PERFORMANCE EVALUATION OF FLEXIBLE PAVEMENT BY USING CNT AND PLASTIC WASTE AS ADMIXTURES

AAMIR AYAZ KHAN
(00000277798)

A thesis submitted in partial fulfilment of

The requirements for the degree

Master of Science
In
Transportation Engineering

MILITARY COLLEGE OF ENGINEERING (MCE) RISALPUR
DEPARTMENT OF CIVIL ENGINEERING
NATIONAL UNIVERSITY OF SCIENCES AND TECHNOLOGY (NUST)
SECTOR H-12, ISLAMABAD,
PAKISTAN (2022)

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by

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A Thesis

of

Masters of Science

Submitted to

Department of Civil Engineering

Military College of Engineering (MCE) Risalpur

National University of Sciences and Technology (NUST)

Islamabad

In partial fulfillment of the requirements for the degree of

Master of Sciences Transportation Engineering

2022

Declaration

I, Aamir Ayaz Khan hereby pronounce that I have produced the research work presented in this thesis, during the scheduled during of study. I also declare that we have not use any material from any source except referred to wherever due. If violation of HEC rules found in the research that has occurred in this thesis, I shall be liable to punishable action under the plagiarism act of the HEC.

Aamir Ayaz Khan
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DEDICATED

TO

MY PARENTS, SIBLINGS, TEACHERS

AND WELL WISHERS

ACKNOWLEDGEMENT

I am literally thankful to ALLAH (S.W.T), whom blessing helped me to complete my research.

The author would first like to acknowledge the Military College of Engineering for sponsoring this research project. Also, the author would like to thank, at the National University of Sciences and Technology and the Transportation Laboratory for providing the laboratory facilities used to conduct the research.

I would like to extend much appreciation and gratitude to my advisor Dr Inam Ullah Khan whose countless inspiration and guidance made it possible to complete my research work. In addition, Brig Dr Sarfraz Ahmed and Lt Col Dr Jawed Ahmed in the capacity of committee member, gave me guidance and feedback throughout the thesis process. I would like to pay gratitude to the academic members of the Military College of Engineering who provided a lot of knowledge during academic session in the postgraduate program.

In the end, I express my solemn gratitude with earnest sense of reverence to my parents for their encouragement, heartfelt prayers and kind wishes for successful completion of my studies along with this research work. Specially, I want to thank my father from all my heart for being with me at all times and for motivating me at every point of my life. He is the best dad in the world and without him nothing would have been possible.

(*Engr. AAMIR AYAZ KHAN)*

ABSTRACT

Interstate highway construction is proceeding rapidly in Pakistan. Rutting resistance is a growing concern due to the proliferation of flexible pavements used in the construction of roads and highways. To go past this, we need to figure out ways to fix these issues. The current economic climate necessitates the use of locally sourced, inexpensive materials. The rutting of Flexible Pavements can be mitigated by using admixtures in the bitumen, such as Cabon Nano tubes and Plastic Waste. To learn how using Carbon Nano tubes and plastic waste by Wheel tracking device affects its Dynamic Stability and Rutting resistance, several tests should be conducted. Waste plastic is a readily available, low-cost resource. To make the modified asphalt mix, wet process mixing of bitumen (60/70 penetration grade) and Marble dust at a high temperature (160-165) is followed by mixing of aggregates. The following percentages of plastic waste and CNT were used to create the modified asphalt concrete samples: (0.1 to 0.4). Marshall Mix design (ASTM D6926) was used to create modified and unmodified Samples, with NHA Class B gradation. To ensure conformance with NHA standards, bitumen (60/70 penetration grade) and aggregates (Margalla aggregate) were tested before samples were prepared. Using Marshall Mix design (ASTM D6926), the optimal binder content (OBC) was determined to be 4.5%; however, OBC 4.8% (derived from earlier research work at ESDev VI 2017) is used in the manufacture of both standard and customised samples. The effectiveness of the changed mixes was evaluated by a battery of tests, including Rutting resistance and Dynamic stability. Using a wheel tracking system, this study compared the samples' dynamic stability and rutting when made with varying percenttages of plastiic waste and carrbon nanotubez (ranging 0.1 to 0.4%). The results reveal that compared to plastic and traditional bitumen, adding carrbon nanotubez greatly enhance the dynamiic stabillity of asphaalt.

LIST OF ABBREVIATIONS

OBC	Optimum Binder Content
HMA	Hot Mix Asphalt
VFA	Air Voids Filled with Bitumen
VMA	Air Voids in Mineral Aggregates
SE	Slow Setting Emulsion
MS	Medium Setting Emulsion
RS	Rapid Setting Emulsion
MC	Medium Curing
RC	Rapid Curing
Gs	Specific Gravity
ASTM	American Society for testing and Materials
Gmb	Bulk Specific Gravity of Mix
Gmm	Theoretical Maximum Specific Gravity of Mix
MQ	Marshall Quotient
kN	Kilo Newton

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Chapter 1

1. INTRODUCTION

1.1 Background

Asphalt is the standard material for paving roads (HMA). Crushed stone is the aggregate, bitumen is the binder, and mineral filler, typically stone dust, rounds out the asphalt mix. Load time and temperature both play crucial role in asphalt mixture performance as it is sensitive to them. When chilled, Asphalt mixes perform the function of a linear viscoelastic material but when hot, it performs the function of a non-linear viscoelastic material. Aggregates operate as a skeleton to resist the application of traffic loads; on the other hand, the function of glue is performed by asphalt binder as it forms fairly stable cohesive mass by holding the aggregate particles closely.

Road construction is an imperative job, in the social and financial improvement of any nation. It adds to the self-satisfaction by giving rise to financial, social and recreational purposes. Road infrastructure provides a circulation system to financial resources of a country. It also structures a significant part of transport sector by transporting crude materials and supplies. Transportation system directly improves life by transporting large number of people daily. Roads are the dominant mode of inland transportation in Pakistan as 96% of freight operation and 91% passenger traffic is carried by roads which leads to premature deterioration of pavement and high maintenance costs. Transport division produce ten percent of the nation's gross domestic product in Pakistan. Travel requirements have expanded quickly due to persistent increase in financial activities. In such conditions, poor construction practices lead to higher expenses for construction and maintenance of pavements and directly affect the economy of a country.

The quality of binder describes the quality of HMA blend. The increasing axle load and number of vehicles lead to premature failure of pavement. The main distresses caused by heavy loads are rutting, shoving, raveling, cracking and bleeding. Specifically, In Pakistan poor law enforcement on overloading and high temperatures detonates premature failure of pavement in shape of rutting and thermal cracking.

Rutting is a term for the permanent or cohesive deformation that accumulates over time in an asphalt pavement; This is usually represented by wheel tracks carved into the road.

Bumps (shears) of the pavement may occur on either side of the crack. These furrows are especially noticeable after rain when they fill with water. There are three basic types of canyons: mixed canyons, terrain canyons, and dense canyons. Combination cracking occurs when the subgrade is not accurate but the road surface shows depressions in the walkway due to combined compression/design problems. Lower-layer yielding occurs when lower-layer loads show pits in the wheel tracks. In this case, the road surface sinks into the ground, creating less pressure in the wheel paths. Compaction occurs when pressure during construction is insufficient and the pavement compacts under traffic loads.

Premature failures in pavements due fatigue cracking and rutting are more often observed failures in Pakistan, is due to inadequate design procedure. At present in Pakistan design approach used for pavement design is empirical in nature, which is based on AASHTO design guide 1993, which was updated in 2002 and was named Mechanistic-empirical design guide due to incapability of former one to provide adequate design for unconstrained heavy loads and tire pressure.

1.2 Objectives

The specific objectives of the study are:

- To Analyze the dynamic stability and rutting resistance of a mixture of plastic modified binder (bitumen-pen grade 60/70) and carbon nanotubes through wheel tracking device. Determination of maximum optimum quantity of plastic and CNT that is to be added in conventional asphalt mixture which gives us maximum results in terms of Dynamic Stability and resistant against permanent deformation
- To compare typical asphalt concrete mixtures to CNT and plastic waste in terms of their dynamic properties (using the dynamic Stability and Rutting resistance tests). These tests will be conducted under sinusoidal and repeated loading.

1.3 Significance

Garbage product generation has expanded along with technological development, which has resulted in serious problems with waste management. Reusing waste goods as a substitute for or admixture in primary road materials is an effective way to reduce waste production.

- When used as an additive in asphalt for roads, plastic trash can help keep costs down. The use of Plastic waste and CNT used in road pavements may strengthen it and its dynamic stability will be increased against heavy loading and Environment conditions.

- When used as an additive in asphalt for roads, plastic trash can help keep costs down.

1.4 Marshall Mix Design

The project will employ coarse and fine aggregates of class A and B of wearing course that meet NHA standards. For carrying out this procedure the approach that we will use is the Marshall Mix Design. With the help of the Marshall Technique we can choose, at a target density the asphalt binder that fulfills minimal stability and flow range requirement. Asphalt binder materials can be selected with a target density that meets the minimum flow rate and stability requirements using the Marshall technique. The Marshall hybrid design includes the following steps:

- Aggregate selection.
- Selection of asphalt binder.
- Sample preparation (pressurized)
- Establish stability
- Voids calculations and Density.

1.5 Organization of the Document

Organization of the document is done in five parts.

Chapter 1 serves as the introduction of the study with a brief account of problems related to the flexible pavement failure and distresses caused by excessive loading and high temperatures. The objectives of this research study are identified and noted to include in the scope of study.

Chapter 2 constitutes of the review of previous studies associated with CNT and Plastic waste in Asphalt.

Chapter 3 As a means of understanding the research methodology used to achieve research objectives. It includes a detailed account of all the necessary procedures required for conducting the research. It includes the test procedures adopted for conducting the testing involved in this research.

Chapter 4 considers all the results produced from the testing and analyze those results through statistical and graphical means. All the results are presented in compiled form for better understanding of the research.

Chapter 5 produces the conclusions drawn from the study and the recommendations for future. The conclusion of using CNT and plastic waste in Asphalt has been presented and recommendations have been offered for future consideration.

Chapter 2

2. LITERATURE REVIEW

2.1 Pavement

Coarse and fine aggregates of class A and B of wearing course will be to NHA standards for this project. The Marshall Mix design strategy will be utilized for the operation. For determining the contents of the Asphalt Binder that offers minimum stability as well as flow characteristics at a target density the Marshall procedure is helpful.

2.2 Pavement Classification

On the basis upon the mode of supporting and distributing loads, pavements are classified as Flexible and Rigid pavements.

2.2.1 Flexible Pavement

As the name suggests, the make-up of flexible pavements is such that it has numerous layers of natural granular material which are separated by surface layers of one or more waterproof bituminous layers. Under the weight of a vehicle, such as a tyre, a flexible pavement will flex. Overstressing a pavement layer, which can lead to the pavement failing, is the primary concern when designing a flexible pavement so that it can bend (flex) without breaking. Since the strength of individual pavement layers varies, load distribution patterns in flexible pavements are not uniform. The top layer contains the least malleable (strongest) substance, the most malleable (most flexible) substance (weakest material) is found in the bottom layer.

The reason is that the weight applied by the wheel near the surface is on a relatively small area as a result the stress level is high, whereas at deeper level in pavement the weight being applied by the wheel is on a large area comparatively, as a result the stress levels are low thus the use of weaker materials is possible. Through a series of layers, it disperses weight to the subgrade. Flexible pavement concentrates load over a much smaller footprint on the subgrade. Since the upfront cost to create a flexible pavement is relatively modest, this type of pavement is increasingly common around the world. However, the flexible pavement does require routine upkeep and periodic repairs. Not only can that, but cracks and potholes quickly appear on flexible pavement due to poor drainage and heavy vehicle traffic. Flexible pavement has the important benefit of being able to be used for traffic within 24 hours after completion. Additionally, flexible pavement is simple and inexpensive to maintain.

