a detailed description of the polymer, waste plastic, crumb rubber including its type, sources, blending, mixing process as well as mechanics of polymer modified binder the polymer, waste plastic, crumb rubber modified bitumen. The benefits and drawbacks of modification of bitumen as well as brief history and application of the polymer, waste plastic, crumb rubber modified bitumen are also highlighted in this chapter. Finally, a summary of the whole literature review is added at the end of the chapter.

Chapter 3 Materials and methods of investigation employed in this research and also the description of the tests, blending technique, and the properties of raw materials to perform those tests in the study.

Chapter 4 enumerates the analysis of test results on binders and mixes. It also includes the finding on the evaluation of the polymer, waste plastic, crumb rubber as compared to that of traditional binder and mixes regarding rheological properties as well as field performances. The conclusions of the whole study and some recommendations for future research are presented in Chapter 5.

Chapter-2

Literature review

2.1 General

The main objective of this chapter is to review the available literature on rubberized bitumen. It also deals with past researches that are related to crumb rubber, waste plastic, and polymer. A polymer is a large macromolecule of high to the very high molecular weight which consists of many repeating units called monomers which are covalent bonds to one another. In many cases, monomers are linked together in a row, like links in a chain, however, branching and cross-linking between chains do occur.

Another side plastic waste and micro plastics in the oceans. These plastic particles or micro-plastics result largely from the presence of plastic debris in the marine environment and in turn, are directly related to the quantities of solid waste entering the oceans from land-and sea-based sources.

Bitumen is a by-product of the fractional distillation of crude oil but is also found in a natural deposit. It has a unique combination of excellent waterproofing and adhesive properties which have been used effectively for more than 5000 years. Bitumen is a low-cost thermoplastic material that is widely used in roofing, road, and pavement applications. However, it is brittle in called environments and softens readily warm environments. In this chapter, an introduction to bitumen structure and properties, and a short review of the published literature on PMB is provided. Finally, an outline of the focus and content of each chapter in the book is described.

2.2 Background

The first use of bitumen in the new world was by indigenous peoples. On the west coast, as early as the 13th century the Tongva, Luiseno, and Chumash peoples collected the naturally occurring bitumen that seeped to the surface above underlying petroleum deposits. All 3 groups used the substances.

When bitumen is will brittle in cold environments and soft in a hot environment it is the first problem. In addition, when hard traffic and high loading weight will give the effect for pavement material such as cracking, fatigue cracking, and the rutting at high temperature, causing its quality and performance in the pavement of roads to decrease. This will make the roadway need maintenance year by year. The properties of bitumen-aggregate mixed such as stiffness, stability, durability, fatigue, resistance, fracture, characteristics, skid Resistance, permeability, and workability majority depends on the content of bitumen. The performance of unmodified bitumen only in the pavement is not fully efficient because bitumen has a limitation and it needs additives. That caused a range of rheological and durability properties of the bitumen is not boundless for resistance on distresses caused by the increased traffic and total loading on the current highway.

In pavement can be seen in different types of defects on the impact of heavy transport. Defects in flexible pavements can be placed into one of five classes. These classes are cracking, distortion, disintegration, slippery surfaces, and surface treatment problems. For the cracking, it has alligator cracking, edge cracks, edge joint cracks, reflection cracks, and lane joint cracks. Reflection cracks normally occur in asphalt overlays. These cracks reflect the pattern of the cracks in the pavement structure underneath. There are most frequently found in bituminous overlays over Portland concrete and cement-treated bases. In the pavements beneath the overlays, reflection cracks are normally caused by vertical or horizontal movements, resulting from traffic loads, temperature and

earth movements. Therefore, bitumen replacement or modifications need to be carried out to ensure that bitumen is strong enough yet economical to be used as road pavements.

2.2.1 Rubberized Bitumen as a Slurry Materials

"Recognizing that fatigue cracking generally occurred in larger areas that small patches couldn't handle, the concept was extended to full pavement sections by spreading the rubberized bitumen with slurry seal equipment, Aggregate application with standard chip spreaders [MCD81]. This process had two distinct construction problems. First, in order to achieve the desired reaction of the bitumen and crumb rubber in the limited time available in the slurry equipment, it was necessary to employ bitumen temperatures of 450°F (232 °C) and higher. Second, the thickness of the membrane varied directly with the irregularity of the pavement surface. This resulted in excessive materials in areas such as wheel ruts and insufficient membrane thickness quick" [7].

2.2.2 Rubberized Bitumen as a Chip Seal Application

In 1971, technology had developed to the point that standard bitumen distributor Lorries were employed to apply a uniform thickness of binder to the pavement, in the figure. Although problems with distribution and segregation of MacDonald were encountered on the early projects, these were recognized as primarily equipment limitations. Within the next few years equipment was developed with pumping, metering, and agitation capabilities needed to handle the highly viscous rubberized bitumen materials. Following the development of suitable equipment to spray apply rubberized bitumen Charles MacDonald and his colleagues were granted a patent in 1975 in the development of this material. "This patented process is described as the "MacDonald Process or Wet Process for making Asphalt Rubber (AR)" [note: "rubberized bitumen" and "AR" are used interchangeably. It should be noted that AR patents ended in 1992. In the chip seal or slurry

applications, rubberized bitumen needs to be maintained at between 191°C and 218 °C (375 °F and 425 °F) to ensure a viscosity thin enough for spraying. An ambient and surface temperature of at least 18 °C (65 °F) is recommended so the applied material does not set too quickly" [8].

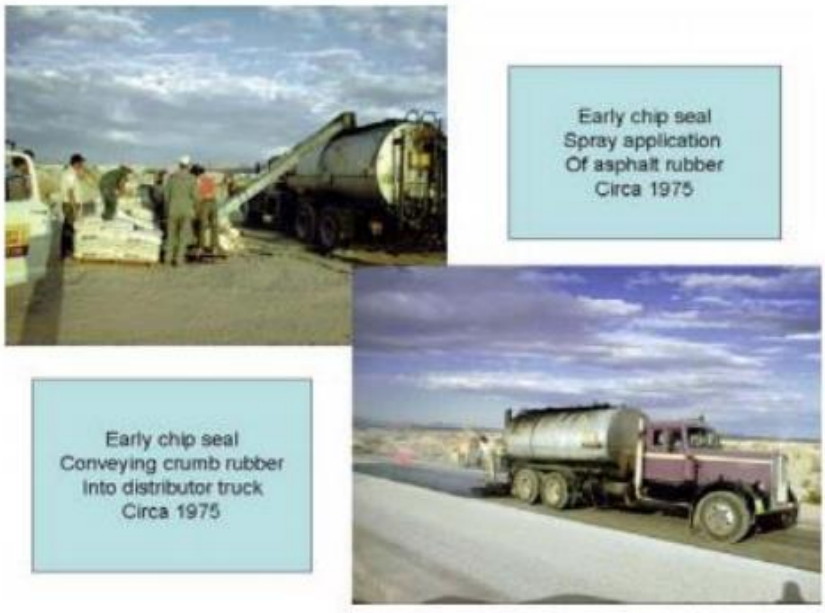

Figure 2.1: Crumb rubber chip seal (source: George Way, 2006)

2.2.3 Crumb Rubber

Crumb rubber is a recycled rubber product for automotive and truck scrap tires. During the recycling process tires and steel are cord removed, leaving tire rubber with a granular consistency. The first synthetic grass was placed over concrete in 1964 and became known as "chem grass" a new artificial turf Bitumen developed in early 2000 based on "crumb rubber". The black crumbs are small pieces of styrene-butadiene rubber made grinding up old vehicle tires.

2.2.4 European Use of Crumb Rubber in Pavements

“Since about 2003 Portugal and Spain both have acquired modern crumb rubber blending equipment and are placing AR mixes very similar to those used in the United States. These mixes are performing in a manner consistent with the experience in the United States” [9]. Germany has also experimented with rubber same blending equipment with their own brand of CRMB mixes, however, performance information about them is not presently available. In addition, Germany also has been placing dry process crumb rubber mixes. Its plays graded dry process hot mixes as an aggregate that typically use larger size crumb rubber as an aggregate. The dry process mixes can be mixed with hot bitumen with or without special modifiers that aid in binding the waste to the bitumen. In France, Proprietary crumb rubber mixes have been developed to reduce noise. Varying amounts of crumb rubber are used in preparing these mixes and in some cases the rubber content is less than 15 percent and the blending reaction process may not be utilized. These mixes all contribute to some degree to recycling waste tires, however, the performance of all these various crumb rubber mixes that are not rubberized bitumen is not as well documented and thus at this time cannot be fully evaluated.

“The UK Highways Agency does not permit the use of the Dry Process in the United Kingdom” [10].

2.3 Polymer

Polymer modified bitumen is an important material for constructing and maintaining pavements. A very large molecule made by chemically reacting many smaller molecules to one another in long-chain or clusters is referred to by the term “polymer". The properties of the modified bitumen

depend on the polymer system Peterson, 1998. The polymer will recover its original shape from deformation after the removal of stress. All types of polymer available in the market cannot be used for modification of binder, in nature, some polymers are thermoplastic where as some are elastomeric. At low temperature, it is less stiff and its ductility and Frass breaking points are improved.

2.3.1 Types of Polymer

Polymer is a chemical compound. Polymer manufactured artificially in chemical industry to use in various purposes. It's classified according to their origin structure chain.

A. Thermoplastic polymer.
B. Elastomer (rubberized).
C. Thermo- harden polymer.

2.3.2 Classification of Polymer

a) Based on structure

1. Linear.
2. Nonlinear.

b) Based on density.

1. Low density polymer.
2. High density polymer.

c) Based in physical form.

1. Pellet.

2. Powder.

2.4 Polymer modified bitumen

Polymer modified bitumen is bitumen combined with one or more polymer materials. It typically used for road pavements, particularly those that are intended to withstand heavy-duty traffic and the highest weather deformation. “PMB is typically made by combining bitumen with a styrene-butadiene-styrene (SBS) copolymer. The addition of the polymer makes the bitumen more elastomeric in nature. Some of the desirable properties of polymer modified bitumen include improved strength, cohesiveness, and resistance to fatigue and deformation” [11]. PMB also processes less temperature sensitivity than plain bitumen. The material will not flow soft or high temperature for pavement applications while it maintains workability and flexibility in colder temperatures.

2.5 Waste plastic

Waste plastics are directly related to the quantities of solid waste entering the oceans from land and sea- based sources. There are different waste plastics in our market place.

2.5.1 Types of Waste Plastic/ Polymer

For quick reference, here's a quick look at the different codes.

A. Polyethylene Terephthalate (PETE or PET)
B. High density polythene (HDPE)
C. Polyvinylidene Chloride (P or PVC)
D. Low- density polythene (LDPE)

E. Polypropylene (PP)

F. Polystyrene (PS)

G. Miscellaneous plastics.

2.6 Engineering properties

Some of engineering properties that are of particular interest when CRM is used in granular base application include granular, bearing strength, compacted density, moisture content, permeability and Durability.

2.6.1 Dimension

The dimension for milled CRM is governed by the spacing of the teeth and speed of the pulverizing unit. Wider tooth spacing and the higher speed results in larger particle sizes and coarser gradation. Crumb rubber modified can be readily processed to satisfy requirements for granular base and sub-base specifications, such as AASHTO.

2.6.2 Compacted density

Due to coating of asphalt cement of RAP aggregate, which inhibits compaction, the compacted density of blended granular materials tends to decrease with increasing CRM content.

2.6.3 Permeability

The permeability of blended granular material containing CRM is similar to conventional granular base course material.

2.6.4 Ductility

The ductility is a distinct strength of bitumen, it to undergo notable deformation for elongation. The ductility is defined as the distance in centimeter, to which a standard sample or briquette of the material will be elongated without breaking. The finer rubber particles resulted in higher ductility elongation and also, that toughness would increase as rubber content increases (Mashaan et al., 2011). A combined effect of both time and temperature was noted with minimum elastic recovery value improved at the maximum time and maximum recovery value of two hours and 240 Celsius, respectively (Jnesen et al., 2006). However, the modified binder was susceptible to decomposition and oxygen absorption. There were problems of low compatibility, because of the high molecular weight but the recycled tire will decrease reflective cracking, which in turn increases durability.

