Jimma University

Jimma Institute of Technology

School Of Graduate Studies

Faculty of Civil and Environmental Engineering

Department of Civil Engineering

Construction Engineering and Management Chair

INVESTIGATION ON MATERIAL QUALITY OF ASPHALT LAYER IN JIMMA TOWN ROAD PROJECT

By: Bikila Megersa

A Thesis submitted to the School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Construction Engineering and Management.

May, 2018

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Co-Advisor: Ing. Asmare Molla

May, 2018

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SCHOOL OF POST GRADUATE STUDIES JIMMA UNIVERSITY

As a member of the examining board of the final MSc open defense. We certify that we have read and evaluate the thesis prepared by Bikila Megersa Entitled "**Investigation on Material Quality of Asphalt Layer in Jimma Town Road Project"**; and recommended that it be accepted as fulfilling the thesis requirement for the degree of Master of Science in Construction Engineering and Management.

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DECLARATION

I, the undersigned, declare that this thesis entitled "**Investigation on Material Quality of Asphalt Layer in Jimma Town Road Project"** is my original work, and has not been presented by any other person for an award of a degree in this or any other University, and all sources of material used for theses have been dually acknowledged.

Candidate:

Mr.BikilaMegersa

Signature_______________

As Master research Advisors, we hereby certify that we have read and evaluate this MSc research prepared under our guidance, by Mr. Bikila Megersa entitled: **"Investigation on Material Quality of Asphalt Layer in Jimma Town Road project"** We recommend that it can be submitted as fulfilling the MSc Thesis requirements.

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ABSTRACT

Roads contribute to regional cohesion by playing a prominent role in the geographic distribution of economic growth and wealth. Generally, zones with high job densities are located near major road arteries because of the businesses' need for easy access to suppliers, customers and employees. Those roads may construct either in Flexible pavement or rigid pavement. Flexible pavement is one of the most important infrastructures that involve multiple layers of different materials subjected to non-uniform traffic loadings and varying environmental conditions. The repetitive traffic loadings that the road experiences during its service life, combined with temperature fluctuations, cause rutting, fatigue and other forms of deteriorations, which ultimately degrade the performance and durability of pavement structures. Both traffic volume and loads are increasing from year to year with rapid rate.

This study emphasizes on the material quality of asphalt layer which is constructed in Jimma town, either the failure due to material quality or due to construction management which is workmanship, leadership problem. From this point of view the main objective of the research is to investigate the material quality of asphalt layer.

According to test procedure specified by ASTM D1559 several hot asphalt mixture were prepared, the aggregate blend made by Job mix formula to obtain the percentage of mix material is give Hot-bin one is 26%, Hot-bin two is 23%, and Hot-bin three 51% where hot-bin one is (20-13.2mm), hot-bin two (13.2-5.0mm) and hot-bin three (5.0-0.00mm).

The result of Marshall Test on mix design for hot asphalt mixture, for wearing coarse were conclude that the material used for mix design is good, which gives Marshall stability, 12.57 KN with optimum bitumen content of 5.2% (by weight of total aggregate). Hence the quality of aggregate is good but the influence of other factors such us poor drainage courses, level of ground water table, Varity of geological materials along the road rout and poor construction methodology caused the defect.

The flow result of the Marshall mix design gives as 3.6 % which is approach of upper limit of specification 4%, So when flow become high in the mix it result long term deterioration of asphalt performance, hence the pavement condition along the study area has been affected by different failure types such as cracks, surface defect and disintegrating from site observation may result of this.

Finally a possible remedial measure is recommended for every observed result is to minimize the value of the flow in the Marshall mix design either by minimizing the bitumen content or adding additional filler to the hot-bin material and failures or distress on the pavement condition of the study area in order to sustain the design life of the pavement.

Key words; Hot-bin, Aggregates, Flexible pavement, Asphalt layer, Hot Asphalt mix design , Optimum bitumen content, Marshall Mix Design.

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ACRONYMS

AASHTO	American Association of State Highways and Transport Officials
AC	Asphalt Concrete
ASTM	American Standard for Test Method
ATPB	Asphalt Treated Permeable Base
BC	Binder Content
BS	British Standard
CBPD	Cement by Pass dust
CBR	California bearing ratio
DC	Data Collector
DEC	Data Entry Clerk
DGA	Dense Graded Asphalt
DGM	Dense Graded Mix
ERA	Ethiopian Roads Authority
ERCC	Ethiopian Road Construction Corporation
HMA	Hot Mix Asphalt
HMAC	Hot Mix Asphalt Concrete
JIT	Jimma Institute of Technology
JMF	Job Mix Formula
Mb	Mass of Binder in Specimen
OGFC	Open Graded Friction Course
OGM	Open Graded Mix
OPC	Ordinary Portland Cement
Pb	Total Asphalt Binder content
PI	Personnel Investigator
RA	Research Assistant
RSDP	Road Sector Development Program
SMA	Stone Matric Asphalt
VMA	Void in Total Mix

CHAPTER ONE

INTRODUCTION

1.1 Background

A highway pavement is a structure consisting of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to distribute the applied vehicle loads to the sub-grade. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favourable light reflecting characteristics, and low noise pollution. The ultimate aim is to ensure that the transmitted stresses due to wheel load are sufficiently reduced, so that they will not exceed bearing capacity of the subgrade.