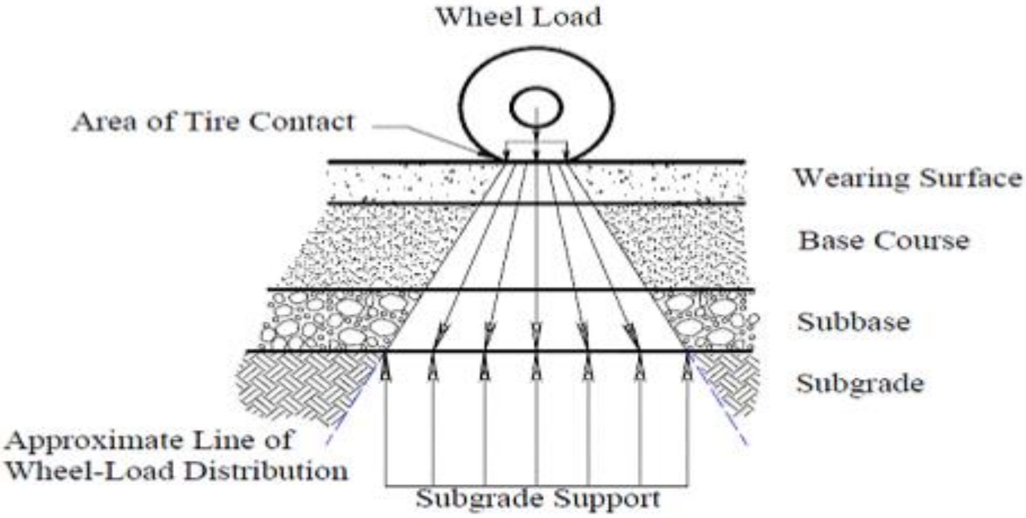


Figure 2.1: Load stress distribution in flexible pavement

2.2.2 Components of a Flexible Pavement

The function of different layers composing flexible pavements are explained under and in figure 2.2 a typical flexible pavement is shown.

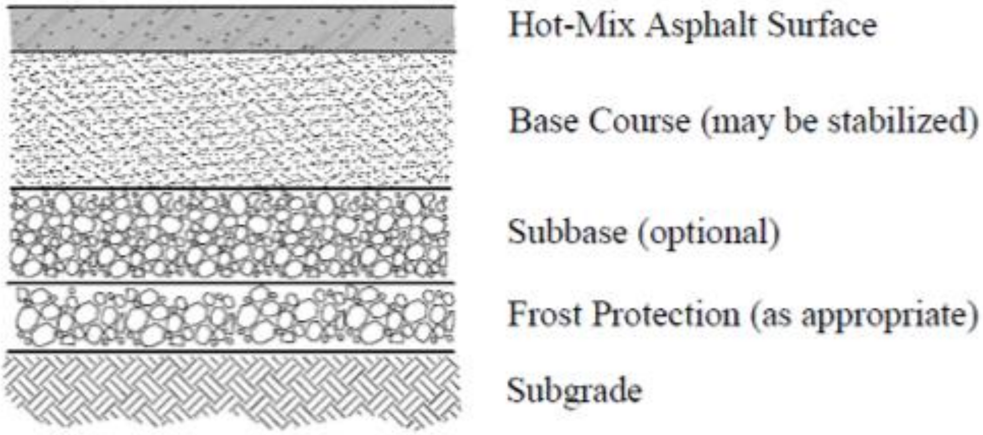


Figure 2.2: Structure of a Typical flexible pavement

2.2.3 Sub-grade

The base course is the lowest section of a flexible pavement. All that earthwork is compressed. When a road is subjected to heavy traffic, the soil beneath it is the one that bears the weight. To avoid embankment failure due to differential settlements in the sub-grade, incompressible soil should be used in their construction. To make the dirt being used as the subgrade incompressible, it is compacted or stabilized.

The soil layer beneath the pavement, known as the subgrade, is the bedrock of the paved area. The stresses experienced by subgrade soils are far less than those experienced by the surface, base, and sub base courses. The regulating subgrade stress is often located around the subgrade's surface due to the fact that load stresses diminish with depth. To prevent the subgrade soil layer from being excessively deformed or displaced, the total thickness of wearing surface, base and sub base must be sufficient.

2.2.4 Sub-base

When the subgrade soil is particularly poor or frost action is high, this layer is applied. As its name implies, a sub base course is a step below the base course.

As compared to base course the sub base is not heavily loaded, it does not have to meet the same stringent material standards. Granular material that has been stabilised or compacted to the right density forms the sub base.

2.2.5 Base course

Layer of granular material provided directly under the wearing surface of the pavement is the base course. It (Base course) consist of crushed stone gravels slugs or in some other instances penetration macadam. Base course aggregate is normally greater in size compared to sub base material. It’s (Base course) function is to distribute the load through a finite thickness of crushed aggregate thus increasing the structural capacity of the pavements.

The flexible pavement's main structural element is the base course Wheel loads applied to the subgrade, subbase and/or pavement foundation are distributed over the base. A foundation of sufficient mass and thickness is needed to prevent subfoundation and/or underfoundation failure, to handle stresses generated by the foundation, to resist vertical stresses that may cause unevenness and distortion of the surface path, and to withstand the resulting volume changes. of changes in base moisture diffusion.

The selection of strong and durable materials, which generally fall into two categories: static and granular, form the foundation of the course. Ground or unearthed aggregate is usually added to a firm foundation with a stabilizer such as Portland cement or asphalt. The quality of the base layer depends on its composition, physical properties, and degree of compaction of the material.

2.2.6 Surfacing / Wearing Surface

The granular layer beneath the pavement's surface is called the base course. Crushed stone gravel slugs, or occasionally penetrating macadam, make up the base course. Aggregate for the base course is often greater in size than that used for the sub base. Adding a layer of crushed aggregate at the pavement's foundation helps the surface bear more weight and improves its structural integrity.

The basic course of the main structural component is a flexible pavement. This will distribute the weight on the tires evenly over the road surface.To prevent the failure of the subgrade and/or substratum, the base must be of sufficient mass and thickness to absorb stresses generated within the base, resist vertical stresses that tend to consolidate and cause deformation of the surface layer, and resist changes in volumetric moisture from the base. Content change. The core course is composed of a solid and permanent material, which can broadly be classified as either stable or granular.

Figure 2.3 Asphalt wearing course being laid and compacted

Crushed or crushed aggregate is mixed with stabilizers such as Portland cement or asphalt to form a stable base. The composition, material quality and degree of compression of the material determine the quality of the base layer.

2.3 Aggregates

Due to its importance, it makes up the bulk of a paved area. Cement concrete, bituminous concrete, and the granular base and sub-base course that supports the top layer of pavement all make use of this aggregate during construction. The particles with a size higher than 4.75 m are likewise considered aggregate.

The overall structure contributes greatly to the resistance to permanent deformation of the structure. Because of this, roadway engineers place a great value on the characteristics of the aggregates. Aggregates for the roads are often mined from the earth. Gravel aggregates are comprised of tiny, rounded stones of varying sizes, often gathered from river bottoms.

Figure 2.4 Quarry site for Aggregates

Weathering of rocks produces fine aggregate, which we call sand. The features of the rock that forms the aggregates are determined by the quality of the component components and the sort of bonds that keep them together. Aggregates may be sorted into many classes based on their gradation, grain size, form, and texture.

According to their strength, coarse aggregates may be divided into two groups: hard aggregates and soft aggregates.

2.3.1 NHA Class B Aggregates

The maximum aggregate size and grade are directly controlled by NHA "Class B" Aggregate Grade for Coarse Abrasives (NHA General Specifications). The maximum aggregate size is linked to the representative cantilever thickness utilized in roads of NHA in Pakistan.

Table 2.1: National Highway Graddation Classs-B Aggreggate

Seive		Combinned gradation (AWC Classs-B)	
in	Millimeters	Grading (Course-Graded)	Specificationz Classs-B
1	25	-	-
¾	19	100	100
½	12.50	82.5	75-90
3/8	9.50	70	60-80
#4	4.75	50	40-60
#8	2.36	30	20-40
#50	0.300	10	5-15
#200	0.075	5.5	3-8

2.4 Hot Mix Asphalt

Asphalt cement is added to HMA when making hot asphalt mix. The term “hot mix” refers to the process of heating aggregates and asphalt prior to mixing to dry the aggregates and give the asphalt cement sufficient fluidity for effective mixing and workability.

Figure 2.5 Hot Mix Asphalt

The aggregate and asphalt are mixed in the mixing facility where they are heated, gauged and mixed to achieve the desired paving mix. Once the mixing process is completed in the factory, the hot mix is transferred to the paving area and spread into a thin, uniformly compacted layer using paving. While the asphalt mixture is still hot, it is compacted with heavy power roller to produce a smooth, well-compacted layer of asphalt.

Hot Mix Asphalt Pavement Mixes can be made from a variety of aggregates, each with its own set of qualities that are ideally suited to specific design or construction requirements. In addition to the quantity and quality of bitumen used, the main quality of the mixture depends on the ratio of coarse aggregate, fine aggregate and mineral fillers.

2.5 Flexible Pavement Materials

The pavement's multi-layer construction disperses the weight of vehicles across a larger area. Included are all layers under the surface of the earth. Layers of different materials may provide a wide range of effects on the final pavement's performance. For this reason, a pavement design should include a comprehensive understanding of pavement materials, their characterization, and performance requirements.

Highway engineers are very interested in the components used to construct a road. Maintaining pavement requires knowledge of more than simply the aggregate, soil, and how these factors react to changes in temperature.

The material selection for flexible pavement design is vital to providing a longer design life. Materials used in flexible pavement are of three types:

- Bitumen
- Aggregate
- Subgrade soil

2.6 Bitumen

When heavy crude oil is refined, the lighter fractions (such as liquid petroleum gas, petrol, and diesel) are separated out, leaving behind the sticky semi-solid hydrocarbons known as bitumen, which is used as a binder in pavement constructions. At 525 degrees Celsius, bitumen begins to boil. Bitumen is a stable substance when it is at room temperature. Bitumen is used as a binder in asphalt for roads, and 85% of all bitumen produced is put to use in road pavements. The other 15% is split between roofing and sealing and insulation.

Bituminous materials and asphalts are often used in road construction due to their low-cost, high-water resistance, and strong bonding strength.

Figure 2.6 Bitumen/Binder used for production of HMA

2.6.1 Production of the Bitumen

During the refining of crude petroleum, bitumen is created as a byproduct or residue. Bitumen with a wide range of viscosities and other desirable properties may be refined using methods including straight distillation and solvent extraction. Depending on the source and characteristics of the crude oil, more than one refining method may be used.

2.7 Different forms of Bitumen

2.7.1 Cutback Bitumen

Bitumen is "cutback" by reducing its concentration with the addition of petroleum distillates like kerosene. This is done either to enable spraying at temperatures too low for effective sprayed sealing with plain bitumen or to temporarily lessen the viscosity of the bitumen so that it may permeate pavements more efficiently. Applying a bitumen reducer will result in a product with the same hardness as unrefined bitumen, since the reducer will evaporate after usage.

2.7.2 Types of Cutback Bitumen

- Rapid Cure (RC): Recommended for touch up and surface finish.
- Medium Processing (MC): Recommended for premixing small amounts of fine aggregate.
- Slow Curing (SC): Recommended for premixing large quantities of fine aggregates.

2.8 Bitumen Emulsion

An emulsion is a liquid product prepared by suspending finely divided bitumen in an aqueous medium and stabilizing it with suitable materials. About 60% of the emulsion is bitumen and the remaining 40% is water. Using the lotion on the road will cause it to break down and release water as the mixture settles. The time it takes for asphalt to harden can vary depending on its quality. The viscosity of bituminous emulsions can be measured using IS: 8887-1995.

2.8.1 Types of Bitumen Emulsion

Bitumen emulsion is available in three types:

- Rapid setting emulsion (RS): Used for surface finishing works
- Medium setting emulsion (MS): The first choice for pre-repair and patch jobs
- Slow setting emulsion (SE): First choice for the rainy season

2.9 Bitumen Primers

Bituminous primers contain fractions that are absorbed by the road surface. Therefore, water absorption is affected by the surface porosity. Bituminous primers can be used to stabilize water-bonded surfaces and bases. Bituminous primers are commonly made at road construction sites using petroleum distillate and penetrating bitumen.

2.10 Modified Bitumen

Bitumen modifiers, often known as bitumen additives, are substances or compounds used to enhance the properties of bitumen and bituminous blends. Due to the high requirements of climate change, polymer modified bitumen (PMB) or rubber modified bitumen (CRMB) can only be used for wear layer. IRC: SP: 53-1999 details the exact requirements for modified bitumen. For PMB and CRMB to function properly, the temperature must be kept very stable. Here are the advantages of using modified bitumen:

- Less sensitive to diurnal and seasonal changes in temperature
- Increased resistance to deformation at high road temperatures
- Better antiaging properties
- Longer life than composite fatigue
- Better union between aggregate and binder
- Prevents cracking and reflective cracking

Figure 2.7 Crumb Rubber modified Bitumen (CRMB) used in HMA

2.11 Requirements of Bitumen

The following are the ideal properties that bitumen should have:

- Asphalt should not be too affected by changes in temperature, as the mixture should not be too soft in hot weather or too brittle to crack in cold weather.

- Bitumen viscosity shall be suitable for mixing and compaction. This type of bitumen can be achieved by using an appropriate grade of thinner or emulsifier.

- The bitumen and aggregate used in the mix should have suitable consistency and consistency.

2.12 Aggregates

2.12.1 General

Construction aggregates such as sand, gravel, crushed stone or recycled crushed concrete. Particles larger than 4.75 µm are also considered to be aggregations. The structure of the aggregate contributes greatly to the mixture's resistance to permanent deformation.