2.7 Benefits of Three Particles

2.7.1 Crumb rubber

One of the major advantages of using CRM in road pavements is that it can improve bitumen resistance to surface-initiated cracks, the reduction of fatigue/ reflection cracking, the reduction of temperature susceptibility, improved durability as well as the reduction in road pavement maintenance costs.

Adding the crumb rubber provides a number of environmental, strength, and economic benefits by reducing:

a) Demand for aggregates;

b) Demand bituminous binders;

2.7.2 Waste plastic

The process of recycling plastic helps waste management by saving available space in landfills. Plastics disposed of in the trash take up a lot of space and increase the amount of solid waste. Recycling a ton of plastic can save 7.4 cubic yards of landfill space helping to reduce land and water pollution.

2.7.3 Polymer

In bearing and wear applications, polymers provide extensive advantages over metals by allowing for lower power motors for moving parts due to lower frictional properties of polymer wear components compared to metals. The low frictional properties provide for less wear as well.

2.8 Construction process of Crumb rubber

"As the rapidly growing number of vehicles in Indonesia, the waste of tire rubber becomes a major environmental concern. The use of crumb rubber, which is the recycled tire rubber, as an additive in hot mix asphalt mixture is considered as a sustainable construction method. The purpose of this study was to investigate the effect of adding crumb rubber to asphalt mixture using a wet process. The laboratory hot mix asphalt design tests were

The laboratory hot mix asphalt design tests were done by the Marshall Method procedure. In this study, two different crumb rubber contents (1% and 2% by weight of asphalt mixture) and two different crumb rubber sizes (#40 and #80) were investigated. A comparative study was done among the unmodified and modified asphalt concrete mixtures considering the Marshall Stability value and the volumetric properties. The results showed that crumb rubber is recommended as an additive in asphalt mixture, as all the test results are within the standard requirements. The addition

of crumb rubber tended to increase the strength and quality of the asphalt mixture. However, it should be more concerned about the durability of asphalt mixture because of the lower asphalt content in crumb rubber modified asphalt the addition of crumb rubber tended to increase the strength and quality of asphalt mixture. However, it should be more concerned about the durability of asphalt mixture because of the lower asphalt content in crumb rubber modified asphalt mixture. As an additive in asphalt mixture, as all the test results are within the standard requirements. The addition of crumb rubber tended to increase the strength and quality of the asphalt mixture. However, it should be more concerned about the durability of asphalt mixture because of the lower asphalt content in crumb rubber modified asphalt mixture" [12].

2.9 Necessity Crumb Rubber

When Crumb rubber dealing with asphalt overlays, reflection cracks can arise and cause an unwanted crack pattern beneath the pavement. Rubber-modified asphalt uses stress absorbing membranes that reduce the reflective cracking because of its elastic properties. With fewer cracks, there are fewer repairs, so crumb rubber assists in reducing maintenance costs. The pavement has an increased lifespan because, after multiple uses and exposure to different elements, regular asphalt loses elasticity over time. The use of artificial rubber resists the formation of cracks and has an anti-aging effect that keeps the asphalt in a better condition.

2.9.1 Reduced demand for aggregates

Aggregate resources are becoming more and scarcer, especially in urban areas where the most heavily trafficked pavements are located. It takes so expensively when want to make maintenance or repair the defect of the road. Therefore, when using the crumb rubber, it will reduce the cost for

maintenance and it will re-use significant benefits.

2.9.2 Reduced demand for bituminous binder

The quantity of additional bitumen asphalts is needed to produce road highway material is reduced because the CRM already contains some bitumen. This provides benefits in terms of reduced cost and lowers energy demands with respect to both the production and distribution binders.

2.9.3 Reduced waste

Pavement application means that fewer waste materials are going to landfills when using CRM. This saves valuable space in landfills. This is an important factor considering the cost of establishing environmental compliance for new landfill variations. Now, every year quantity of the waste tires is increasing and it will be giving an effect or impact on the environment. The waste tires very difficult to dispose of because if use the wrong method to dispose it will give the effect. Therefore, when using this method to save the environment, it also gives the benefits of economy and quality structure road pavement.

2.10 Summary

In this chapter, can see rubberized bitumen about the year start on1960 with the simple goal of developing a maintenance patching material to hold old crack pavements long enough to allow for the future overlaying or reconstruction 9f the pavement. 50 years intervening its use has grown and expanded into a myriad of areas and in this time in America, Africa, Europe, and Asia have routine paving material. Adding crumb rubber useful products to pavements will continue to be developed because that pavements are last longer and always demand needs less maintenance.

Chapter-3

Materials and Properties

3.1 General

The characteristics of materials are the principal part of this research to decide the qualities of the bitumen change. It is used for the treatment of bitumen, with a certain degree of Penetration, and is combined with the shredded plastic, crumb rubber, and polymer to change. These include penetration tests, Ductility tests, Flash and Fire Point tests basic tests of gravity. The next step is the Marshall test to determine Bituminous paving mixes using pure and residue plastically modified bitumen. The key thing in this chapter is to determine the Properties of bitumen with crumb rubber, plastic waste, and polymer. How is this method and the bituminous? Blends are the most efficient and environmentally friendly? We'll explain this as well. Compact mixes not only depend on their efficiency but on the mechanical and physical characteristics of the ingredients.

3.2 Material Properties

Material used in this study

1. Aggregate
2. Bitumen
3. Crumb Rubber
4. Waste Plastic
5. Polymer

3.2.1 Aggregate

"The main component of pavement construction is aggregated and bears the greatest part of the traffic load. The quality and physical characteristics of the Unit must be checked to ensure that flooring" [13].

The aggregate should then have the following features:

1) In order to endure the aggregate being used in construction work stresses caused by the load on the wheel and possess adequate strength to Crash.

2) The surface coarse aggregate should be hard enough to withstand wear because of Traffic load abrasive action. 24

1) In contrast, the mixture in the flooring should be durable and decimation because of The weather action.

2) In bituminous pavement this same aggregate used should have reduced affinity to water to withstand the Problem with depriving.

3) The capacity of the water besides absorption should be under the target level. Aggregate found two types:

- Fine Aggregate (FA)
- Coarse Aggregate (CA)

3.2.1.1 Fine Aggregate

Fine aggregates are harmless chemically inactive materials, most of which move through a sieve of 4.75mm and contain no more than 5% of the coarser content.

Fig 3.1: Fine Aggregate

3.2.1.2 Coarse Aggregate

The inert substance, primarily kept on a 4.75mm strain and having no more than 0- 10% fine material, is known as a rough aggregate.

Fig3.2: Coarse Aggregate

3.2.2 Bitumen

“Bitumen is made from crude oil obtained from marine species and Put on the ocean bed vegetables. The matter accumulates over a million years and is compressed in the lower layer due to the massive weight of the upper layers. Combined with the heat of the surface of the earth, the matter creates crude oil that forms huge underground pools trapped by impermeable soil. Often the crude oil can Rose to the ground surface via the defects of the layers above. Boring now produces the bulk of crude oil from the underground. There are many crude oil suppliers, but only a handful of them have the required bitumen raw material. Bitumen shall be described as a viscous liquid or solid, mainly composed of hydrocarbons and derivatives, which is soluble in it is substantially non-volatile and softens when heated steadily. It is derived from a crude oil refining process and is found” [14].

3.2.2.1 Structure of Bitumen

“Bitumen has a predominantly physical property dependent on the chemical composition of the current molecular organisms. Bitumen is a complex chemical blend of primary hydrocarbons, consisting of a small volume of heterocyclic structurally related and support roles of Sulphur, nitrogen and oxygen” [15]. The itemized list of hydrocarbon chains into bitumen is difficult to determine since bitumen has been derived from crude oil and has a complex composition due to its sources. However, simple analyzes of bitumen derived from a variety of crude sources suggest that other bitumen includes:

a. Carbon: 82-88%
b. Hydrogen: 8-11%
c. Sulphur: 0-6%

d. Oxygen: 0-1.5%

e. Nitrogen: 0-1%

The chemical form of bitumen depends on the raw source. While the energy content is extremely complex, bitumen can be classified into four major elemental composition.

3.2.2.2 Alternative Property Material

In order to measure the strength and accuracy of processed bitumen, there are many traditional physical property checks. These tests are standardized in many ASTM and European standards requirements. Both these processes, though, are almost similar to insignificant variations Consistency tests are one of the key types of standard tests which define the degree of bitumen.

3.2.2.3 Analysis of Infiltration

This testing process is an analytical means of assessing bitumen quality. ASTM D5-86 defines the process of research (AASHTO T49-93). Penetrations are measured using Method D5-86. when a typical 100g weighing needle penetrates 5 seconds into a bitumen sample. In the case of a hot-mixture pavement (HMA), penetration is usually estimated at 25°C, which is approximate.

3.2.2.4 Importance of even the exam

As a standard of accuracy, the infiltration test. Low replacement values indicate smoother reliability, although stable interest model templates tighter reliability.

1. This research method tests the tensile characteristics of bituminous materials and can be used for ductility calculation for specification specifications.
2. The bituminous materials used in pavement architecture should be adequately ductile if the paving is not cracked due to pressures of weather or traffic or the surface will be weakened

by the framework of the pavement.

3. The value of ductility ranges between 5 and 100 cm.
4. Roads grow through the day and at night. Therefore, it will happen if the bitumen is not properly ductile.

3.2.2.5 Countess

Compressive strength is the feature of bitumen that allows it to be deformed or elongated greatly. The ductility is measured as the area in cm to be used to expand without split a regular sample of briquette of the substance. A ductility measure for the volume of bitumen is done. Extends below the melting points at temperature. The ASTM D113- 79 test is performed (AASHTO T51-93).

Tar sands oil Flexural Indicated

Source of paving bitumen and penetration grade	Min ductility value (CMS)
Assam Petroleum A25	5
A35	10
A45	12
A65, A90, and A200	15
Bitumen from sources other than Assam Petroleum S35	50
S45, S65 and S90	75

Table3.1: Flexural qualities advocated.

3.2.3 Crumb Rubber

A pen consists of three primary materials: compound, silk, and dye elastomeric (rubber). The tread, sidewalls, apexes, filler, and shoulder wing form the structural structure of the tire with the leather, forming the 'flesh.' The skeleton of the tire consists of steel or tissue beads, which are the "backbone," depending on the application of the tire (Figure 3.3). The Perlis are designed to have low expansion and to improve the rubber pneumatic framework. The tire has a set of bead-to-bead support cords or belts around the tire that are formed of nylon cloth or steel, although the two styles are used in greater general. The rubber strips cover the belts, which have the pull area on the pavement. The goal of the skeleton is to stabilize the tire to perform properly against the deformation.