Highway Roads are one of society's most essential components. Without them, it would be very difficult to get from one place to the other in a timesaving and smooth way. Roads are therefore facing a major challenge in order to deliver these functions and consequently increase the quality of life. In order to fulfil these functions, roads must be properly designed and durable. However, there are roads built on weaker subgrade material and thus perform worse and cause losses in both serviceability and economy.

Therefore, in recent decades, further demands on the design of roads have been made. Thus the construction costs shall be reduced and the miscellaneous maintenance work performed in small extent as possible. The major causes of loss in the serviceability and maintenance work is rutting and surface roughness [1]. Road sector construction projects in Ethiopia are means through which development strategies are achieved. Development strategies which are fulfilled through successful road projects out end to import accessibility of urban areas, lower costs associated with transport maintenance and open more areas for development activities. Road projects, involving large amount capital, also contribute to the total economy through job creation and in a ripple effect to other business activities. The traffic volume and traffic loads on these roads are getting higher. Hence there have multi problems which are caused by poor quality subgrade or material used for construction. In large cities, the problem becomes one of the challenges for the economic activity of the country [8].The function of road pavement is to provide a safe, comfortable, convenient and economical running surface for the passage of fast moving traffic [10].Pavement performance evaluation is an important activity in the maintenance and rehabilitation works. It includes evaluation of existing distresses, road roughness, structural adequacy, traffic analysis, material testing and study of drainage condition. This section deals with types of bituminous surfaces, types and causes of distresses.An ideal pavement should meet the following requirements:

Sufficient thickness to distribute the wheel load stresses to a safe value on the sub-grade soil, Structurally strong to withstand all types of stresses imposed upon it, Adequate Smooth surface to provide comfort to road users even at high speed, Produce least noise from moving vehicles, Dust proof surface so that traffic safety is not impaired by reducing visibility, Impervious surface, so that sub-grade soil is well protected, and Long design life with low maintenance cost [21]. A typical flexible or bituminous pavement structure consists of the following pavement courses: sub-base, base, and bituminous wearing surface. The wearing surface is the uppermost layer of the pavement structure. In a flexible pavement, it is a mixture of bituminous binder material and aggregate. The binder may be sprayed on the surface followed by application of aggregate and referred to as a bituminous surface treatment. The binder and aggregate may be mixed in a central plant or mixed in place on the road and referred to as hot or cold mixes. The wearing surface may range in thickness from less than 2.5cm, as in the case of a surface treatment, to several centimeters of high-quality paving mixture such as hot-mix asphalt concrete [4].
The wearing surface has four principal functions: to protect the base from abrasive effects of traffic, to distribute loads to the underlying layers of pavement structure, to prevent surface water from penetrating into the base and sub-grade, and to provide a smooth riding surface for traffic [2].To make asphalt with recommended strength it needs proper proportioning of the ingredients and the right selections of materials to ensure a long-lasting asphalt structure that does not require always excessive maintenance in the future. This study will conduct laboratory experiment on asphalt (wearing surface) making ingredients mainly bitumen and aggregate which helps to know the strength of normal asphalt.

1.2 Statement of the problem

Material quality of wearing course affects the overall performance of all layers of roads such as base course, sub base and subgrade. A road is designed for parameters like traffic, surrounding atmospheric condition, and material property based on certain design principles and the standard for the intended use of the road.

Pavement failure of roads in Ethiopia is becoming a common problem and great challenge, consuming a lot of money, in some cases failure is appearing even before the completion of a project in certain road projects. In most projects road surface condition defects like rutting, cracking and surface deformation are common before the design life and require a lot of maintenance cost. Under low volume road context and other higher standard roads to have better performing and long lasting nature of the road is basically depends on the material it wears; therefore studying the performance of the road surface material is key to the selection of alternative Asphalt materials with better load bearing capacity and longevity [13]. So, the purpose of this study will focus on the study of the performance of asphalt layer material used as the wearing surface of the road, taking a case study of the Jimma town road having selected aggregate, mineral filler and bitumen material located at the road of Jimma town.

1.3 Research question

- What are the Engineering properties of asphalt layer material are effects on asphalt performance?
- Does the mix design property give good result when worked with Marshall Mix design?
- Is the material is acceptable when we compare with ERA standard?