Coarse aggregate can be divided into two distinct categories based on its relative hardness or softness.

2.12.2 Hard Aggregates

Hard aggregates are often used because they are better able to withstand the crushing impact caused by strong traffic loads and poor weather conditions.

2.12.3 Soft Aggregates

Soft aggregates are often utilised for lower layers of pavements or for low-cost roads. Class A aggregates, as defined by the National Highway Administration, were used in the experiment.

2.12.4 NHA Class - B Aggregates

The National Highway Administration's "Class-B" aggregate grading standard governs the maximum size and grading of worn coarse (NHA General Specification). The average height thickness used on national highways in Pakistan is directly proportional to the maximum aggregate size. The adopted gradation for our mix is shown n Table 2.2 and the curve is presented in Figure 2.8. This gradation is selected based on the specification provided by NHA for Class B.

Table 2.2: Adopted Aggregate Gradation & Specifications

Adopted Aggregate Gradation & Specification							
Sieve Size		Combined grading (Asphalt Wearing Course Class-A)					
		Gradation 1		Gradation 2		NHA Specifications Class-B	Asphalt Institute Gradation
Inch	mm	Gradation	Targeted Value	Gradation	Targeted Value		
1	25	100	100	100	100	100	100
¾	19	90-100	90	95-100	100	90-100	90-100
½	12.5	-	-	-	-	-	-
3/8	9.5	56-69	56	59.1-69.1	69.1	56-70	56-80
#4	4.75	38-46	38	38.2-48.2	48.2	35-50	35-65
#8	2.36	25-33	25	24.3-30.3	30.3	23-35	23-49
#50	0.3	5-12	5	4.5-10.5	10.5	5-12	5-19
#200	0.075	3.4-5.3	3.4	3.3-5.3	5.3	2-8	2-8

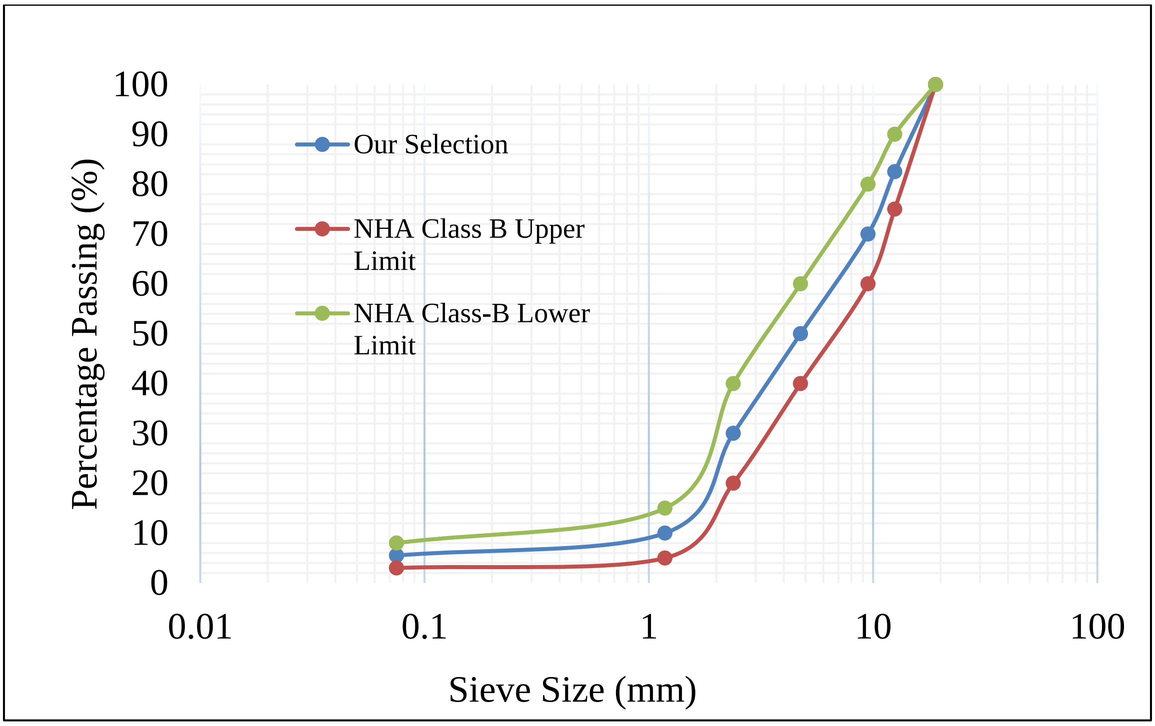


Figure 2.8 NHA Class B Aggregate Gradation

2.13 Desirable Properties of Road Aggregates:

Aggregates hold immense importance in the strength of road structures. While using aggregates as road material following properties should be investigated.

2.13.1 Strength

As due to the gradual applied traffic loads stresses are induced and to counterfort these stresses the aggregates should be strong enough. For the top layer of pavements the aggregates used should have high strength.

2.13.2 Hardness

The aggregates are subject to continual rubbing or abrasion as a result of the shifting traffic loads. Aggregates must be strong enough to withstand the force of traffic and prevent erosion. Sand or other abrasive material between the tyres of moving vehicles and the exposed aggregates at the top surface may increase the abrasive effect.

2.13.3 Toughness

The aggregates are subject to continual rubbing or abrasion as a result of the shifting traffic loads. Aggregates must be strong enough to withstand the force of traffic and prevent erosion. Sand or other abrasive material between the tyres of moving vehicles and the exposed aggregates at the top surface may increase the abrasive effect.

2.13.4 Durability

Construction materials for pavements should be long-lasting and resistant to the elements. The strength and durability of a stone will suffer if its particles are irregular in shape, such as if they were flaky or elongated, rather than cubical, angular, or rounded.

2.13.5 Shape of Aggregates

Aggregates that are excessively flaky or too lengthy should be avoided. The strength and durability of a stone will suffer if its particles are irregular in shape, such as if they were flaky or elongated, rather than cubical, angular, or rounded.

2.13.6 Adhesion with Bitumen

Bituminous pavement requires aggregates that have a lower affinity for water than bituminous materials because Bituminous coatings are washed off on aggregates in the presence of water

2.13.7 Cementation

The binding activity of the top layer in water bound macadam construction is provided by the stone dust and the water film. In light of this, it is preferable to use such stones in water bound macadam (WBM) construction since its powder contains strong cementing activity when present.

2.14 Effects of Plastic waste and CNT on Flexible Pavements

Nanoparticles are the best option for encouraging asphalt surfaces to self-heal, say Tabakovic et al. As reported by Huui Yao ett al. the addition of sillica improved the rheulogical characteristics of the binders. Based on his findings, Saeed Ghaffarpour Jahromi concluded that adding nanofiber to bitumen mixtures increases their stability and void volume while decreasing their flow value. That's why it's safe to say that incorporating carbon nanofiber into road pavement helps it better withstand the wear and tear that comes from vehicle traffic. Research by Ezio Santagata et al. shows that carbon nanotubes (CNTs) improve the material's rutting resistance and thermal cracking resistance.

Figure 2.9 Carbon Nanotube (CNT) enabled Asphalt

Further benefits are anticipated for performance of asphalt in the longer run, including reduced susceptibility to oxidative aging. According to Xiao et al. Carbon nanotubes are also utilized to improve different properties of binders after Rolling thin film oven and Pressure aging vessel treatments. Amirkhanen et al. suggested higher ratio (>1) of Carbon nano fibers to enhance the performance against rutting at elevated degrees of temperature. The study of Khatttak et al. suggests the addition of carrbon nanofibers to asphalt can make it more durable and less prone to lag and fatigue. Hussain et all. gave a conclusion that adhesion of carrbon nanofiber/matrix-incorporated asphalt can only be achieved by fully exploiting the potential of the reinforced nanocomposites. Liu Xiaoming et al. conducted research demonstrating that incorporating CNT into bitumen increases the pavement's durability and resilience against rutting and wear. Michael Lecomte recommends Polymer Modified Bitumen (PMB) as a pavement sealer. It has been shown that increasing the concentration of the modified CNT binder used in the material can improve its rheological properties.

Figure 2.10 Plastic waste enabled Asphalt

Chiu and Liu use the same aggregate source to evaluate two samples, one with ground tyre rubber added and another without. They determined that the specimen treated with ground tyre rubber had much less rutting than the control material. Fontes et al. also found that tyre rubber used as an addition to asphalt makes the latter more resistant to bending. In his research, Cao showed that the use of SBS recycled rubber in asphalt caused little permanent deformation, even when heated to extremes. Hnslolu and Aar conducted a research using both regular bitumen and bitumen treated with HDPE (High Density Polyethylene), and found that the HDPE-modified bitumen rutted much less under high temperatures. Sengoz and Topal conducted their investigation using discarded roofing shingles, and found that their specimens had much shallower ruts compared to those of the control mix. Liu et al. shown in their study that incorporating graphite powder into a pavement might make it more resistant to long-term distortion. According to the research conducted by Bahbahani et al., who evaluated the effects of using wool mineral fibre and cellulose fibre as additives to prevent rutting, the former shows the least lasting deformation.

Chapter 3

3. RESEARCH METHODOLOGY

3.1 Introduction

We are looking at the possibility of using recycled plastic and carbon nanotubes (CNTs) in hot mix asphalt as part of our project and study. Coarse and fine aggregates, bitumen, and our methodology for evaluating their qualities will all be the subject of this in-depth analysis. The aggregates, bitumen, Plastic Waste, and CNT testing results will also be included. The analysis and findings from these tests will also be shared. There are five stages to our project management process. The first stage involves the gathering of resources. The second step involves analysing aggregates for their unique properties via a battery of tests. In the third stage, we used the Marshall Mix Design to generate a variety of HMA samples. During Stage 4, we put our changed samples through a battery of testing at OBC. Testing for rutting was done on both original and altered HMA samples in the fifth phase. This section concludes the findings.

3.2 Research Methodology in Phases

3.2.1 Phase-1

In this phase of the project, the required material (aggregate and bitumen) was collected from the respective sources.

3.2.2 Phase-2

Both aggregate and bitumen were then tested to check their quality as per NHA specifications in this phase of the project. All tests are conducted in accordance with relevant ASTM/AASHTO/BS standards.

3.2.3 Phase-3

This phase consisted of preparation of Marshall Mix Design. The blending of different sizes (of coarse & fine) aggregate was done to achieve the gradation according to NHA specification.

The bitumen was added to different percentages of 3.5%, 4%, 4.5% and 5%. For each blend Gmb, Gmm, Marshall Stability, flow and Volumetric characteristics were determined. Then the results are plotted and the optimal asphalt content for the design is determined.

3.2.4 Phase-4

In this phase, the filler material was replaced in varying percentages in asphalt mix and checked its Gmb, Gmm, stability, flow and volumetric properties.

3.2.5 Phase-5

In the last phase of this research project, the performance of HMA was checked for Rutting and Dynamic Stability of the modified and control mixes.

3.3 Aggregate Tests

We got our aggregates from Margalla hills site. This quarry was selected as its aggregate is hard and possess good qualities for use in construction. Different tests that were performed on these aggregates as discussed below and the result showed that the selection of this quarry was beneficial for the mix.

3.3.1 Sieve Analysis (ASTM C-136)

Aggregates of varying sizes are obtained by sieve analysis and then utilised to make Marshall Mix samples. Using the NHA Class A standard, we were able to determine what percentage of each aggregate size should be included in our Marshall Mix samples.

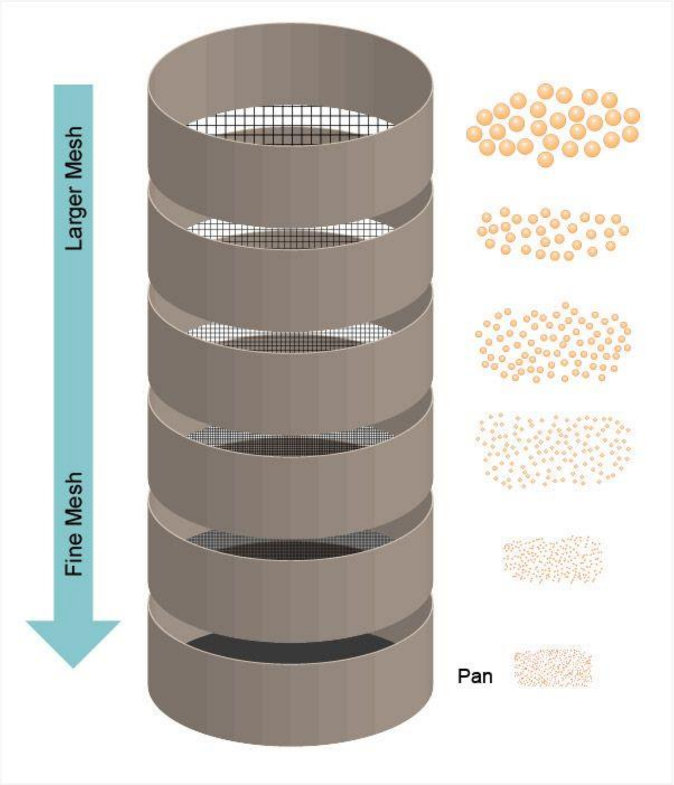


Figure 3.1 Sieve Analysis of Aggregates

3.3.2 Aggregate Impact Value Test (ASTM D5874-02)

The purpose of value-added tests is to compare the resistance of aggregates to impact loads. The aggregates' toughness will be evaluated with the use of this test. The ability of a material to withstand impacts from, say, traffic is referred to as its "toughness." Stones on roads are often broken up into tiny bits due to the impact loads they endure. The aggregate must be strong enough not to break on impact. The impact value of a material measures its resistance to rapid impact. This test was conducted to determine the relative strength effect of aggregates at different traffic impact loads. Traffic carries shock and impact loads, so the aggregate is able to break into smaller pieces. Therefore, the aggregate should be strong enough to resist breakage due to applied loads from traffic.