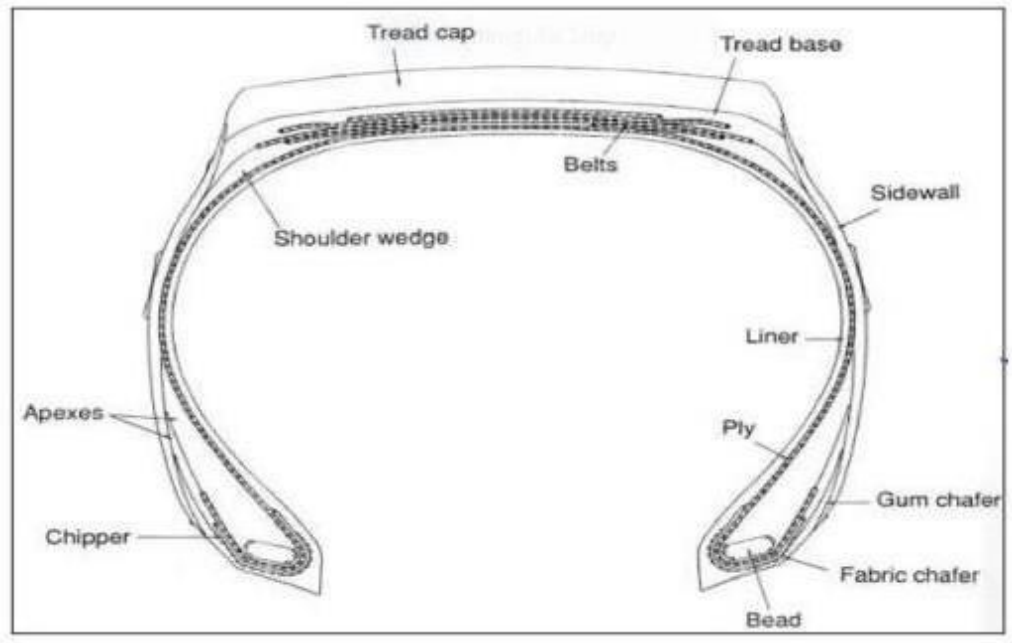

Fig3.3: Typical Hydraulic Cylinder cross-section schematic chart

3.2.4 Waste plastic

Two essential types of polymers can be categorized according to their response to heat: thermoplastic hardness and thermoplastic hardness. It is difficult to remold the product of thermo-harden polymer. Thus 28 this polymer is not appropriate for use as a bitumen modifier. Recyclable are thermoplastic polymers. Recyclable polymers to be used as a modifier. In fact, if it is compliant with bitumen, any thermoplastic polymer can be used as a bitumen altered. The consistency test is conducted with waste (polytheism waste, PET bottle, etc.) in this analysis and eventually with waste (LDPE) polytheism waste (LDPE) in order to establish the required PMB mixture for this study. Laboratory tests taking into account the higher cost of PET waste bottles. Pet bottles are used to achieve a clear result in a shredded and powdered manner. The type shredded is 1⁄4"x 1⁄4" or smaller. The mechanical shredding unit is used for shredding. Definition of the waste bin. There are four major components for the waste plastic shredder, the feeding unit, the shredder, the control unit, and the system frame the feeding machine has a galvanized 16-gage, mild steel sheet, and is 2 mm thick with a scale of 200mm to 550mm. This is used to feed the waste material into the shredder. The shredding machine consists of the breaking of the plastics into smaller dimensions. The machine has a shaft with a circumference of 50mm, consisting of a mild stainless-steel rod with a cylinder length of 55mm and a diameter of 200mm. Cutters made of 12mm mild steel with nine tightening tines, which are 2 mm apart, are connected to the shaft. The cylinders also have rough edges on the same cutters to shred the waste. The outlet is constructed from 43mm/27mm galvanized mild steel 16-gauge shredding. Beneath the scraping unit. The plastic waste wastes are readily released from the shredder thru the stream.

3.2.5 Polymer

At least 40 years ago, in California, USA, and the use of polymer with bitumen began. On the road surfaces, crumb rubber was then used to make it less temperature dependent and more suited to weathering. In this area of highway material, researchers are led to improve the efficiency of rubberized roads. Unique polymers were later invented for use by several pharmaceutical industries as bitumen modifiers. POL YBIL T and SBS Shell and Exxon chemicals are respectively sold for polymers. These two polymers are commonly used for the alteration of bitumen.

Chapter-4

Comparison Results and Data Analysis

4.1Introduction

The main topic of this chapter is to discuss the review work performed in the current investigation and their findings. Several tests were performed on waste plastic modified bitumen, crumb rubber modified bitumen, and polymer modified bitumen to determine specific targets. Review our comparisons like penetration test, flexibility test, softening point test, and specific gravity test. Each test data sheet and sample count will also be displayed in detail.

4.2 Binder Test Comparison Result

4.2.1 General

The review tests result that were performed on the binders are very conventional. The results of these tests on binders and conventional tests from temperature sensitivity, consistency, adhesive quality, etc. have been evaluated.

4.2.2 Penetration Test Result Review

The penetration is usually used to measure the continuity of semisolid and hard bituminous components. The penetration test is a very important test for monitoring the consistency of bituminous elements and classifying them in terms of consistency. Several series of bitumen grades are seen but the most commonly used in Bangladesh are 60/70 grade and 80/100 grade in

particular. Since grade does not imply quality, the penetration test binder has no relation to quality. Penetration test has done with varying percentage of Waste Plastic, Crumb Rubber and Polymer with bitumen and also unmodified bitumen.

"The results are shown in the table and a plot of Penetration value vs. %Waste Plastic content is shown in Table 4.1" [15].

Test Method	Waste plastic Content (%)	Penetration (0.1 mm)
AASHTO T49-93 ASTM D5-86	00	63
	2.5	56
	5	39
	7.5	23
	10	19

Table: 4.1 Penetration Test Results for different plastic contents

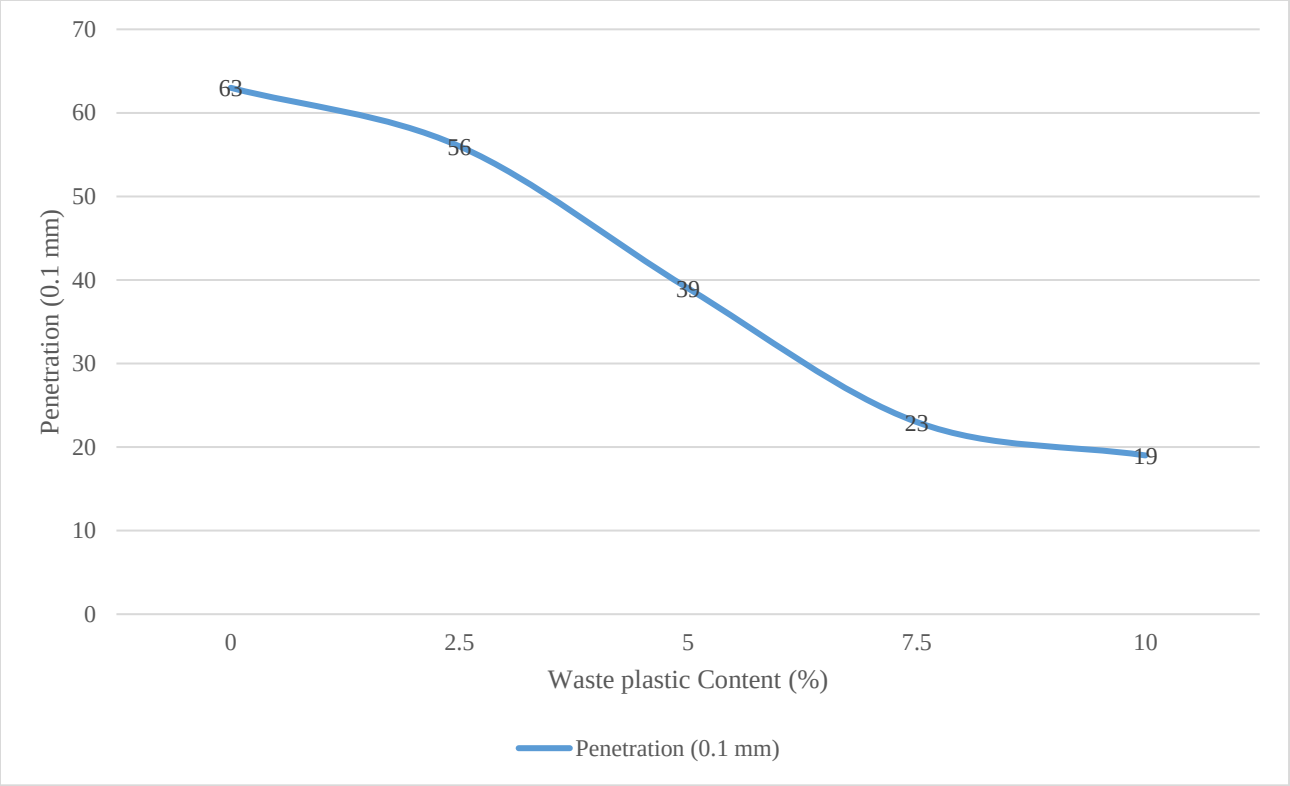

Figure 4.1: Penetration Point (0.1 mm) vs. Waste plastic %

The results of penetration test on unmodified bitumen and Waste plastic -modified bitumen are shown in Table4.1. A plot of penetration versus Waste plastic content is shown in the Figure 4.1. Penetration test was performed at 25°C. From the Figure 4.1, it can be said that the value of penetration decreases almost uniformly from a value of 63 in case of pure bitumen to 19 in case of the binder containing 10 percentage of LDPE content. This mean that LDPE increases the consistency in a way stiffness of bitumen. Generally, we know that higher values of penetration are preferable for bitumen to use in tropical countries to prevent bleeding in pavement. On the other hand, in the field bitumen gradually hardens due to aging or oxidation process and penetration value decreases with time.

"The results are shown in the table and a plot of Penetration value vs. %LDPE content is shown in Table 4.2" [16].

Test Method	LDPE Content (%)	Penetration (0.1 mm)
AASHTO T 49-93 ASTM D5-86	00	87
	2.5	65
	5	55
	7.5	35
	10	24

Table: 4.2 Penetration Test Results for different LDPE contents

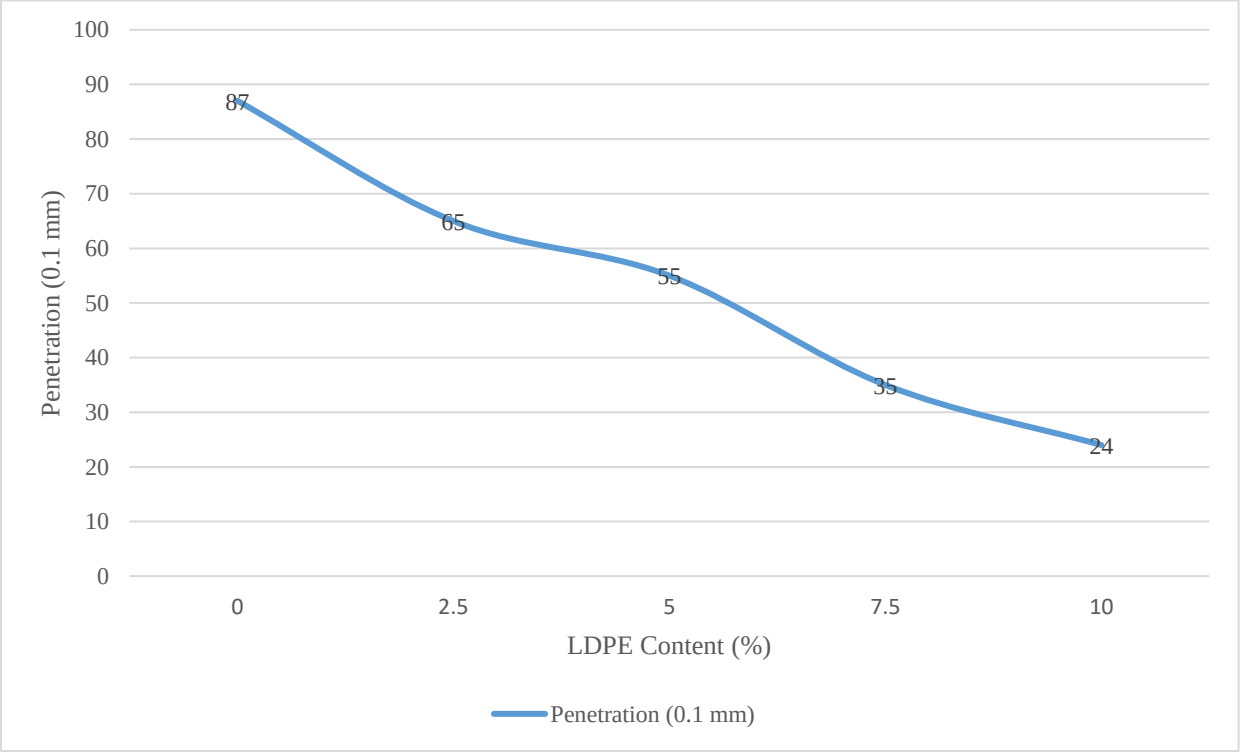

Figure 4.2: Penetration Point (0.1 mm) vs. %LDPE contents

The results of penetration test on unmodified bitumen and LDPE-modified bitumen are shown in Table 4.2. A plot of penetration versus LDPE content is shown in the Figure 4.2. Penetration test was performed at 25°C. From the Figure 4.2, it can be said that the value of penetration decreases almost uniformly from a value of 87 in case of pure bitumen to 24 in case of the binder containing 10 percentage of LDPE content. This mean that LDPE increases the consistency in a way stiffness of bitumen. Generally, we know that higher values of penetration are preferable for bitumen to use in tropical countries to prevent bleeding in pavement. On the other hand, in the field bitumen gradually hardens due to aging or oxidation process and penetration value decreases with time. Serious cracking may occur when penetration value falls below 20.