1.4 Objectives

1.4.1 General objectives

The general objective of the study is to investigate the material quality of the asphalt layer used in Jimma town, considering asphalt layer of the pavement.

1.4.2TheSpecific objectives of the Study

- To investigate the engineering properties of the asphalt layer material.
- To check the mix design properties using Marshall Mix design method.
- To check the acceptability of the material comparing with ERA manual.

1.5 Scope of the study

The scope of this research is limited to evaluation of material quality for asphalt layer at the laboratory and identification of the main causes of the defects of the specific road of

Jimma town on the basis of the sampled asphalt materials (bitumen, mineral filler and aggregate) used as the wearing course of asphalt surface of the road.

1.6 Significance of the study

Asphalt pavements are a crucial part of our nation's strategy for building a high performance transportation network for the future. The continuing rapid growth in traffic demand, along with the increase in allowable axle loads, necessitates the improvement of the highway paving materials.

- The City Administration of Jimma will benefit from the study as a source of information and foundation for the construction industry that can help to improve and control qualities of the materials regarding to standard and specifications.
- It may relieve the problem from failure of pavement due to unsuitability of construction materials, which has low bearing capacity.
- Contractors and consultants will benefit from the study as a source of information for road construction projects, in case of Jimma town.
- Other researchers will use the findings as a reference for further research on effects of material quality on the performance of asphalt pavement

CHAPTER TWO

LITERATURE REVIEW

2.1 Theoretical review

Pavement materials are an important component of pavement design, the selection of appropriate quality of materials for selected, sub grade, sub base, base courses and asphalt determine the capital and whole life costs of the road which primarily determines the performance of the road. In the selection of pavement materials guide line principles used for the material performance indication are: California bearing ratio (CBR) strength, gradation, Unterberg limits (liquid limit and plasticity limit) and plasticity indexes[13].Design of Pavement depends on the materials to be used and the conditions which the pavement must meet [7].

Performance of a pavement is measured by its serviceability to the expected use; it is the change in pavement performance with time [32]. The concept is to design a pavement, which at the end of the proposed performance period will still have a predefined minimum level of serviceability .The terminal level of serviceability is selected based on the lowest index the user will tolerate, or as defined in a pavement management strategy before rehabilitation, resurfacing or reconstruction becomes necessary. The goal of a pavement design is to produce a pavement that when placed will perform functionally and structurally while maintaining its safety characteristics for at least the selected service life [11]. The two basic materials in asphalt concrete (AC) pavement are the bitumen and the aggregate which have their own distinct behaviors. The asphalt binder is what gives an asphalt pavement its flexibility, binds the aggregate together, and gives waterproofing properties to the pavement [13].

Even though the binder content is a key mixture design parameter, the binder grade plays a significant role on the performance of pavement. Selecting a binder grade is essential in insuring that the asphalt will not experience significant levels of distress at the prevailing climatic condition. Asphalt binders are visco-elastic materials in nature whose resistances to deformation under load are sensitive to loading time and temperature [15]. Less viscous asphalts make the mixture less stiff and therefore more susceptible to irrecoverable deformations, i.e. rutting. On the other hand, if asphalt is too hard, it would be brittle at low temperatures ultimately leading to cracking under loading [5].

2.2 Pavement

Pavement is anything which is paved; a floor or covering of solid material, laid so as to make a hard and convenient surface for travel; a paved road or sidewalk; a decorative interior floor of tiles collared bricks.

2.2.1 Types of pavement

Pavements are typically divided into the following two general categories: flexible pavement and rigid pavement.

2.2.1.1 Flexible (Bituminous Pavements)

A flexible pavement are constructed of several layers of natural granular material covered with one or more waterproof bituminous surface layers, and as the name imply, is considered to be flexible. A flexible pavement will flex (bend) under the load of a tyre. The objective with the design of a flexible pavement is to avoid the excessive flexing of any layer, failure to achieve this will result in the over stressing of a layer, which ultimately will cause the pavement to fail. In flexible pavements, the load distribution pattern changes from one layer to another [28], because the strength of each layer is different. The strongest material (least flexible) is in the top layer and the weakest material (most flexible) is in the lowest layer. The reason for this is that at the surface the wheel load is applied to a small area, the result is high stress levels, deeper down in the pavement, the wheel load is applied to larger area, and the result is lower stress levels thus enabling the use of weaker materials