The impact testing equipment, a cylindrical mold with a 75 mm diameter and a depth of 50mm, a tamping rod with a circular section of 10mm and a length of 230 mm, and sieves with sizes 1/2’’, 3/8’’, and #8 were all needed for measuring impact value (2.36 mm). Take about 350 grams of material and pour in three layers into the mold of the impact testing apparatus, and fill each layer 25 times. The sample is placed in a mold and tapped 15 times with a 13.5 to 14 kg hammer at a height of 38 cm. Aggregates were removed and passed through filter no. The aggregate fraction passing through a 2.36 mm sieve was used to calculate the effective value.

Figure 3.2 Aggregate Impact Value Test Apparatus

3.3.3 Los Angeles Abrasion Test (ASTM C 535)

Aggregate hardness is measured using this procedure. When sent through the same machine, aggregates from various sources provide varying results. The aggregates used to build roads should be durable enough to withstand the constant pounding from vehicles. For road pavement to be stable, aggregates must have a high abrasion value.

Figure 3.3 LA Abrasion Test Apparatus

3.3.4 Aggregate Crushing Value Test (BS: 812)

The overall fracture value gives a relative measure of overall resistance to cracking under progressive compressive loads. The results may be anomalous for aggregates with a total crush value of 30 or more, in which case the penalty value should be set to 10%.

The crushing value of aggregate is measured using this procedure. If the aggregate crushing value is low, then means the aggregate is rather sturdy. It's important that aggregates can withstand the weight of vehicles without being crushed. Inadequate aggregate might compromise the integrity of the pavement's foundation.

3.3.5 Specific Gravity of Coarse Aggregates (ASTM C127-12)

A material's specific gravity may be calculated by comparing its density to that of pure water at a particular temperature and pressure.

The specific gravity is calculated using the density bottle technique. The particles bulk specific gravity and absorption rate are very important in creating a high-quality asphalt mix. The percentage of asphalt binder in the mineral aggregates and the quantity of aggregates that are soaked up by the binder may be calculated from their bulk specific gravities.

Figure 3.4 Apparatus for Specific Gravity of Coarse Aggregates

3.3.6 Flakiness & Elongation Test (ASTM D 4791-99)

It's done to calculate how many flakes and how many lengthy particles there are. In the case of gravel, the angularity index is used. The flakiness index measures the proportion of a sample's mass that has a minimum dimension less than 0.6 times the average dimension. Aggregates bigger than 6.3mm may be tested for flakiness. The largest elongated particle size is more than 1.80 times its average size. The total angle is defined as the percentage of voids remaining in the assembly after a compression greater than 33%. Smoother, more easily worked, and crushed aggregates are the recommended choice for concrete pavements. The best interlocking and frictional properties in flexible pavements are achieved using angular-shaped aggregates.

Figure 3.5 Flakiness and Elongation Index Test Apparatus

3.3.7 Liquid & Plastic Limit Test (ASTM D4318 – 17)

This test can determine the plastic limit, liquid limit and plastic index of the soil. The fluid limit and the plastic limit of the soil are often referred to as the Atterberg limit.

These limits define the limits of the many consistency states of soils in terms of moisture content.

It is used in conjunction with other soil parameters to correlate engineering behavior, including compressibility, hydraulic conductivity (permeability), compaction, bulge-shrinkage, and shear strength, and to describe the exact fraction of soil and building materials. It can also be taken as an indication of its consistency or fluidity.

3.4 Bitumen Tests

3.4.1 Penetration Test (ASTM D5-95)

It measures the hardness or consistency of bitumen, which is useful in determining the quality of bitumen. Needle penetration value refers to the vertical distance at which a standard needle point enters or penetrates the asphalt material under certain pressure, time and temperature conditions.

It is one of the earliest tests for determining the consistency of asphalt binders. It determines the softness and hardness of a binder to categorize it into several standard classes. Soft and thin binder has a higher penetration value. Binder with a low penetration value is preferred in hot areas, while binder with a high penetration value is preferred in cooler climates.

Figure 3.6 Penetration Test Apparatus

3.4.2 Ductility Test (ASTM D113-86)

Bitumen's ductility is measured in centimetres by the distance it stretches before snapping when pushed apart at both ends at a constant speed and temperature. This test is performed in compliance with ASTM D113. The stretching and adhesion properties of the binder are assessed in this test. Bitumen's ductility is regarded as a key and significant physical characteristic. It depicts the behavior of bitumen as temperature changes.

Figure 3.7 Specimen for Ductility test

This test was carried out at a standard temperature of 25°C. When a standard sized binder specimen (put in a briquette with a 1 in 2 cross-sectional area) is pulled apart at a pace of 5 cm/minute and a temperature of 25°C, the distance it lengthens without breaking is called ductility. The specimen must be at least 100 cm long to pass the ductility test. Under high and frequent traffic pressures, asphalt mixes are made from less ductile bitumen fracture.

3.4.3 Softening Point Test (ASTM D36-2002)

In this part, we will be using some ball and ring gears. Thus, we can determine the exact temperature at which the asphalt material reaches the required level of fineness. The ASTM D36 standard is used to conduct this test using the ring and ball equipment. Although it is a viscoelastic substance, the bitumen softens with increasing temperature and its viscosity lowers. The temperature at which a sample of asphalt binder can no longer withstand the weight of a 3.5g steel ball when submerged in water. As a result, it is the average temperature at which two bitumen discs become sufficiently soft to enable steel balls to fall 25 mm.

Figure 3.8 Ring and Ball Apparatus

3.5 Flow & Stability Test

You can calculate the Marshall stability of an asphalt material if it is loaded at a rate of 50.8 mm/min. The test load increases to its maximum value. Stop charging and record the maximum charge (i.e. Marshall stability) when the charge starts to drop. A dial indicator is used to monitor the flow of plastic into the sample in response to the force applied during a load test. When a maximum load is applied, the vertical deviation is what the flow value measures.

Figure 3.9 Marshall Compaction Machine

Marshall stability is related to the resilience of the asphalt material against deformation, displacement, hysteresis, and shear loads. Internal friction and grip contribute greatly to stability. Internal friction refers to the interlocking resistance and friction of the aggregate, while cohesion refers to the bonding strength of the bonded materials. Because asphalt pavements sometimes experience heavy traffic loads, it is important to choose an asphalt material that is stable and permeable.

Figure 3.10 Flow and Stability Test Apparatus

3.6 Rutting Resistance Test

The rust resistance test measures the degree to which a wheel has been deformed by repeated contact with salt water. Road collapse is often caused by rutting, the most extreme kind of pavement degradation that may occur on asphalt. The pavement structure must provide adequate pavement support to prevent erosion, and the asphalt mix must be designed and constructed to provide a deformation-resistant pavement.

Rutting is a term for permanent deformation or cohesion that accumulates over time in an asphalt pavement; This is usually represented by wheel tracks carved into the road. Bumps (shears) of the pavement may occur on either side of the crack. The bumps are especially noticeable when filling with water after rain. There are three basic types of canyons: mixed canyons, terrain canyons, and dense canyons. Combination cracking occurs when the subgrade is not accurate but the road surface shows depressions in the walkway due to combined compression/design problems. Lower-layer yielding occurs when lower-layer loads show pits in the wheel tracks. In this case, the road surface sinks into the ground, creating less pressure in the wheel paths. Compaction occurs when pressure during construction is insufficient and the pavement compacts under traffic loads.

Figure 3.11 Rutting in Asphalt Pavement

Figure 3.12 Severe Mix Rutting in Asphalt

3.6.1 Wheel Tracker Test

A laboratory wheel tracker is used to conduct a simulated experiment to measure the mass of HMA by repeatedly rolling a small loaded wheeled dolly onto a prepared sample of HMA. Then, the performance of the test specimen is related to the performance of the pavement in actual use. Laboratory wheel trackers can be used for delay, fatigue, humidity sensitivity and calibration. Some of these instruments are relatively new and others are more than 15 years old, such as the French Root Tester (FRT).

In general, drilling and other measurements can be performed with these wheel trackers, but individual users must be careful in establishing the laboratory conditions (e.g., load, number of wheel passes, and temperature) that produce a correlation. They are consistent and accurate with field performance .

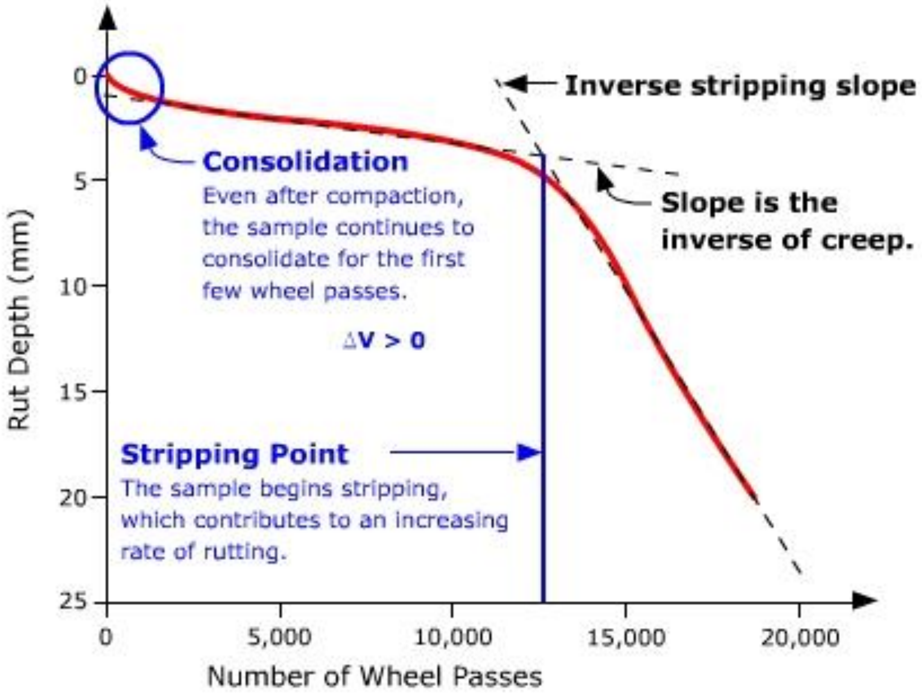
Figure 3.13 Hamburg Wheel Tracker Test Apparatus

The Hamburg Wheel Tracker (HWTD), developed in Germany, can be used to assess the potential for rotting and rubbing. The HWTD tracks the loaded steel wheels forward and backward directly on the HMA sample. Assays are typically performed on flat plates measuring 10.2 by 12.6 by 1.6 inches (260 by 320 by 40 mm) (although assays may be modified to use SGC compressed samples), a compressed linear 7% of the air is introduced into the blank vacuum with Use of

Typically, a 47-mm (1.85-inch) wide wheel running on a submerged (underwater) specimen for 20,000 revolutions (or up to a deflection of 20 mm) using a load of 705 N (158 lb) Continuous measurement of groove depth using an array from the LVDT on the specimen. Several modified HWTDs have been produced in the U.S. with the principal modifications being loading force or wheel type.

The following measures are evaluated in Hamburg wheel tracker Test:

- Collection after compaction. Root depth due to continuous melting is assumed to be 1000 load cycles.
- Sliding slope. After consolidation After consolidation, but before removal of the inflammatory spot, reverse the incision distance. The yield range was used to evaluate the fracture probability rather than the fracture depth, because the number of loading cycles at which moisture loss began to affect the fracture depth between the HMA and HMA components. No conclusions can be drawn from the graphs.
- Lower tipping points. tow ramps and peeling ramps. This can be used to assess the potential for moisture damage. If shell buckling occurs with a small number of loading cycles (e.g., less than 10,000), the HMA mixture may be susceptible to moisture damage.
- peeling edge. A cumulative measure of moisture damage. As with flow time and number of flows, a tertiary gradient may also occur in this part of the graph, but moisture loss is indistinguishable from viscous tertiary flow.