"The results are shown in the table and a plot of Penetration (0.1 mm) vs. crumb rubber Content (%) is shown in Table 4.3" [17].

Test Method	Crumb Rubber Content (%)	Penetration (0.1 mm)
ASTM D5-86 (AASHTO T49-93)	0	67
	2.5	66
	5	63
	7.5	62
	10	60

Table: 4.3 Penetration Test Results for different Crumb Rubber contents

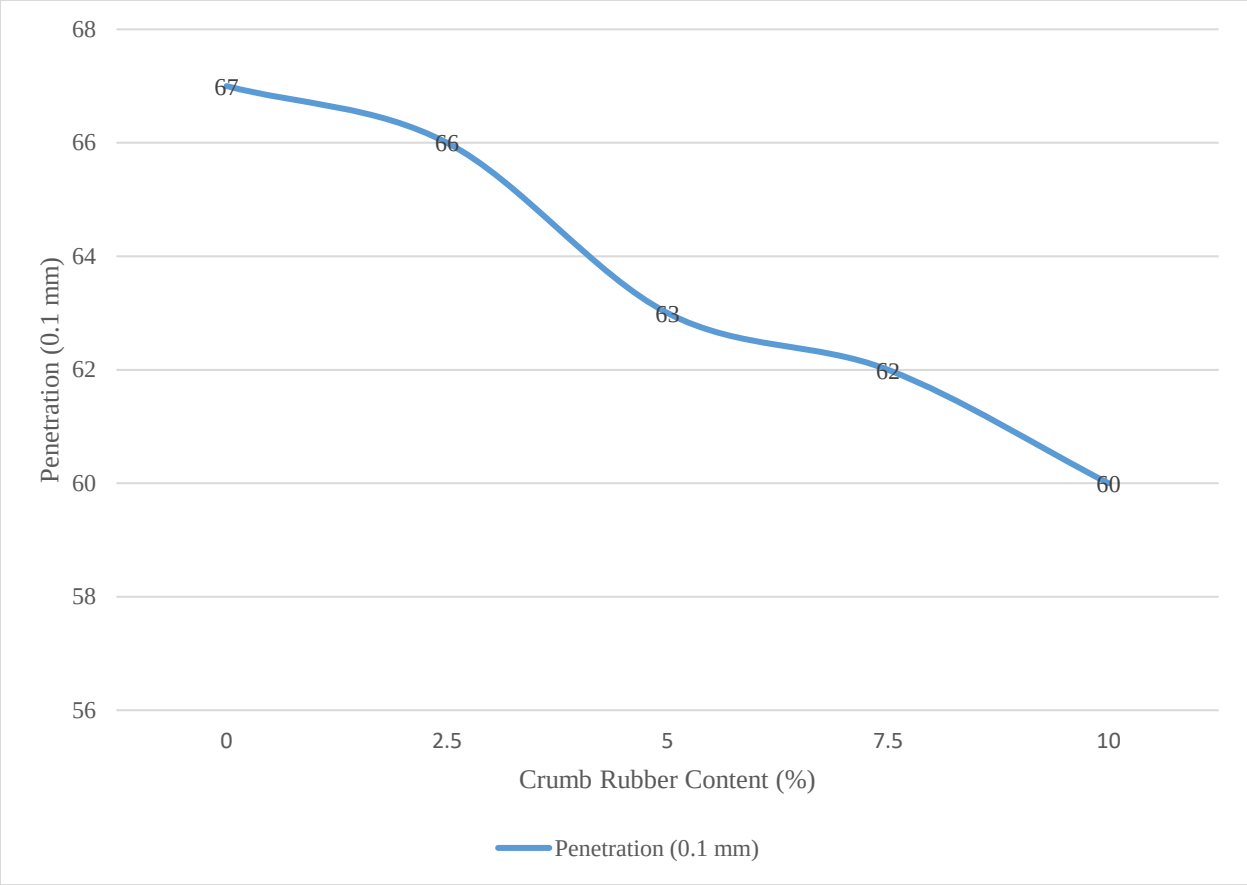

Figure 4.3: Penetration Point (0.1 mm) vs. %Crumb Rubber

The results of penetration test on unmodified bitumen and Crumb Rubber –modified bitumen is shown in Table4.1. A plot of penetration versus Crumb Rubber content is shown in the Figure 4.3. Penetration test was performed at 25°C. From the Figure 4.3, it can be said that the value of penetration decreases almost uniformly from a value of 67 in case of pure bitumen to 60 in case of the binder containing 10 percentage of LDPE content. This mean that LDPE increases the consistency in a way stiffness of bitumen. Generally, we know that higher values of penetration are preferable for bitumen to use in tropical countries to prevent bleeding in pavement. On the other hand, in the field bitumen gradually hardens due to aging or oxidation process and penetration value decreases with time.

The results are shown in the table and a plot of Penetration value vs. %Crumb Rubber, %Waste Plastic, and % LDPE content shown in Table 4.4.

Test Method	Content (%)	Penetration (0.1 mm) in Waste plastic	Penetration (0.1 mm) in LDPE	Penetration (0.1 mm) in Crumb Rubber
AASHTO T49-93 ASTM D5-86	00	63	87	67
	2.5	56	65	66
	5	39	55	63
	7.5	23	35	62
	10	19	24	60

Table 4.4 Penetration value vs. %Crumb Rubber, %Waste Plastic, and % LDPE content

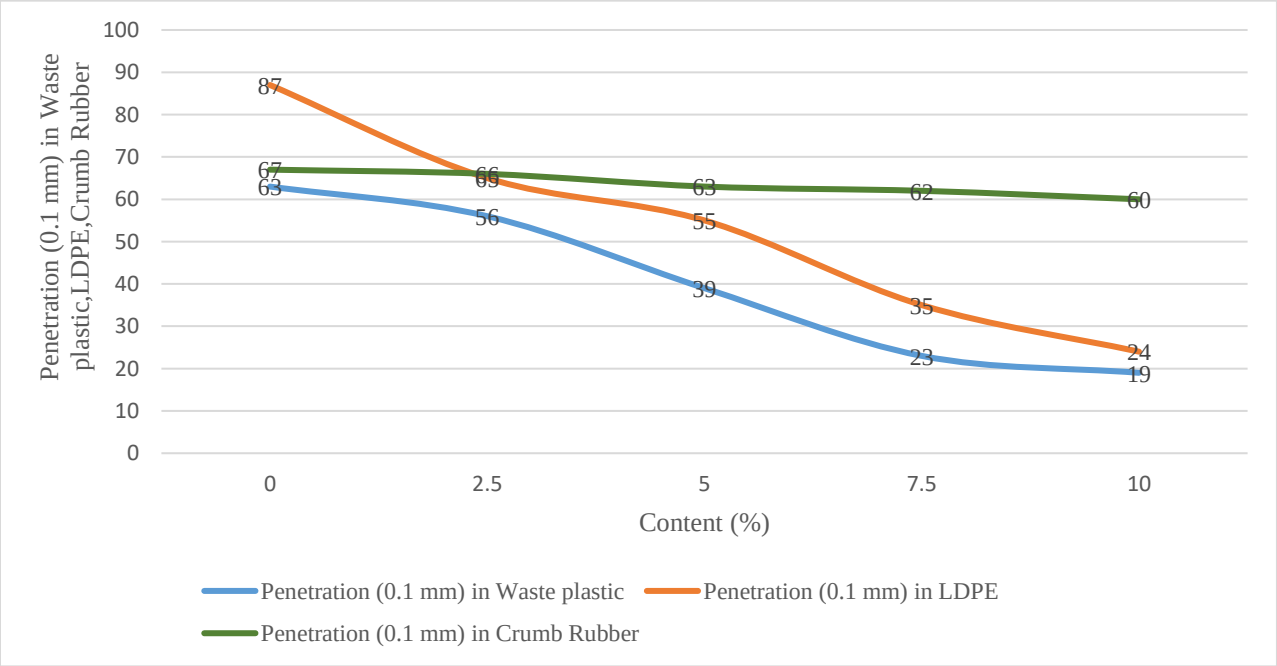

Figure 4.4: Penetration value vs. %Crumb Rubber, %Waste Plastic and % LDPE content

We know that higher values of penetration indicate softer continuity and lower values of penetration indicate more rigid continuity. In general, higher penetration rates are preferred in areas with lower atmospheric temperatures and lower grades, where atmospheric temperatures are higher and higher energy is required, because hard grade bitumen has more energy. High temperatures cause bleeding where bitumen accumulates on the sidewalk surface.

From the Figure (Figure 4.4), when content value is 0.0% then penetration value is 87 in LDPE and content value is 2.5%, 5.0%, 7.5% and 10% then penetration value is 66, 63, 62, and 60 in crumb rubber. Based on the performance of modified bitumen with crumb rubber, Waste Plastic and LDPE content and analysis of previous research work the optimum percentage of crumb rubber has been selected as 10%, the optimum percentage of plastic contents has been selected as 5% and the Penetration value percentage of polymer contents has been selected as 5% of weight of bitumen for the further investigation related to Marshall Mix Design.

From the Figure (Figure 4.4) at the optimum point of crumb rubber the Penetration value shows 55 whereas at the optimum point of Waste Plastic of the Penetration value is 47 and at the optimum point of LDPE the Penetration value is 70. We know that higher values of penetration indicate softer continuity and lower values of penetration indicate more rigid continuity. In general, higher penetration rates are preferred in areas with lower atmospheric temperatures and lower grades, where atmospheric temperatures are higher and higher energy is required, because hard grade bitumen has more energy. High temperatures cause bleeding where bitumen accumulates on the sidewalk surface. So, considering the Penetration result from this result review we can suggest crumb rubber modified bitumen forgiving additional strength to the road and reduces water damage. This improves the pavement performance.

4.2.3 Ductility Test Result Review

Ductility is generally defined as the property of a material that allows it to make great distortions (prolongations) without breaking. This is a distance of centimeters where any standard specimen can be elongated without breaking. The results indicate the cementing strength of the bituminous components. Bituminous materials used in the construction of bituminous pavements have sufficient flexibility otherwise the pavement may crack under temperature or traffic pressure and the pavement should not be wide and damage the pavement structure. Test data and results are provided below:

"The results are shown in the table and a plot of Ductility value vs. Waste plastic Content (%) is shown in Table 4.5" [18].

Test Method	Waste plastic Content (%)	Ductility (cm)
AASHTO T51-93 ASTM D113-79	00	100+
	2.5	52
	5	47
	7.5	23
	10	16

Table: 4.5 Ductility Test Results on different Plastic contents.

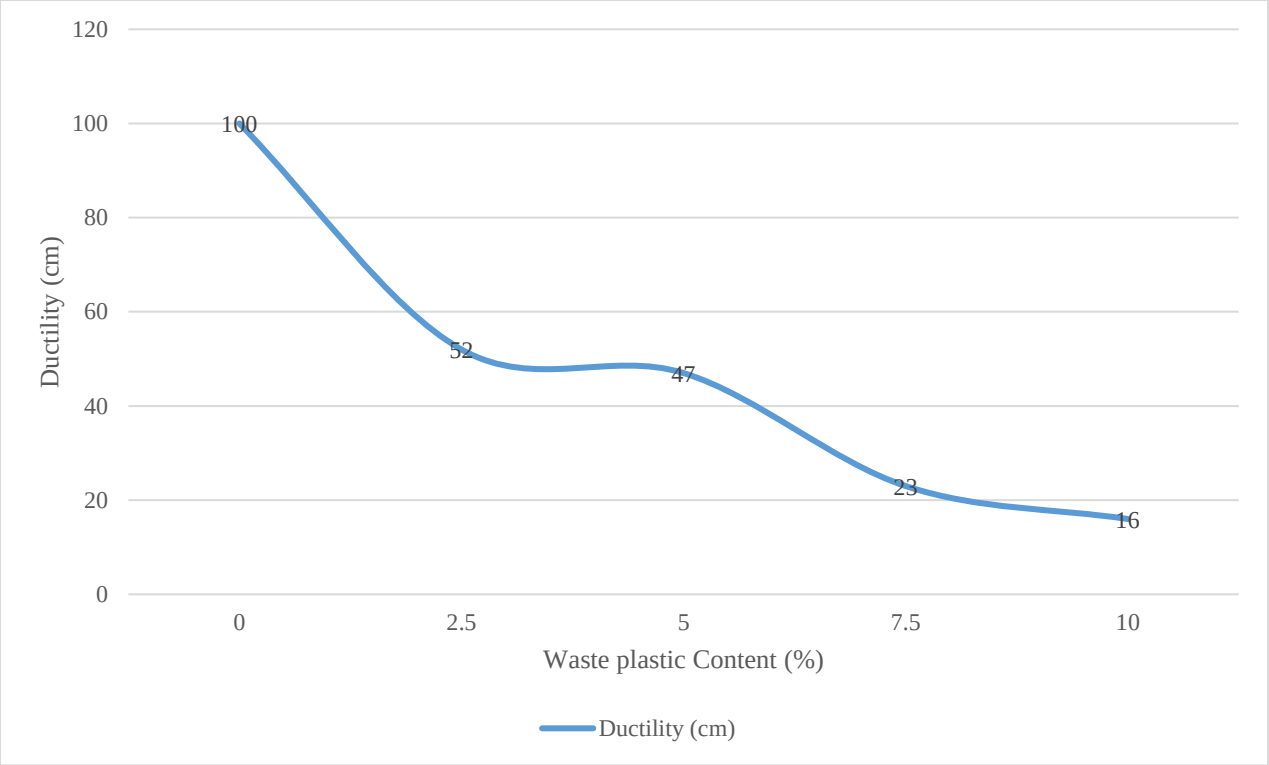

Figure 4.5: Waste plastic Content (%) vs. Ductility (cm)

"The results are shown in the table and a plot of Ductility value vs. LDPE Content (%) is shown in Table 4.6" [19].

Test Method	LDPE Content (%)	Ductility (cm)
AASHTO T51-93 ASTM D113-79	00	100+
	2.5	94
	5	70
	7.5	45
	10	19

Table: 4.6 Ductility Test Results on different LDPE contents.

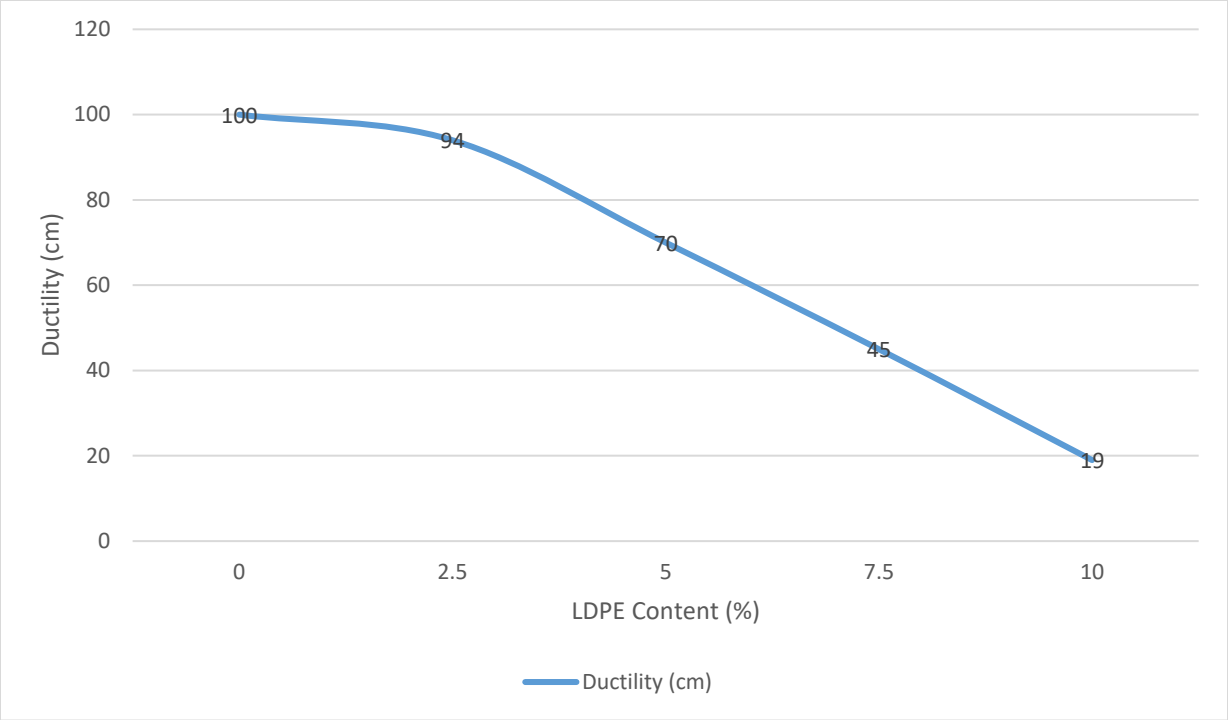

Figure 4.6: Ductility vs. LDPE contents %

"The results are shown in the table and a plot of Ductility value vs. crumb rubber Content (%) is shown in Table 4.7" [20].

Test Method	Crumb Rubber Content (%)	Ductility (cm)
ASTM D113-79 (AASHTO T51-93)	00	115
	2.5	89
	5	71
	7.5	64
	10	55

Table: 4.7 Ductility Test Results on different Crumb Rubber contents.

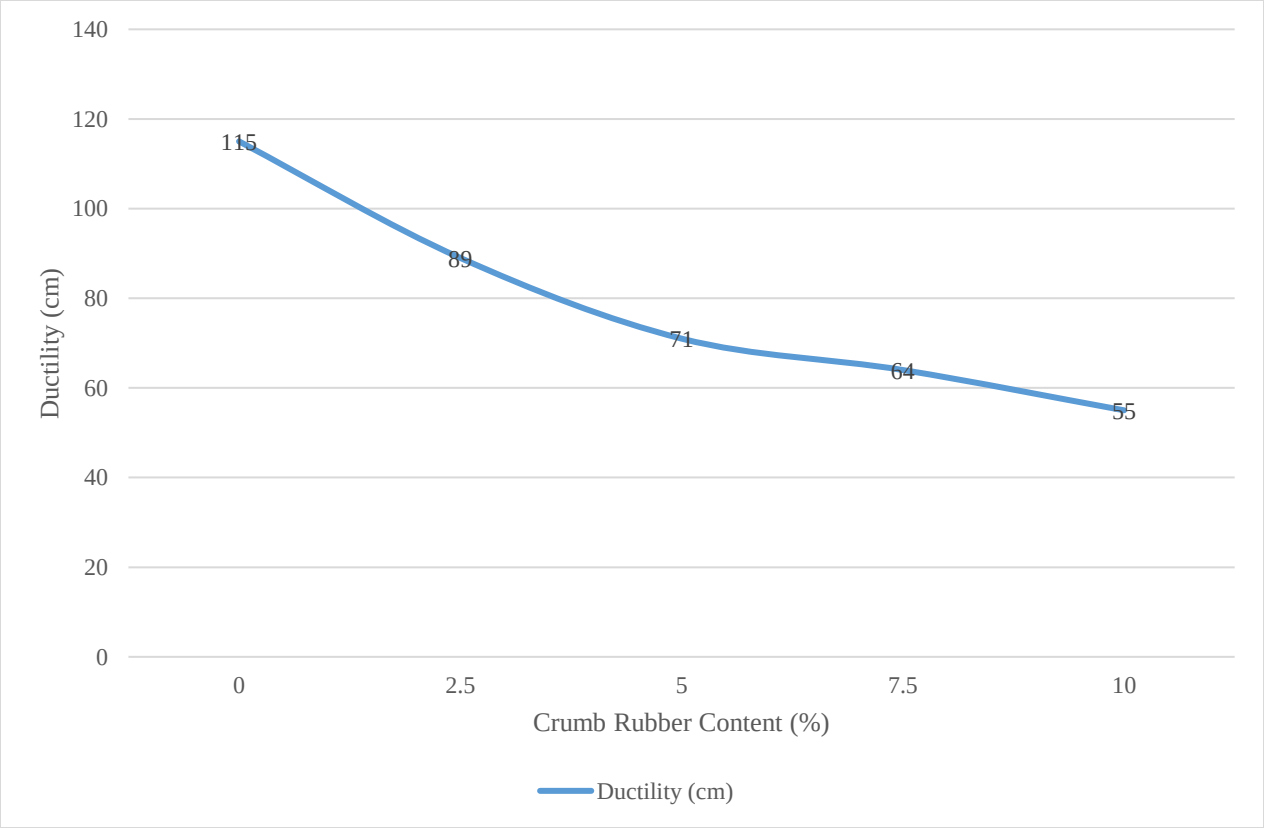

Figure 4.7: Ductility (cm) vs. Crumb Rubber contents %

The results are shown in the table and a plot of Ductility value vs. %Crumb Rubber, %Waste Plastic, and % LDPE content shown in Table 4.8.