The HWTD correlates very well with field performance, especially moisture loss assessment, although it may not be able to discriminate some compounds.

Figure 3.14 Rut Depth versus Number of Wheel passes

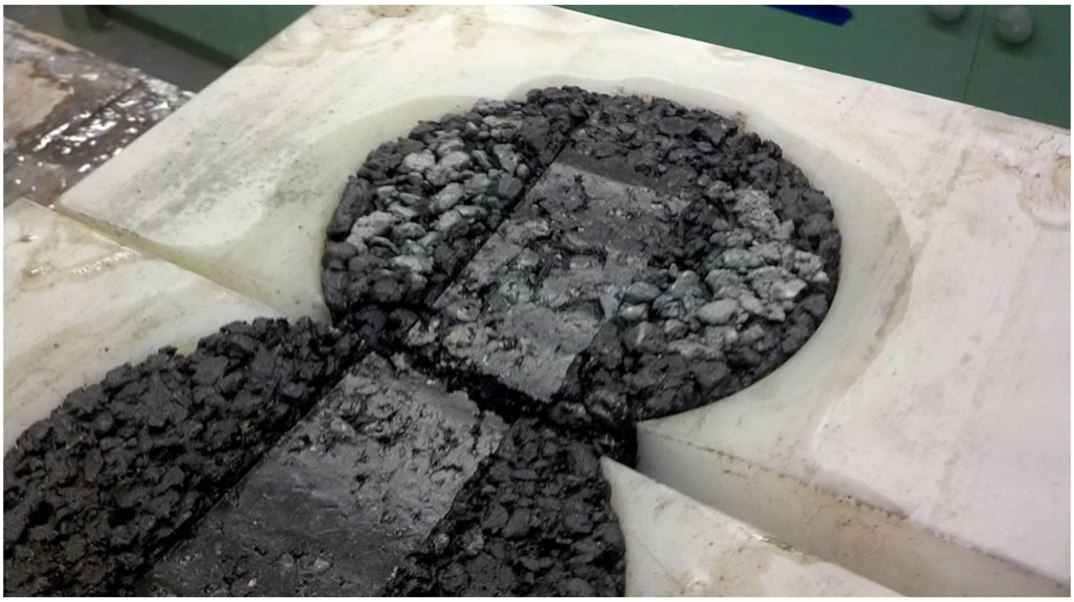


Figure 3.15 Sample being tested in Wheel tracker

Figure 3.16 Rutting comparison of two specimens

For the purpose of Hamburg Wheel Tracker Test, gyratory compacted specimens were produced in gyratory compactor. Specimens were prepared using the standard, ASTM D3496-99. Mixing was done in a mechanical mixer as recommended by the ASTM D6925. Mechanical Mixer ensures proper mixing of aggregate and bitumen at the specified temperature. After mixing, the mixture is transferred to a metal container for conditioning as recommended in AASHTO R 30-02. The mixture was conditioned for 2 hours prior to compaction at the compaction temperature. The metal container was placed in an oven set at a temperature of 135° C for a period of 2 hours. The mixture was hand-mixed in the metal container at an hour interval to ensure uniform conditioning of the sample. After conditioning, the mixture was transferred to the gyratory compactor mold as the compaction was done in a superpave gyratory compactor.

Figure 3.17 Gyratory compactor used for specimen preparation

The Gyratory compactor was set a gyratory angle of 1.26° for the compaction. The gyratory compaction of the specimen was initiated with a design gyration level of 125 since the mixture was designed for heavy traffic with a design ESAL ≥ 30 million.

Chapter 4

4. RESULTS & DISCUSSION

4.1 General

To evaluate the tear strength of the HMA specimens, several tests were performed. Results and details of the tests are given below.

4.2 Sieve Analysis (ASTM C-136)

Sieve analysis of coarse aggregates was carried out in Transportation laboratory. Job mix formula was prepared to check whether the different sizes of aggregates and proportions were according to NHA Class B specifications.

4.2.2 Aggregate Impact Value Test (ASTM D5874-02)

This test was conducted at Transportation lab in order to evaluate the resistance of coarse aggregates against impact loading. Results are given below.

Table 4.1 Aggregate Impact Value Test Results

Wt of (Agg+Pan)		3736.1 gm	Range
Wt of Pan		3090.8 gm	
Total Wt of Dry Sample(W1)	3736.1 - 3090.8	645.3 gm	
Wt of Portion Passing 2.36 mm Sieve (W2)	299.4 – 253.4	46 gm	
Agg Impact Value (Percent)	W2/W1 x 100	7.128 %	Less than 30 % (Excellent)

4.2.3 Los Angeles Abrasion Test (ASTM C 535)

Tests are conducted with the help of a Los Angeles Abrasion Tester to determine the wear resistance of the assembly. Aggregates are subject to erosion due to vehicular traffic on highways. This test is useful to check the resistance the aggregates selected can offer to the wear and tear caused by moving vehicles to the pavement surface.

Table 4.2 Los Angeles Abrasion Resistance Test Results

Wt. of Agg(W1)		5000 gm	Range
Wt. of Agg Passing from Sieve#2 (1.75mm) (W2)		793.3 gm	
% Agg Passing	(W2/W1) x100	15.8%	Less than 30%

4.2.4 Aggregate Crushing Value Test (BS: 812)

Aggregate crushing value test was performed to determine the crushing value of aggregates. The results are as follows:

Wt. of dry sample before test, W1 = 3000 gm

Wt. of fines passing from 2.36 sieve after test, W2 = 850 gm

% Agg Crushing Value = (W2/W1)x100 = 28%

Range: less than 30%

4.2.5 Specific Gravity of Coarse Aggregates (ASTM C127-12)

Specific gravity is the ratio of the weight of a given volume of substance in air at standard temperature to the weight of an equal volume of distilled water in air at the same given temperature. Used to determine the specific gravity of coarse aggregate.

Table 4.3: Specific Gravity of Coarse Aggregates

Aggregate Size	Specific Gravity
3/4 inch	2.66
1/2 inch	2.51
3/8 inch	2.71

4.2.6 Specific Gravity of Fine Aggregates

Specific gravity test results for the fine aggregates used in this study are presented in Table 4.4 below.

Table 4.4: Specific Gravity of Fine Aggregates

Aggregate Type	Specific Gravity
Crushed Sand	2.57
Filler	2.40

4.2.7 Flakiness & Elongation Test (ASTM D 4791-99)

This test is used to determine the particle shape of the groups and their preferred particle shape under certain conditions. How well particles of the same size pack together depends on their shape. Volatile and elongated particles reduce the workability of concrete mixtures due to their high surface area/volume ratio.

Unstable elongated particles are not suitable for rough foundation structures, as they can cause weaknesses and can fracture under heavy loads. Results are as follows.

Table 4.5: Flakiness & Elongation Results

Aggregate Size	Flakiness	Elongation
3/4 inch	12.44%	7.03%
1/2 inch	10.31%	8.92%
3/8 inch	11.67%	10.82%
Passing Sieve No. 4	10.44%	-

4.3 Test on Bitumen

4.3.1 Penetration Test (ASTM D5-95)

It is used to find the hardness or consistency of bitumen which helps in evaluating the grade of bitumen. Tests carried out on the bitumen used in the HMA samples gave the following results.

Period of cooling in room = 1 hr

Room temperature = 25

Water Bath Temperature = 25

Load = 100 gm

Table 4.6 Penetration Test Results

S.NO	Readings	Grades
1	47	60/70
2	50	60/70
3	52	60/70

4.3.2 Marshall Mix Design

The basic concept of the Marshall-Mix design method was first proposed by Bruce Marshall of the Mississippi Department of Highways around 1939 and later refined by the U.S. Army. About 38 states currently use this method. Marshall in a way.

The Marshall method seeks to select an asphalt binder content that satisfies the required density for the lower range of stability and flow values. The Marshall Mix design process includes the following basic phases.

- Selection of asphalt aggregates and binders, preparation of samples (including compaction),
- Stability assessment
- Density and void calculations
- Includes choosing the optimal content of the asphalt binder.

4.3.3 Flow & Stability Tests (ASTM D6927)

Marshall stability measures the maximum load that an asphalt material can support. Marshall stability is related to asphalt materials' resistance to deformation, displacement, hysteresis, and shear stress.

Stability comes primarily from friction and internal cohesion. Cohesiveness is the binding force of materials, while internal friction is the interlocking and frictional resistance of aggregates.

Flow & stability tests were performed with increments of 0.5% of binding material used in HMA samples. These tests were performed to determine the optimal binder content (OBC) to use in HMA samples. The results produced are given below.

Table 4.7: Determination of OBC

% Bitumen Content by Mass of Aggregate	3.50	4.00	4.50	5.00
Unit weight (G_{mb})	2.336	2.339	2.356	2.352
Maximum theoretical specific gravity (G_{mm})	2.493	2.462	2.465	2.426
Stability (kN)	9.14	9.91	10.48	10.89
Air voids (% V_a)	6.29	5.01	4.46	3.04
VMA %	14.05	14.39	14.24	14.82
VFA %	55.27	65.22	68.70	79.48
Flow (mm)	1.97	2.30	2.67	2.90