Test Method	Content (%)	Ductility (0.1 mm) in Waste plastic	Ductility (0.1 mm) in LDPE	Ductility (0.1 mm) in Crumb Rubber
ASTM D113-79 (AASHTO T51-93)	00	100+	100+	115
	2.5	52	94	89
	5	47	70	71

	7.5	23	45	64
	10	16	19	55

Table 4.8 Ductility value vs. %Crumb Rubber, %Waste Plastic, and % LDPE content

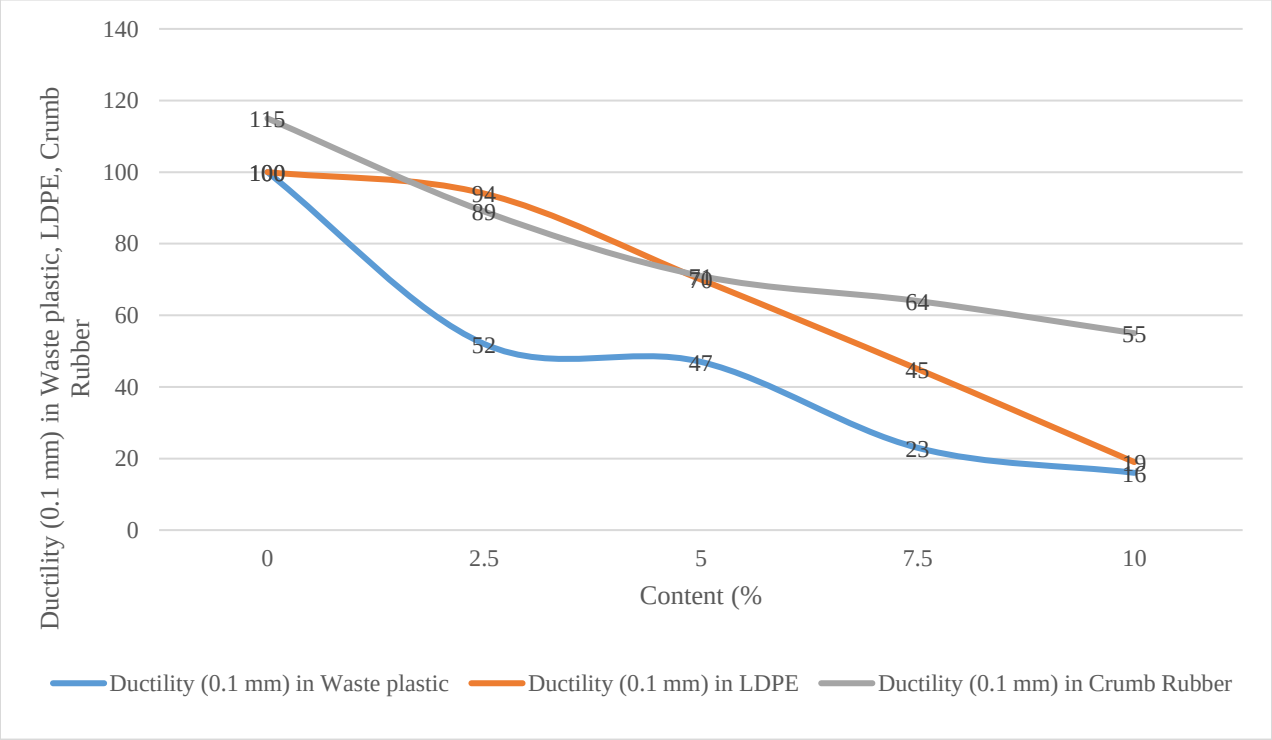

Figure 4.8 Ductility value vs. %Crumb Rubber, %Waste Plastic, and % LDPE content

4.2.4 Softening Point Test Result Review

Softening point indicates that temperature at which the semi-solid bituminous material changes into liquid form under the weight of standard steel ball. It is performed to know the temperature susceptibility of bitumen. It does not indicate the melting point. Because the softening of a bituminous material does not take place at any definite temperature, but rather involves a gradual change in consistence with increasing temperature.

Softening Point Test has done with varying percentage of Waste Plastic, Crumb Rubber and

Polymer with bitumen and also unmodified bitumen were done for normal bitumen and modified bitumen with 4%, 8%, 12% and 16% of content.

“The results are shown in the table and a plot of Waste plastic Content (%) vs. Softening Point Test is shown in Table 4.9” [21].

Test Method	Waste plastic Content (%)	Softening Point Test
AASHTO T47-8 ASTM D6-80	00	51
	2.5	52.5
	5	55
	7.5	58
	10	60

Table: 4.9 Softening Point Test Results on different Waste plastic Content (%)

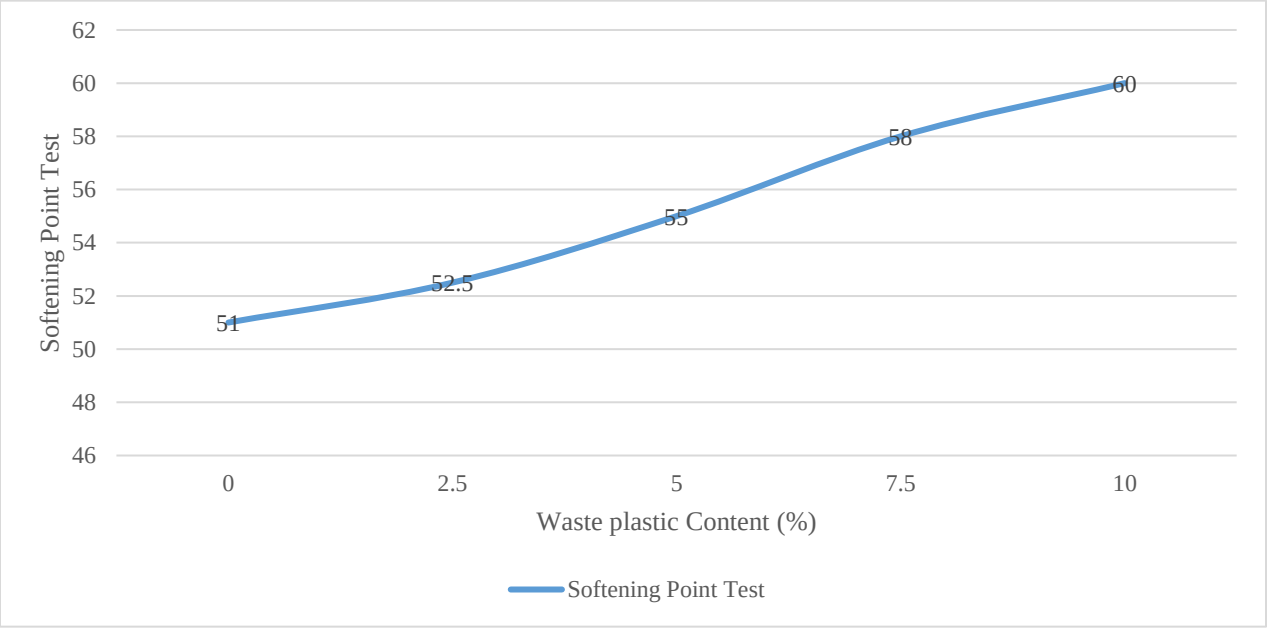

Figure: 4.9 Softening Point Test Results on different Waste plastic Content (%)

From the table and chart, it is clear that the softening point increased from 51 degree to 60 degree for mixing 0%-10% waste plastic content as the replacement of bitumen. This is because the plastic itself has higher softening temperature than bitumen and mixed product shows higher softening point than virgin bitumen.

This reduces the temperature susceptibility of bitumen where the atmospheric temperature is moderate to high near to the softening point of bituminous material. When atmospheric temperature is near to softening point of bitumen it causes several pavement failures, like rutting, bleeding, etc. So, using waste plastic modified bitumen will be a great solution.

"The results are shown in the table and a plot of LDPE content (%) vs. Softening Point Test is shown in Table 4.10" [22].

Test Method	LDPE content (%)	Softening Point Test
AASHTO T53-92 ASTM 036-89	00	45
	2.5	48
	5	54
	7.5	61
	10	68

Table: 4.10 Softening Point Test Results on different LDPE content (%)

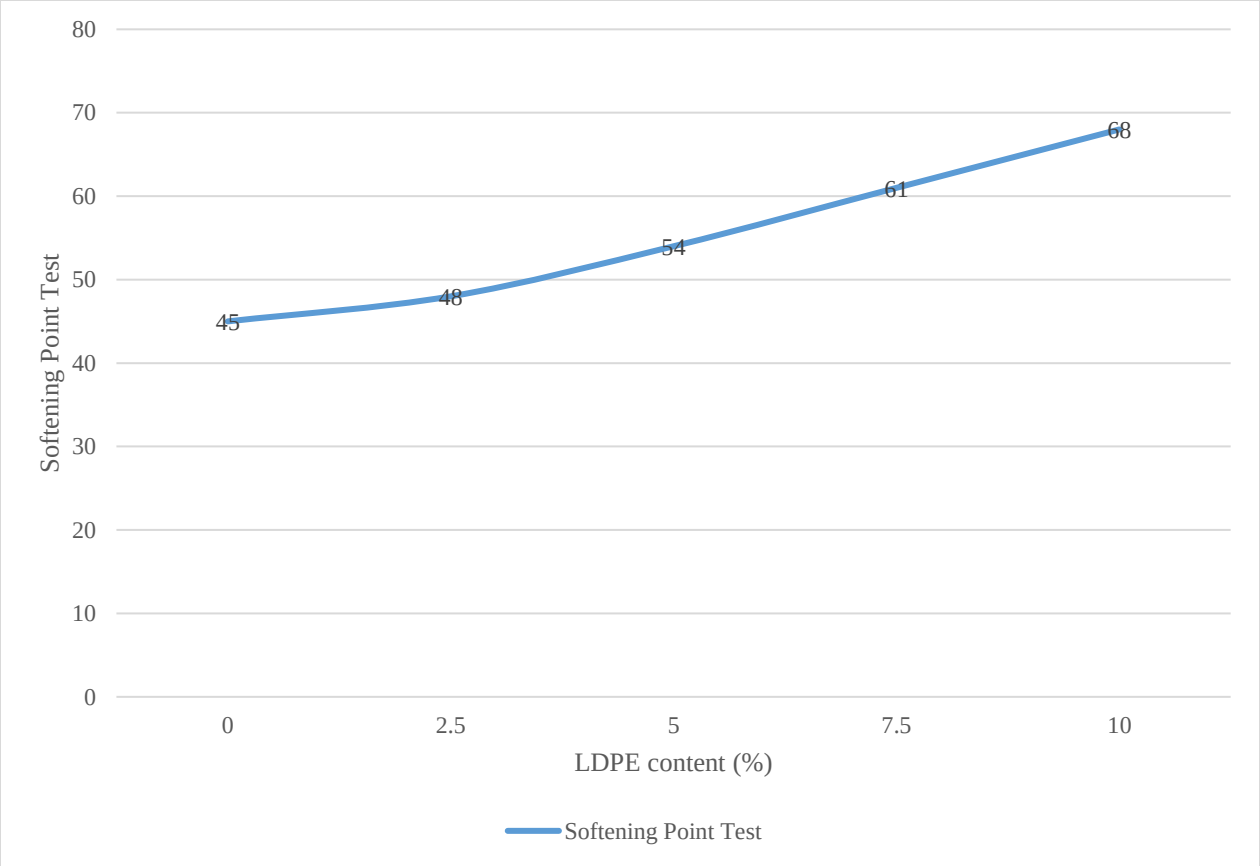

Figure: 4.10 Softening Point Test Results on different LDPE content (%)

"The results are shown in the table and a plot of Crumb Rubber Content (%) vs. Softening Point Test is shown in Table 4.11" [23].

Test Method	Crumb Rubber Content (%)	Softening Point
ASTM D36-89 (AASHTO T53-92)	00	49.7
	2.5	52
	5	54
	7.5	56

	10	57

Table 4.11 Softening Point Test Results on different Crumb Rubber contents.

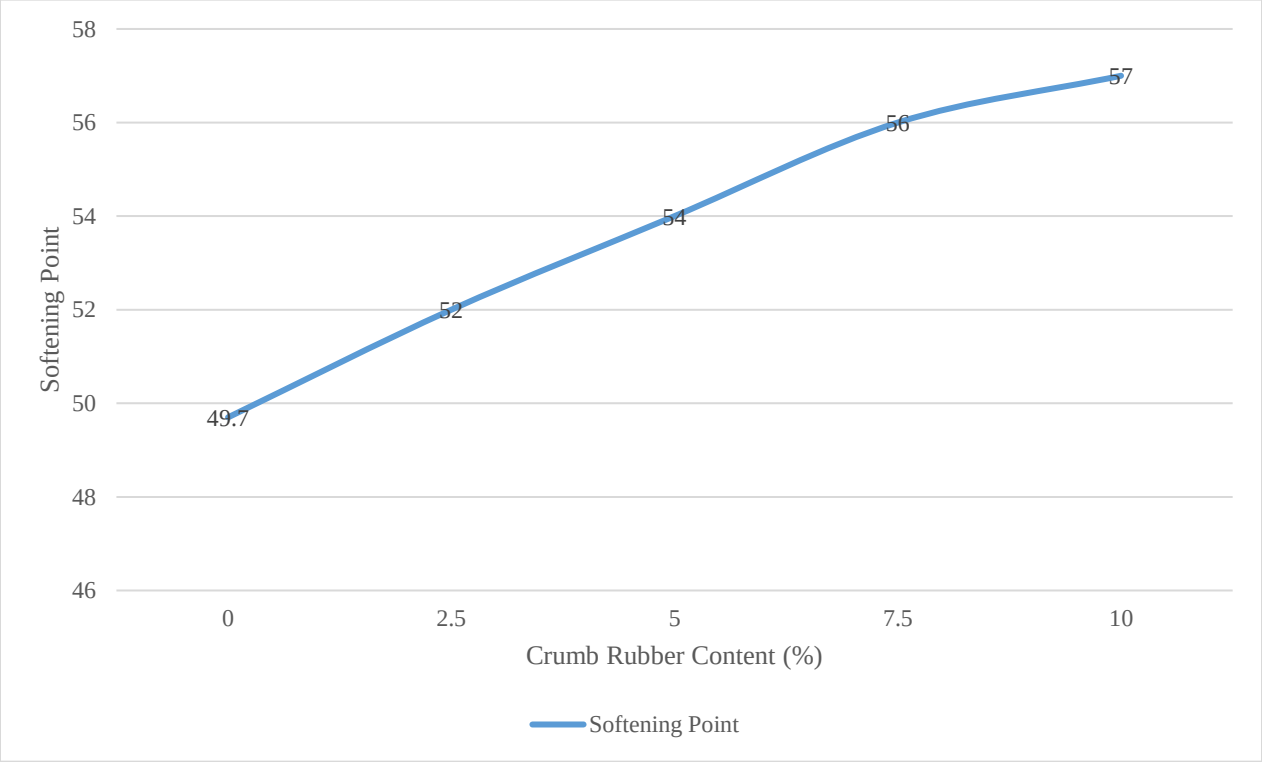

Figure 4.11 Softening Point Test Results on different Crumb Rubber contents.