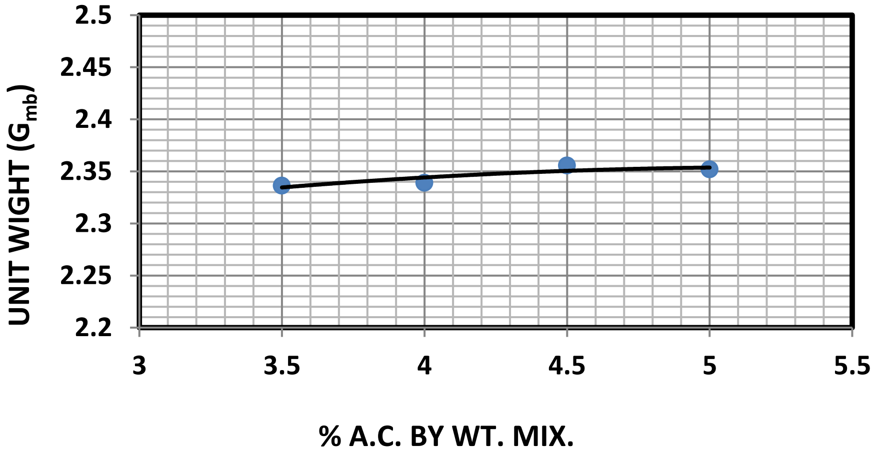


Figure 4.1 AC vs Gmb

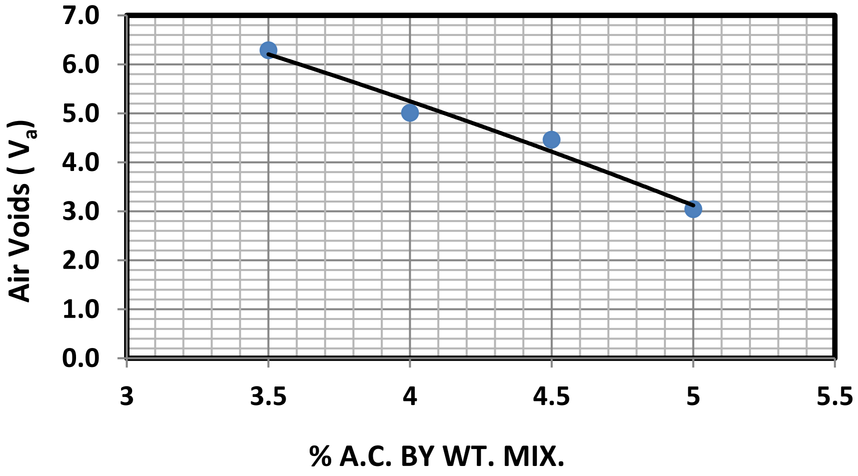


Figure 4.2 AC vs Va

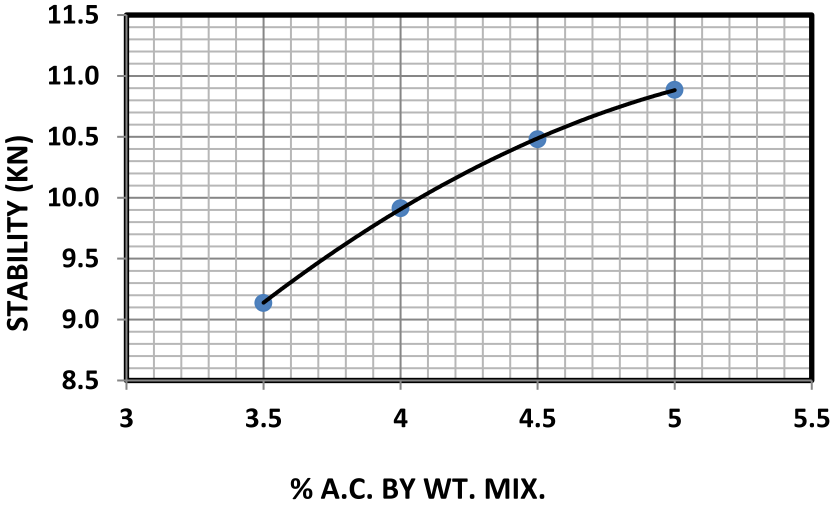


Figure 4.3 AC vs Stability

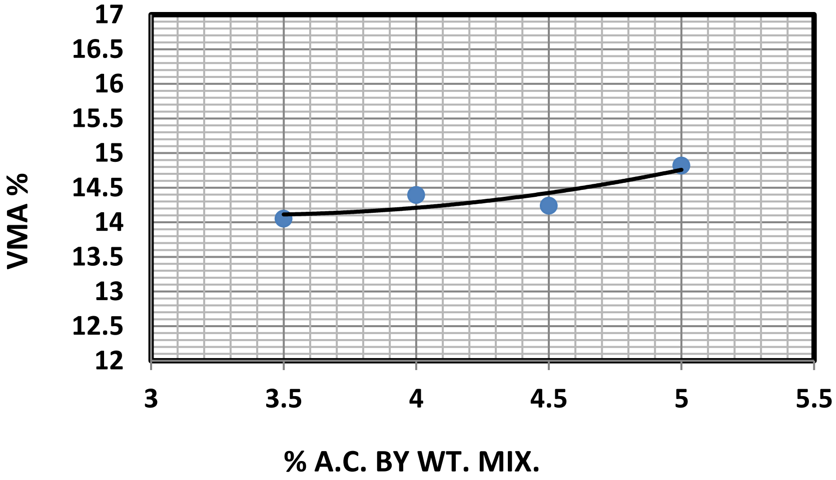


Figure 4.4 AC vs VMA

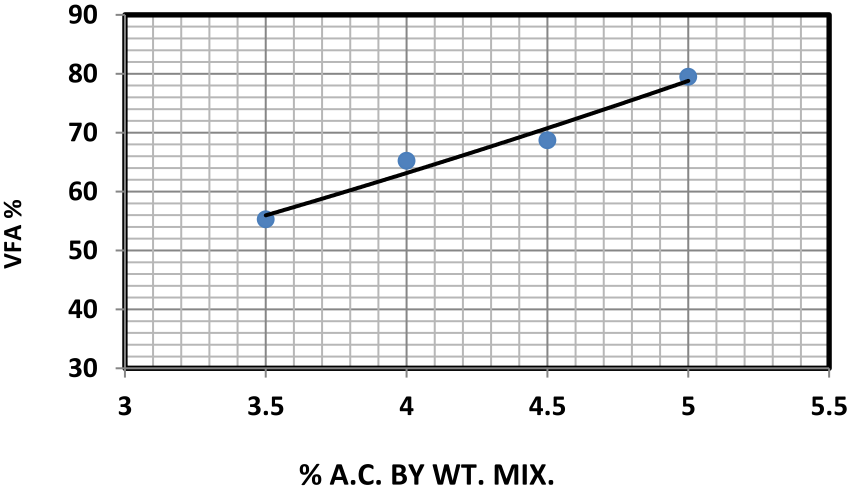


Figure 4.5 AC vs VFA

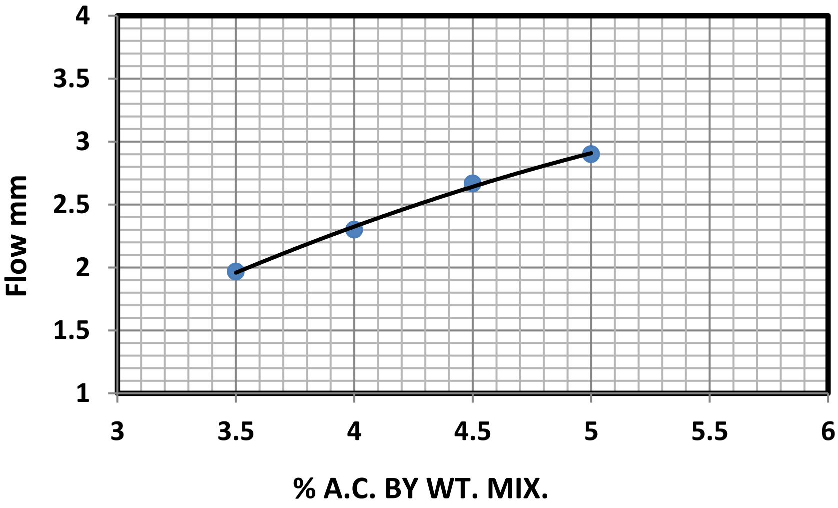


Figure 4.6 AC vs Flow

Table 4.8: Flow & Stability Results at OBC

Test	Unit	Test results	Specification	Test	Unit	Test results	Specification
No. of blows		75	75	Flow	Mm	2.53	2.0 - 5.0
% Bitumen by weight of mix	%	4.5	-	Marshal quotient	N/mm	436.3	-
Bulk Density of Mix (Gmb)	G/cc	2.338	-	% Air Voids	%	4.4	4 – 7
Stability	N	1105	7840	%VMA	%	14.8	14-16

Table 4.8 shows the results of HMA standard samples prepared at OBC. It can be seen that the results comply with specifications. The Flow value is within the allowable range of 2.0 - 5.0. Similarly, the Air Voids are also within the provided range as per specification. The Voids in mineral aggregate (VMA) are also within the range. These results produced show that the results comply with specifications.