The results are shown in the table and a plot of Softening Point vs. %Crumb Rubber, %Waste Plastic, and % LDPE content is shown in Table 4.12.

Test Method	Content (%)	Softening Point in Waste plastic	Softening Point in LDPE	Softening Point in Crumb Rubber
ASTM D36-89 (AASHTO T53-92)	00	51	45	49.7
	2.5	52.5	48	52
	5	55	54	54

	7.5	58	61	56
	10	60	68	57

Table 4.12 Softening Point vs. %Crumb Rubber, %Waste Plastic, and % LDPE content

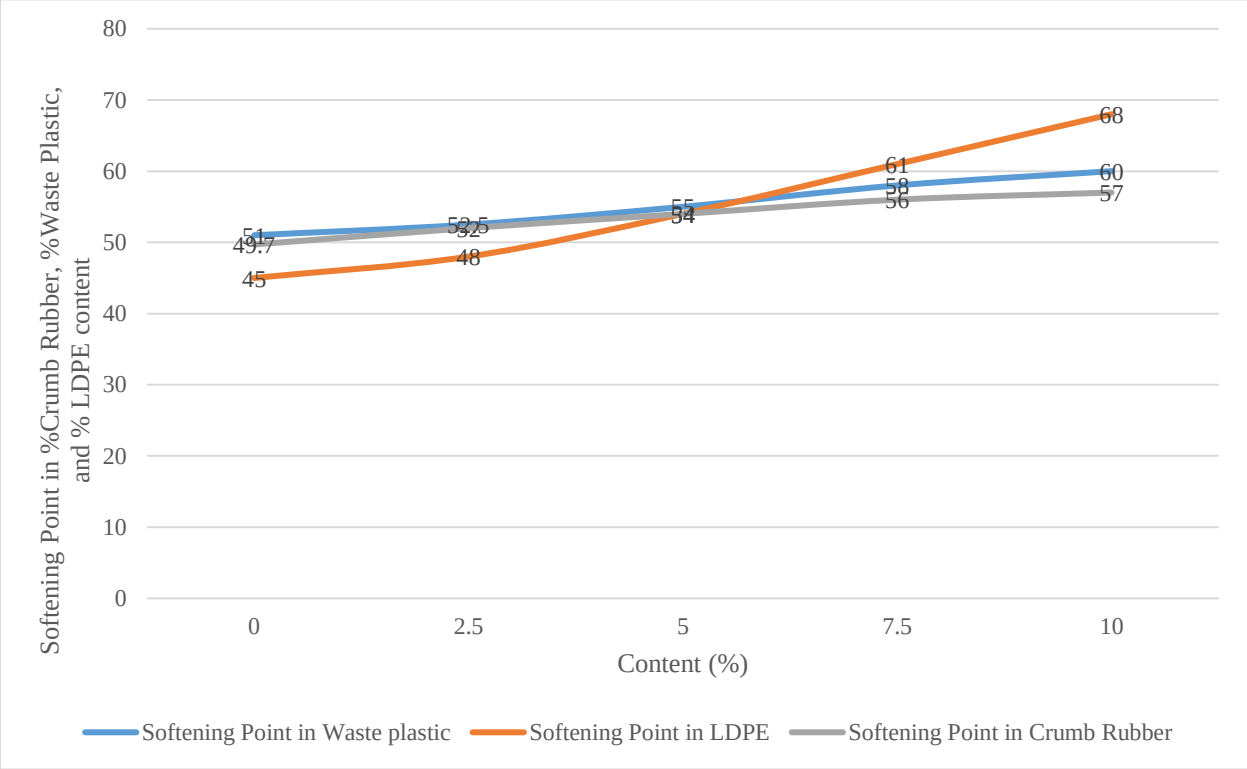

Figure 4.12 Softening Point vs. %Crumb Rubber, %Waste Plastic, and % LDPE content

Based on the performance of modified bitumen with crumb rubber, Waste Plastic and LDPE content and analysis of previous research work the optimum percentage of crumb rubber has been selected as 10%, the optimum percentage of plastic contents has been selected as 5% and the Penetration value percentage of polymer contents has been selected as 5% of weight of bitumen for the further investigation related to Marshall Mix Design.

From the Figure (Figure 4.4) at the optimum point of crumb rubber the Penetration value shows 1.056 whereas at the optimum point of Waste Plastic of the Penetration value is 1.017 and at the optimum point of LEDP the Penetration value is 1.02

Softening point has particular significance for materials to be used as joint and crack fillers. Higher softening point ensures that they will not flow during service. Higher the softening point, lesser the temperature susceptibility. Bitumen with higher softening point is preferred in warmer places.

From the results of softening point test, it is seen that the softening point value increases with the addition of crumb rubber percentage. Since higher softening point is required for better resilience of bituminous pavements. Thus, increase in softening point indicates that CRMB will be less susceptible to high temperature change and more resistance to rutting.

4.2.5 Specific Gravity Test Results Review

"Relative density, or specific gravity, is the ratio of the density (mass of a unit volume) of a substance to the density of a given reference material. Specific gravity for liquids is nearly always measured with respect to water at its densest (at 4°C or 39.2°F); for gases, the reference is air at room temperature (20°C or 68°F). The term "relative density" is often preferred in scientific usage" [24].

We know,

$$\text{Specific Gravity} = \frac{(\mathbf{C}-\mathbf{A})}{[(\mathbf{B}-\mathbf{A})-(\mathbf{D}-\mathbf{C})]}$$

Where,

A =mass of (Pycnometer + stopper)

B = mass of Pycnometer filled with water

C = mass of Pycnometer partially filled with asphalt

D = mass of Pycnometer + asphalt + water

“The results are shown in the table and a plot of Crumb Rubber Content (%) vs. Specific Gravity Test is shown in Table 4.13” [25].

Test Method	Waste Plastic Content (%)	Specific Gravity
AASHTO T228-93 ASTM D70-76	00	1.024
	2.5	1.019
	5	1.017
	7.5	1.015
	10	1.013

Table 4.13. Specific Gravity Test Results on different Waste Plastic Content (%)

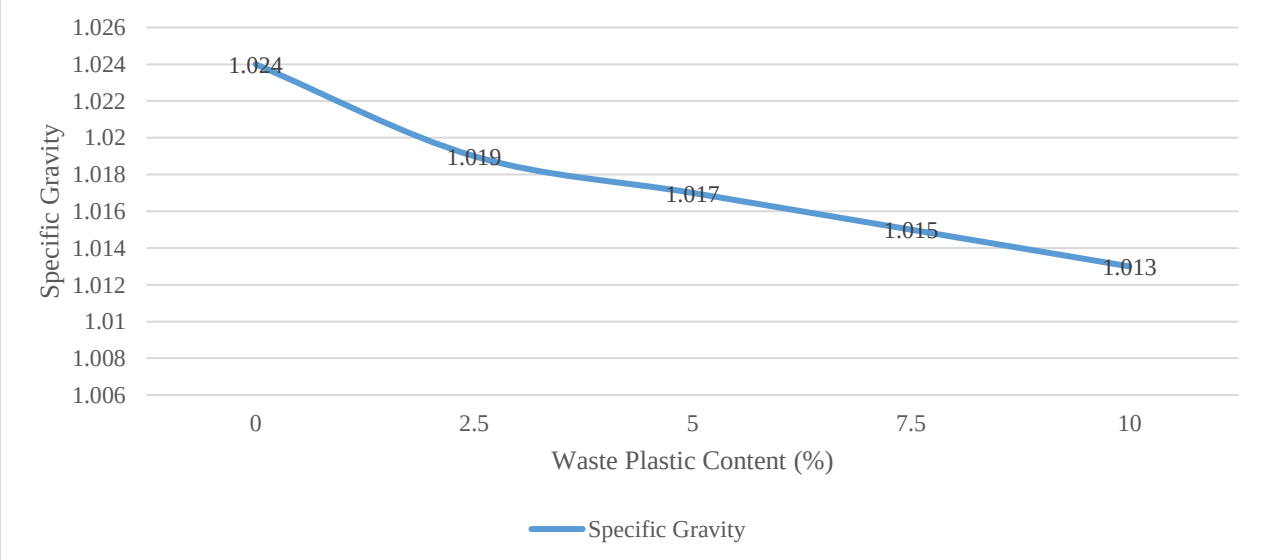

Figure 4.13 Specific Gravity Test Results on different Waste Plastic Content (%)

"The results are shown in the table and a plot of Crumb Rubber Content (%) vs. Specific Gravity Test is shown in Table 4.14" [26].

Test Method	LDPE Content (%)	Specific Gravity
AASHTO T228-93 ASTM D70-76	00	1.030
	2.5	1.025
	5	1.020
	7.5	1.019
	10	1.018

Table 4.14. Specific Gravity Test Results on different LDPE Content (%)

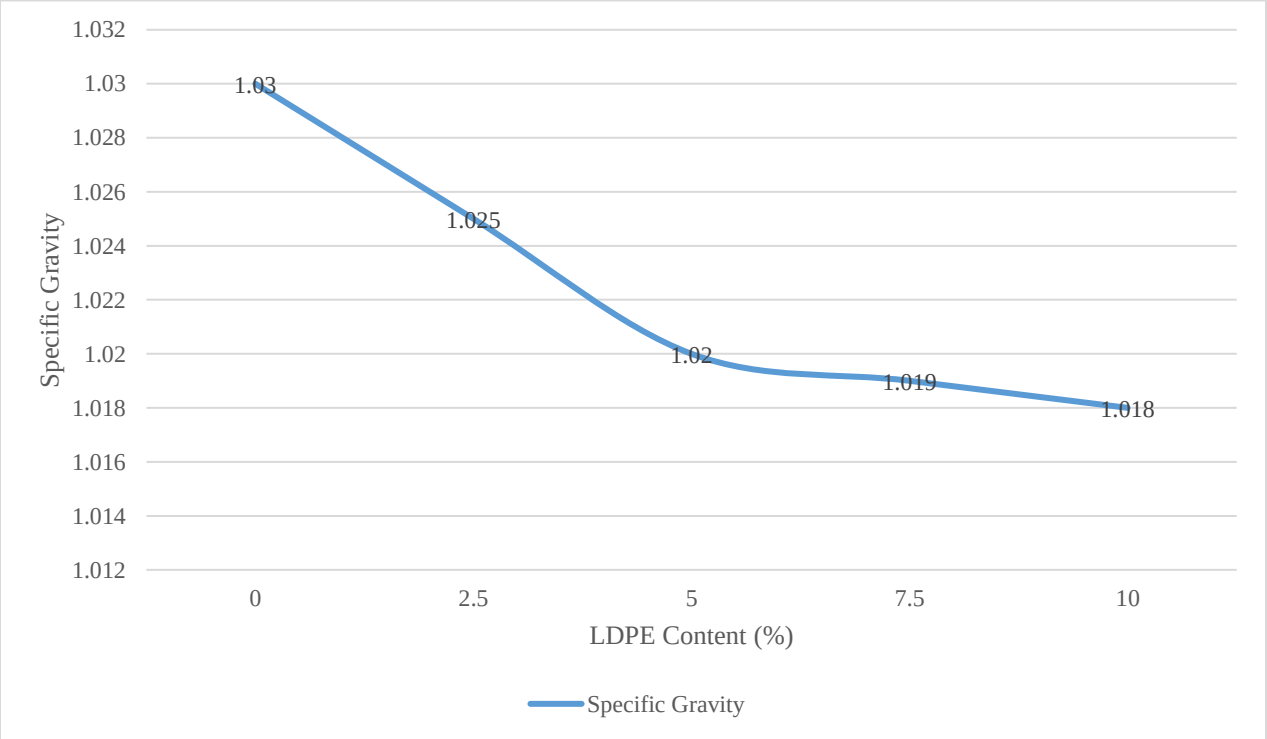

Figure 4.14 Specific Gravity Test Results on different LDPE Content (%)

"The results are shown in the table and a plot of Crumb Rubber Content (%) vs. Specific Gravity Test is shown in Table 4.15" [27].

Test Method	Crumb Rubber (%)	Specific Gravity
ASTM D 70-82	00	1.037
	2.5	1.041
	5	1.046
	7.5	1.051
	10	1.056

Table 4.15. Specific Gravity Test Results on different Crumb Rubber (%)

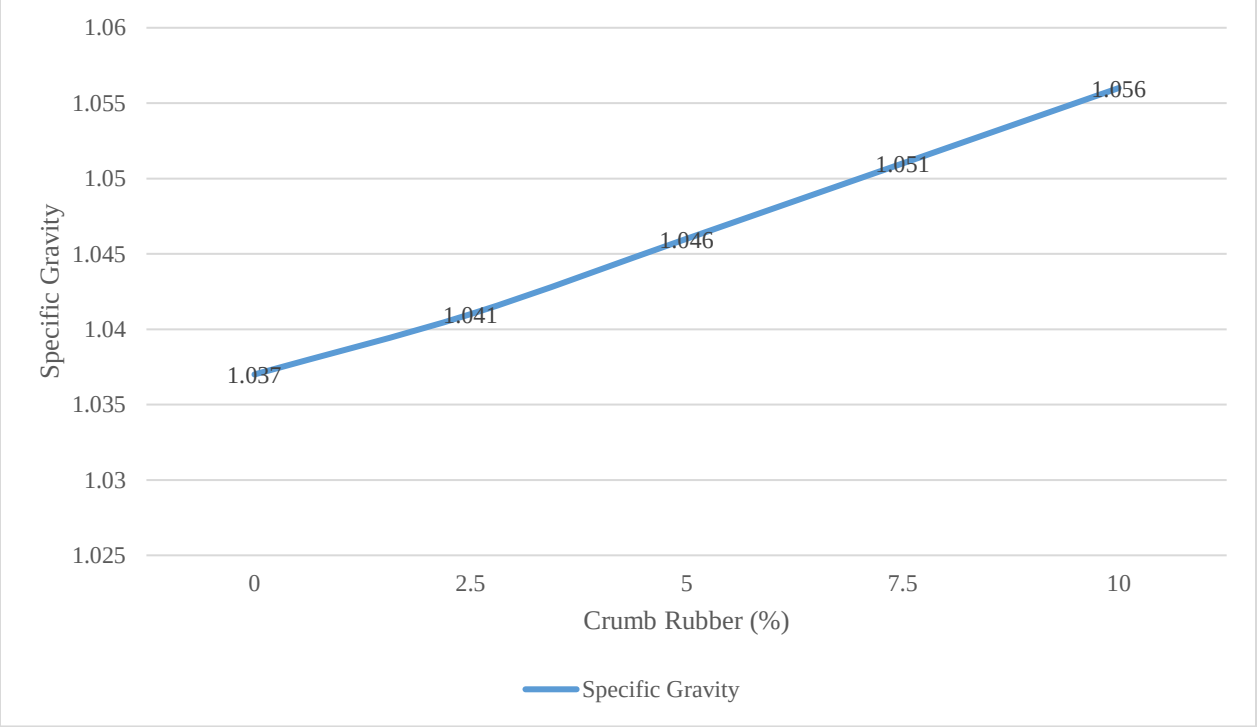

Figure 4.15 Specific Gravity Test Results on different Crumb Rubber (%)

The results are shown in the table and a plot of Specific Gravity vs. %Crumb Rubber, %Waste Plastic, and % LDPE content is shown in Table 4.15

Test Method	Content (%)	Specific Gravity in Waste plastic	Specific Gravity in LDPE	Specific Gravity in Crumb Rubber
Waste plastic, LDPE in AASHTO T228-93 ASTM D70-76 And Crumb Rubber in ASTM D 70-82	00	1.024	1.030	1.037
	2.5	1.019	1.025	1.041
	5	1.017	1.020	1.046
	7.5	1.015	1.019	1.051
	10	1.013	1.018	1.056

Table 4.16 Specific Gravity vs. %Crumb Rubber, %Waste Plastic, and % LDPE content

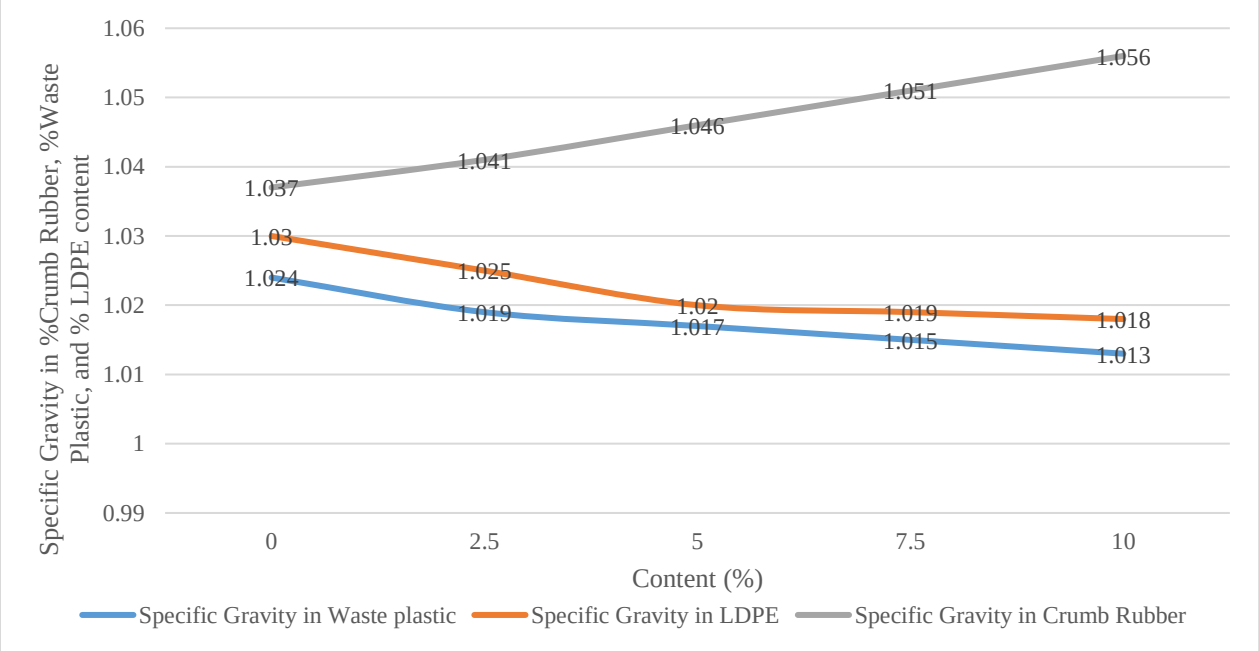

Figure 4.16 Specific Gravity vs. %Crumb Rubber, %Waste Plastic, and % LDPE content

Specific gravity test is done to check the change of unit weight while the asphalt is mixed with waste plastic, LDPE and crumb rubber the results are presented on the table above. The result clearly indicates that specific gravity has decreased with the increase in waste plastic, LDPE content. One the other hand the result clearly indicates that specific gravity has increase with the decreased in crumb rubber.

Chapter-5

Conclusions

5.1 General

The preliminary objective of this study was to find out compatible modifier to blend with bitumen and to find out a simple low-cost bitumen modifier. A manual blending device is fabricated accordingly. In this investigation a total of three modifier such as Waste Plastic Modified Bitumen, Crumb Rubber Modified Bitumen and Polymer Modified Bitumen were used and tested to check their compatibility with bitumen. According to other objectives of the research, the results of different test of modifier bitumen with pure bitumen were investigated through laboratory test report. A comparative analysis of Waste Plastic Modified Bitumen, Crumb Rubber Modified Bitumen and Polymer Modified Bitumen was carried out. The qualitative improvement of crumb rubber modified bitumen and mixes are studied by comparing their characteristics with that of Polymer - modified bitumen and waste plastics modified bitumen. The summary of the test results and important findings are presented in the following articles.

5.2 Conclusion

The related information presented in different chapters of this thesis leads to the following conclusions:

1. The main aim of this study was to utilize the best modifier for mass scale utilization such as in highway construction in an environmentally safe manner. As in the first part of the study, an attempt was made to assess the stabilization of bitumen containing crumb rubber

waste, waste plastic and polymer. From there after selecting optimum percentage of crumb rubber, waste Plastic and Polymer were performed on pure bitumen. The optimum amount of crumb rubber to be added as a modifier of bituminous mix was found 10 % by weight bitumen content.

2. CRMB at 10% of total weight of bitumen shows 6℃ more softening point than the conventional 60/70 penetration graded bitumen. This indicates that CRMB will be less susceptible to high temperature change and more resistance to rutting.
3. Penetration value decreased due to crumb rubber waste added. Lower Penetration thereby making a harder grade of bitumen, giving additional strength to the road and reduces water damage.

5.3 Limitation of the Study

The observations of this research are limited in their scope, within the range of variables investigated, the type of tests employed and the nature as well as the number of specimens tested. For example, only one type of polymer, crumb rubber, has been used throughout their laboratory investigation, keeping the compaction energy unchanged for all the specimens that have been tested. The durability is determined only on the basis of static immersion tests. Due to lack of laboratory facilities, elastic and ductility recovery tests could not be performed. The latter tests are most important measures of indices to study the time dependent behavior of binders. No doubt, the results of this study are encouraging crumb rubber modified bitumen will lengthen pavement service life. But the higher mixing temperature of CRMB than the neat bitumen indicates more amount of fuel cost. The blending procedure to produce CRMB requires extra fuel cost which adds more to the initial cost of construction.

5.4 Recommendations for future research

In order to gain better understanding of the road facilities, more research is required. Some recommendations for future research are enlisted below.

1. In this study, we only research about Specific gravity test result, Ductility test result, and Softening Point test result of bitumen modified by waste plastic, crumb rubber & polymer. If more test result like, Flash point and Fire Point and variation of data can be included with one thesis study it can be more detailed and accurately to find the impacts of modified bitumen in road construction and others facilities.
2. Investigation with different modifier particle size should be done in future research to get the best result.
3. Investigation with different graded aggregate and different graded bitumen may give different result.
4. A training program can be developed to inform the engineers and associated people about the modification and construction process.
5. In this thesis the mixing is done in wet process to modify binder. To know the difference in performance of bitumen in dry mixing process further study may utilize it instead of wet process.

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