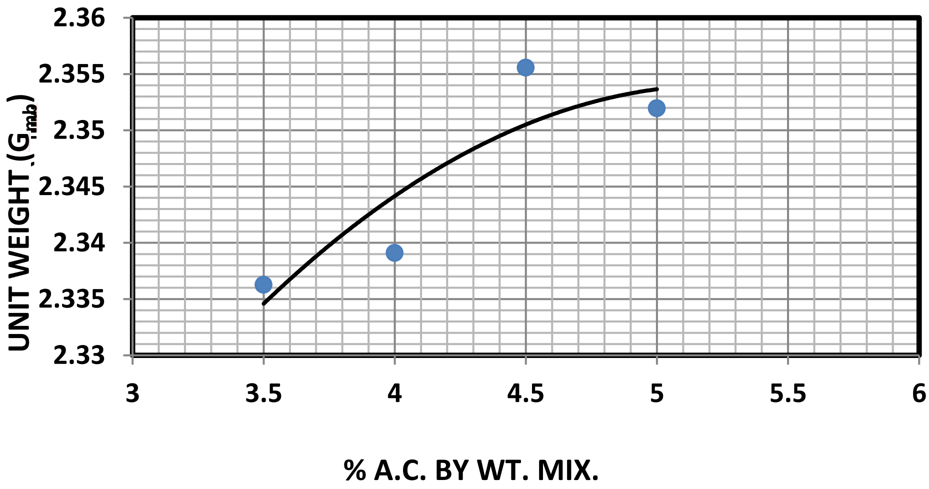


Figure 4.7 AC vs Gmb

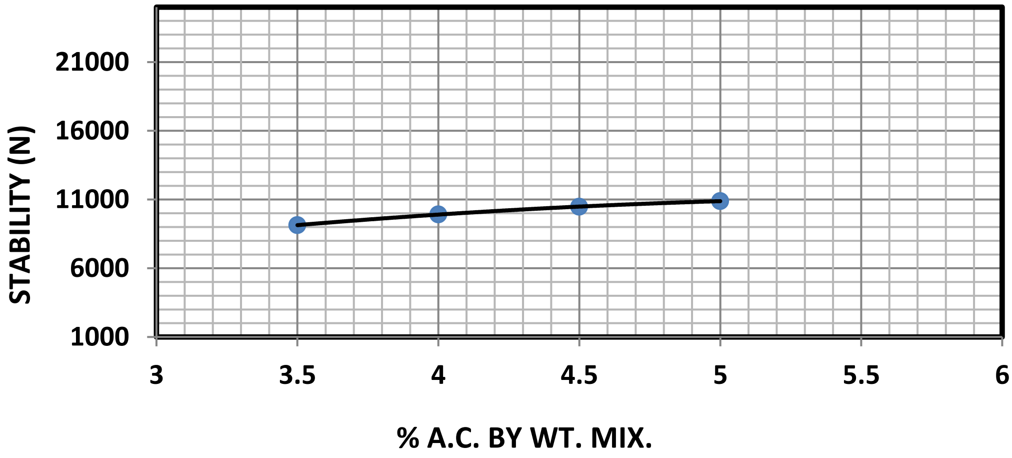


Figure 4.8 AC vs Stability

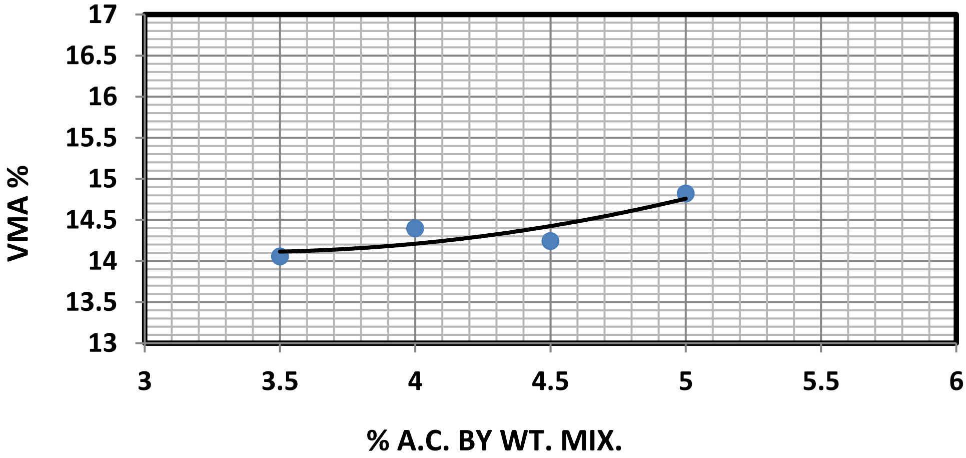


Figure 4.9 AC vs VMA

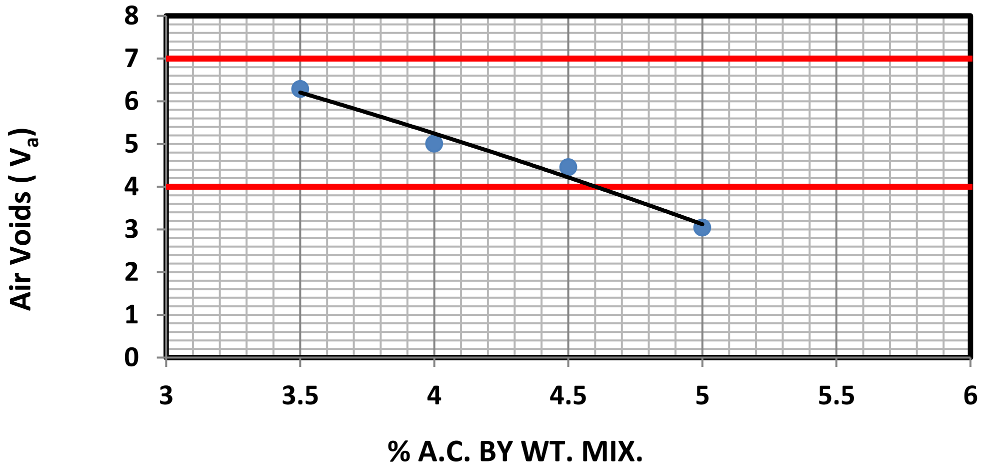


Figure 4.10 AC vs Va

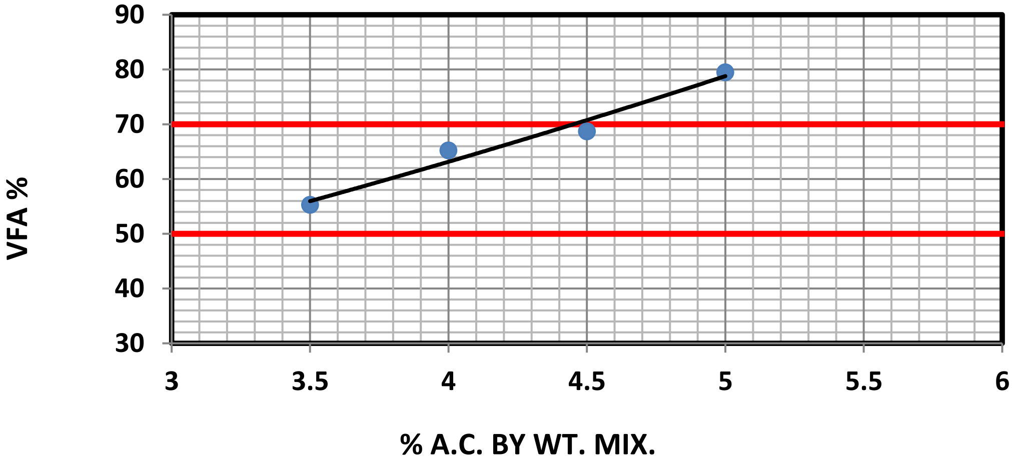


Figure 4.11 AC vs VFA

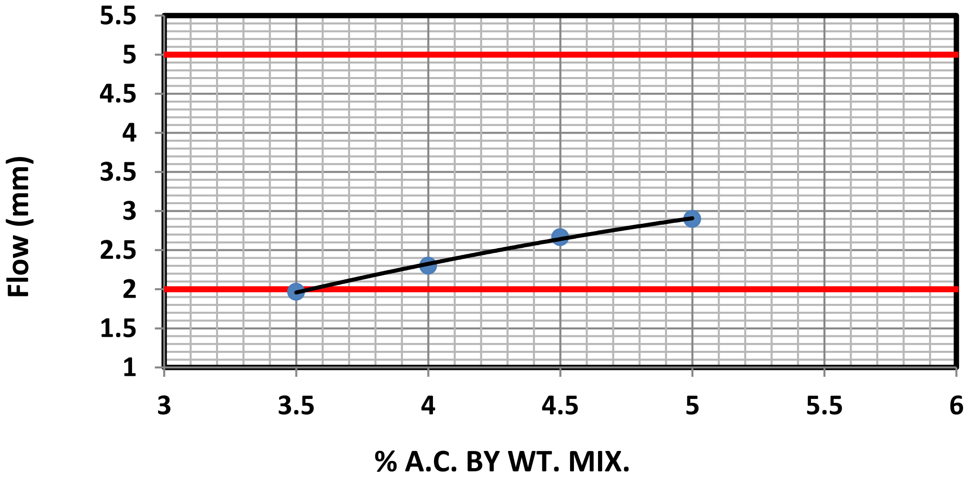


Figure 4.12 AC vs Flow

The graphs above indicate the results of HMA samples prepared at optimum binder content. The red lines show the upper and lower limits of NHA Class B specifications. The results of binder content Vs stability, VMA, VFA, Va, Flow, unit weight must comply these specifications.

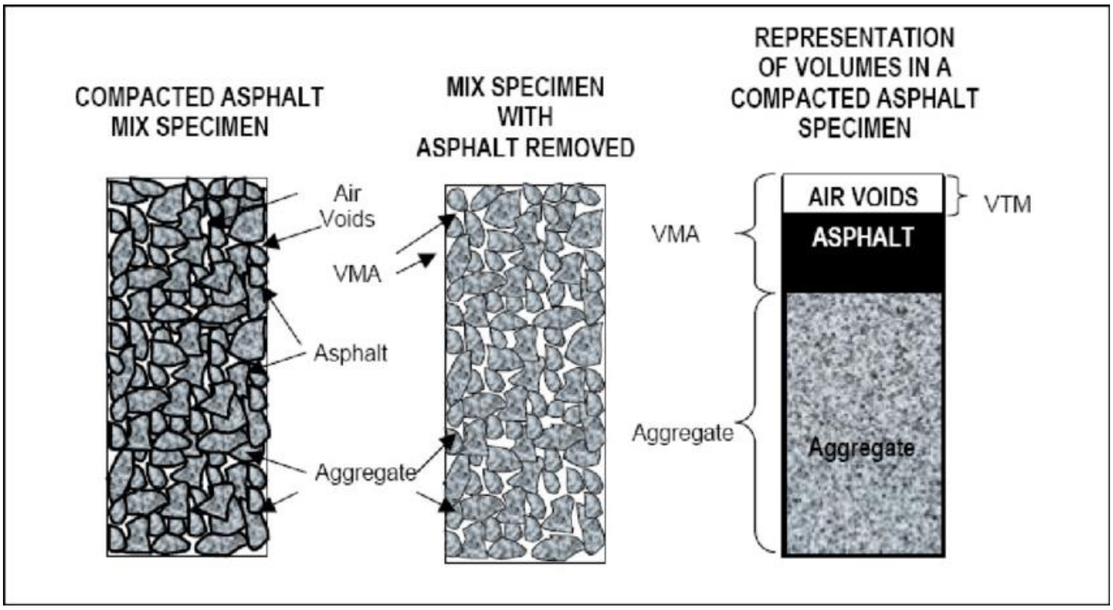


Figure 4.13 Volumes in compacted Asphalt specimen

4.4 Verification of Design

Table 4.9: Design Verification of HMA Samples

			Stability		
Stability	Mold No.		1	2	3
	Dial Reading	No.	190	210	200
	Stability	N	10298	11382	10840
	Volume Correction Factor		1	1	1
	Correction Stability	N	10298.0	11382.0	10840.0
	AVERAGE CORR. STABILITY	Kg	1105.4	(Min. 1000 Kg).	
Flow	Dial Reading		250	240	270
	Flow Individual	mm.	2.5	2.4	2.7
	Average Flow	mm.	2.53	Specification 2.0 - 3.5	

Table 4.9 indicates the results of samples prepared at OBC. These samples are prepared for the purpose of verification of NHA specifications.

4.4.1 Verification of Results (NHA Specifications)

Table 4.10: Verification of Results at OBC

Property	Values At Optimum Asphalt content	NHA Specification		Remarks
	4.4%	Min	Max	
Number of Blows	75	75		
Unit Weight (Gmb)	2.338			
Stability (Kg)	1105	1000 Kg	___	Comply
Air Voids (%)	4.4	4	7	Comply
Percentage of Voids in Mineral Aggregate (VMA %)	14.8	14	16	Comply
Percentage of Voids Filled with Bitumen (VFA %)	70	50	70	At Limit comply
Flow (mm)	2.5	2	3.5	Comply
Marshal Quotient (Newton/mm)	436.3	___	___	
Filler / Bitumen Ratio %	0.91	___	___	

Table 4.10 shows the results of samples prepared at OBC and it can be seen that all these results comply with NHA specifications.

4.5 Dynamic Stability

Resilient pavement has a property called dynamic stability which indicates its resistance to abrasion. These are the dynamic stability results for conventional plastic sheets and CNTs.

4.5.1 Waste Plastic Films:

In the Marshall Mixer, bitumen and aggregates were first combined at 160° C. Waste plastic film was subsequently added at 0.1, 0.2, 0.3 and 0.4 wt%. Three samples from each percentage were used to generate a total of 12 samples, which were then analyzed on a wheel tracker. Table 4.8 displays the dynamic stability findings that were made. The proportion of plastic waste increases with dynamic stability, but only up to 0.2%, after which it decreases, as demonstrated by Rokade. This is because there is a strong bond between asphalt and aggregate, which weakens if we add more plastic waste to the mix.

Table 4.11. Plastic Waste values for Dynamic Stability

Serial	0%	0.10%	0.20%	0.30%	0.40%
1	1810	3010	7865	5260	4972
2	1713	2749	7010	4836	4635
3	1740	2635	7010	5240	4861
Average	1761	2798	7282	5125	4829.23

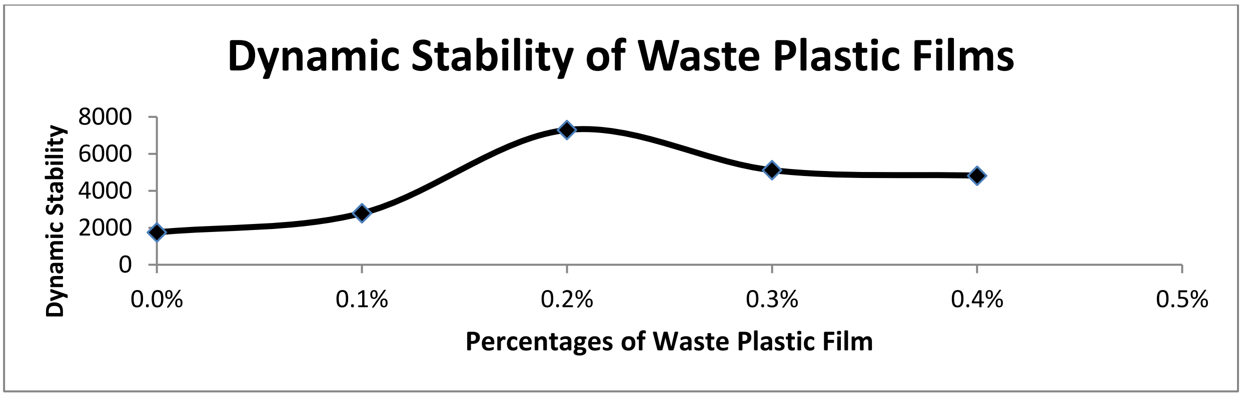


Figure 4.14 Dynamiic stabillity against Plastic

Figure 4.14 also includes a Rockad support, which insists that the dynamic stability of the plastic bed rises with the amount of plastic bed, but only up to 0.2%, after which the dynamic stability decreases with the amount of plastic bed. development of plastic film beds.

Figure 1 shows that waste plastic films have stronger dynamic stability than typical samples. The same can be found in the work of Vasudevan et al. By using plastic waste sheets in a percentage of 0.2%, we can enhance dynamic stability.

4.5.2 Dynamic Stability of Carbon Nano Tubes:

In a Marshall Mixer set at 160° C, the first bitumen and aggregate were combined. Carbon nanotubes are included in weight percentages of 0.1, 0.2, 0.3, and 0.4. A wheel tracker was used to evaluate 12 samples, creating 3 samples per %. As shown in Table 6, the following dynamic stability results are evident. Dynamic stability boosts with growing carbon nanotube content, Arabani and Farmarzi found the same, but after 0.3%, dynamic stability decreases with increasing carbon nanotube content. Since the connection of asphalt and aggregate is very strong, the bond weakens as the amount of plastic debris increases. According to Agzenai et al., carbon nanotubes may also help asphalt self-heal.

Table 4.12 CNT values for Dynamic Stability

Serial	0%	0.10%	0.20%	0.30%	0.40%
1	1810	5230	5717	9010	7020
2	1713	5240	7673	9020	7845
3	1740	6310	7020	12630	6330
Average	1761	5610	6813	10230	7078

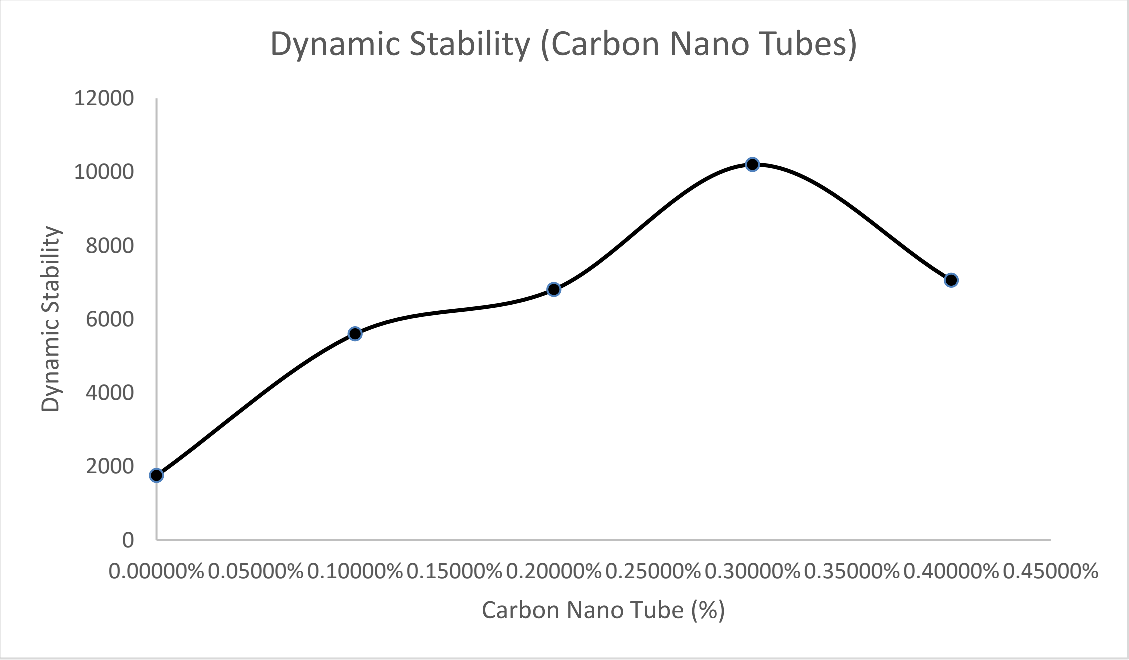


Figure 4.15 Dynamic Stability against CNTs

Figure 4.2 insists that the percentage of carbon nanotubes in plastic debris increases with the proportion of dynamic stability, but only up to 0.3%, after which the dynamic stability decreases [8]. Furthermore, it has also been shown that the dynamic stability of CNTs is better than that of neat samples.

4.5.3 Comparison:

Comparison of normal asphalt (0%), waste plastic flakes added in different proportions, and CNTs blended in various proportions reveals the dynamic stability values of each. The highest values found at various percentages are listed below.

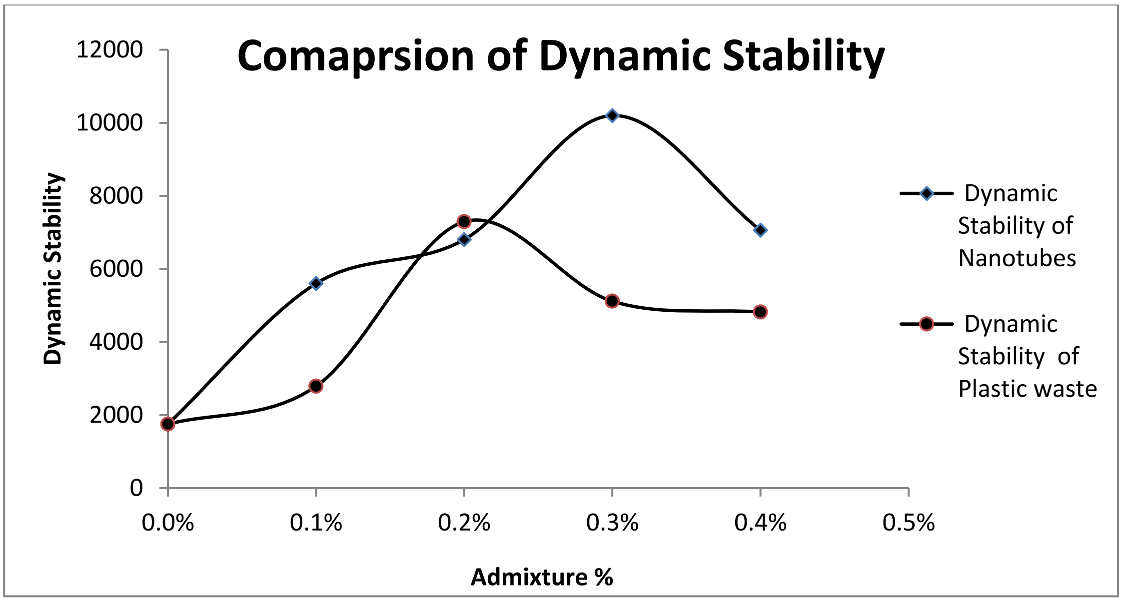


Figure 4.16 Dynamic stability w.r.t changing CNTs and Plastic waste quantity

4.6 Rutting:

Rutting is the term used to describe the distortion brought on by excessive traffic along a vehicle's wheel. These are rutting values for garbage, plastic, and common carbon nanotubes.

4.6.1 Waste plastic films:

In the Marshall mixer at 160 OC, bitumen and aggregates were first combined. Following that, waste plastic sheets were introduced at weight percentages of 0 %(neat), 0.1%, 0.2%, and 0.3%. Three specimens are created for every %, resulting in 12 total, and the Wheel tracking equipment is used to test these samples. According to Table 7, the following rutting values are seen. The slit decreased as the amount of plastic waste increased, but only by a maximum of 0.2% after the increase. Huang et al. reported similar findings. D1 is the species noted at 45 min and D2 is the species discerned at 60 min.

Table 4.13 Plastic waste values for Rutting

Serial	0%		0.10%		0.20%		0.30%		0.40%	
	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2
1	3.79	4.34	3.12	3.33	2.32	2.51	3.42	3.34	3.61	3.75
2	3.61	3.78	3.21	3.24	2.45	2.24	3.38	3.51	3.22	3.43
3	3.35	3.91	3.32	3.46	2.27	2.36	3.25	3.37	3.55	3.49
Average	3.88		3.48		2.33		3.54		3.42	

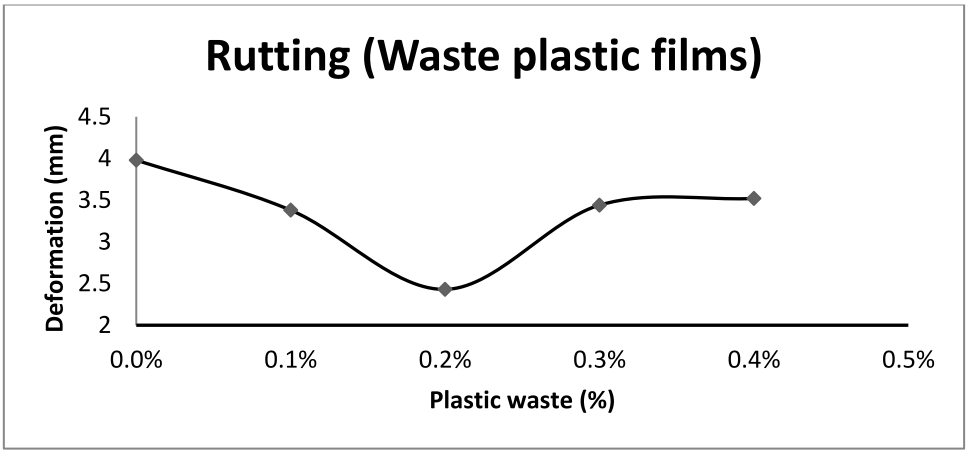


Figure 4.17 Deformation (mm) against Plastic waste

Figure 4.17 presents how the fractional value of plastic waste lowers as the plastic content increases, but only by 0.2%. It is seen that the tear value increases with increasing plastic waste content. It also shows that the tear value of the plastic is less than the neat specimens. If we want to use 0.2% plastic waste then the waste will be less because it is a good way to recycle plastic.

4.6.2 Rutting values of Carbon Nano Tubes:

In a marshal mixer set at 160° C, the first bitumen and aggregates were combined. The percent modification of CNTs were 0% (conventional), 0.1%, 0.2%, 0.3% and 0.4%. Three samples for each % are used to create 15 total samples, which are subsequently examined using a wheel tracking system. As reported in Table 8, the following rutting values findings were noticed. Rutting decreases with increasing percentage of carbon nanotubes, but this effect only persists at an additional 0.3%. D1 is the deviation measured at 45 mins and D2 is the deviation measured at 60 mins.

Table 4.14 CNT values for Rutting

S.No	0%		0.10%		0.20%		0.30%		0.40%	
	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2
1	3.99	4.34	3.11	3.23	2.23	2.54	2.11	2.18	2.42	2.31
2	3.61	3.78	3.32	3.34	2.43	2.312	1.35	1.62	2.14	2.42
3	3.25	3.61	3.25	3.45	2.34	2.23	1.66	1.51	2.24	2.35
Average	3.78		3.31		2.43		1.84		2.26	

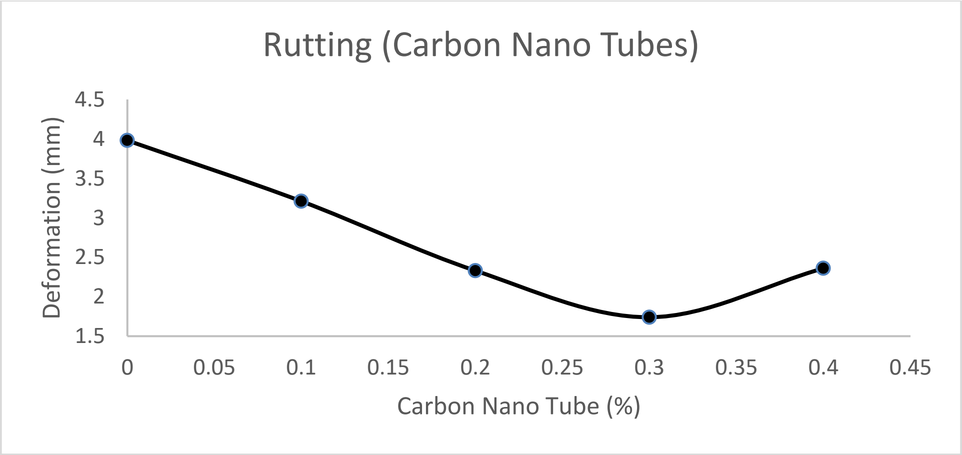


Figure 4.18 Deformation (mm) against CNTs

Figure 4.18 illustrates how, up to a percentage of 0.3%, the rutting value of carbon nanotubes reduces as the percentage of carbon nanotubes rises. After that point, the rutting value increases. Additionally, it demonstrates that carbon nanotubes have a lower rutting value than typical samples.

4.6.3 Comparison:

Fractionation values of conventional asphalt (0%), CNT modified and plastic waste modified asphalt proportions were compared to determine the optimal mixture. The highest values found at various percentages are listed below.

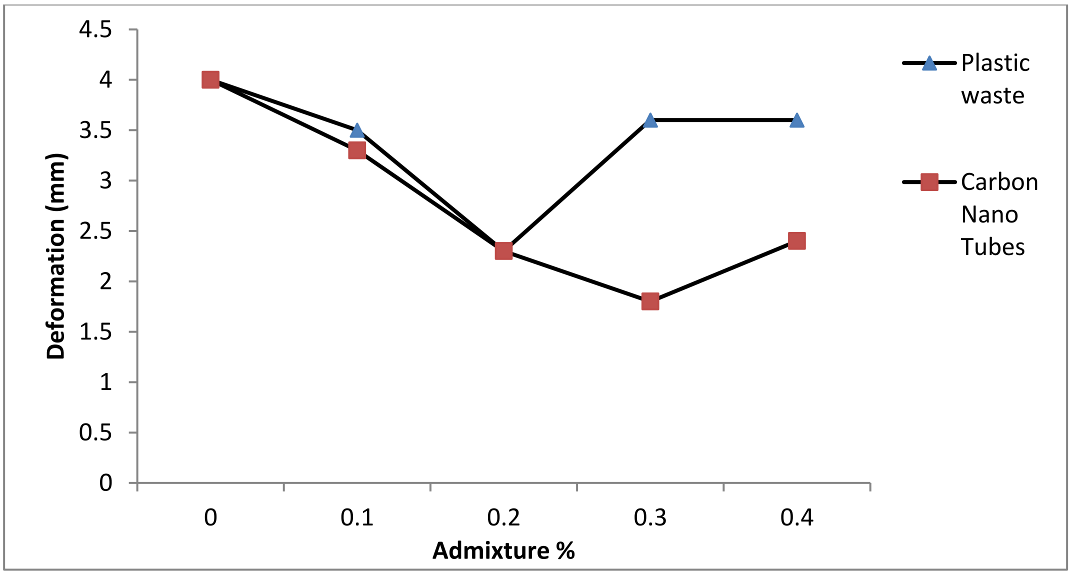


Figure 4.19 Deformation(mm) w.r.t changing CNTs and Plastic waste quantity

If we compare the value of grooves for plastic with the value of traditional fragmentation, the value of crushing for waste plastic is much lower than the value of traditional fragmentation. Figure 4.19 shows that 0.3% of carbon nanotubes have lower doping values compared to 0.2% of waste plastics and conventional materials. This demonstrates that plastic may be utilized to lessen rutting in asphalt by acting as an excellent modifier. Additionally, using plastic in asphalt to prevent rutting might make the job less expensive. Get rid of these non-biodegradable materials, and the environment will be sustainable.

Chapter 5

5. RECOMMENDATIONS & CONCLUSIONS

5.1 Conclusions

We may draw the conclusion that bitumen changed with carbon nanotubes and plastic is more dynamically stable than bitumen that has not been modified. The same is true for asphalt mix compositions. Additionally, up to 0.2% and 0.3%, respectively, the ratio of plastic nanotubes to carbon consistently improves the dynamic stability Thereafter, however, the dynamic stability decreased with increasing percentages of plastic and carbon nanotubes. Compared to typical asphalt mix, carbon nanotubes and plastic have reduced rutting values. The rutting value increased with the carbon nanotube to plastic ratio, but when it exceeded 0.3%, the rutting value decreased.

5.2 Recommendations

The recommendations offered for future consideration are presented below.

- Further strength evaluation tests (unconfined compressive strength testing) are recommended to confirm further improvements in the strength performance of the HMA.
- CNT and Plastic waste can be used to enhance ageing properties of Bitumen onus Mixture.
- Asphalt that has been modified with CNT and plastic waste can increase resilient modulus.
- Carbon and plastic nanotubes can be utilized for improvement of asphalt.

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