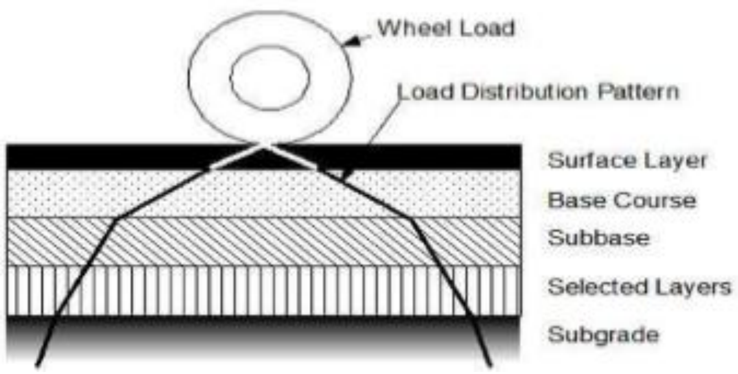

Figure 2.1 Load distribution of flexible pavement (source Google)

2.2.1.2 Rigid (Concrete) Pavements

Rigid pavements are composed of a PCC surface course. Such pavements are substantially "stiffer" than flexible pavements due to the high modulus of elasticity of the PCC material. Further, these pavements can have reinforcing steel, which is generally used to reduce or eliminate joints. The increased rigidity of concrete allows the concrete surface layer to bridge small weak areas in the supporting layer through what is known as beam action. This allows the placement of rigid pavements on relatively weak supporting layers, as long as the supporting layer material particles will not be carried away by water forced up by the pumping action of wheel loads.

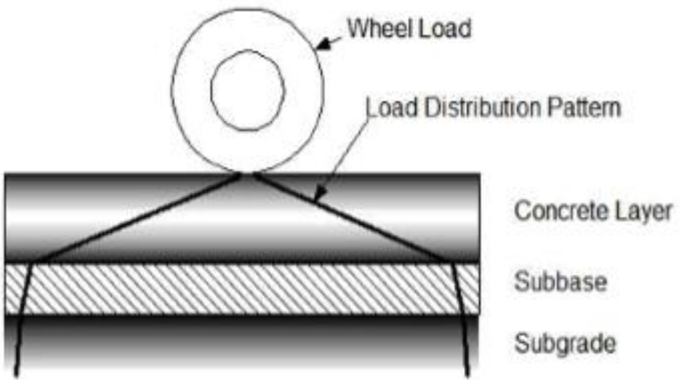

Figure 2.2. Load distribution of rigid pavement. (Source Google)

2.3 Component of Asphalt mix

2.3.1 Aggregate

Aggregates are the key materials used in the construction sector and the largest portion of an asphalt pavement. Aggregates are generally derived from stone minerals and sometimes further mechanically processed to suite for specific applications. Synthetic aggregates, most commonly blast furnace slag from the steel industry, slate wastes and ashes, are also used in the construction of asphalt pavements [9]. The properties of aggregates are very important to the performance of Asphalt pavements layer (APL). Often pavement distress such as rutting, tripping, surface disintegration, and lack of adequate surface frictional resistance can be attributed directly to improper aggregate selection and use. Thus, care has to be made while selecting the mineral aggregate and all quality test assurance has to be conducted to confirm whether they satisfy a definite project specification. The study conducted by [25]. disclosed that aggregate type has a significant effect on the fatigue resistance and permanent deformation of asphalt mixtures

Aggregates are deemed to give the mixture stability after various traffic loads, resistance to wear due to abrasive action of traffic, and still resistant to frost action. Thus, to obtain a mixture having good performance, evaluation of various mineral aggregate physical properties is essential.

2.3.1.1 Aggregate Classification

Aggregate for APL are generally classified accordingly to their formation is divided into three general types: Sedimentary, Igneous, and metamorphic [3].

- **Sedimentary:** Sedimentary rocks are formed in layers by the accumulation of sediment (fine particles) that deposited by wind and water, it may contain: Mineral particles or fragment (in case of sandstone and shale), remains or products of animal (certain limestone), plant (coal), End product of chemical action or evaporation (salt, gypsum), and combination of these types of material.
- **Igneous:** Igneous rock consists of molten material (magma) that has cooled and solidified. There are two types: extrusive and intrusive [3]. Extrusive igneous rock is formed material that has poured out onto the earth's surface during the volcanic eruption or similar geological activity. Because exposure to the atmosphere allows the material to cool quickly, the resulting rock has a glass-like appearance and structure. Rhyolite, andesite and basalt are example of extrusive rock. Intrusive rock form from magma trapped deep within the earth's crust. Trapped in the earth, the magma cools and hardens, slowly, allowing a crystalline structure to form. Examples of igneous rock are: granite, diorite and gabbro. Earth movement and erosion process bring intrusive rock to the earth's surface where it is quarried and used [3].
- **Metamorphic:** Metamorphic rock is generally sedimentary or igneous rock that has been changed by intense pressure and heat within the earth. Because such formation processes are complex, it is often difficult to determine the exact origin of a particular metamorphic rock. Many types of metamorphic rock have a distinct characteristic feature; the mineral are arranged in parallel planes or layers. Splitting the rock along its planes is much easier than splitted. Example of foliated rock is gneisses, schist (formed from igneous material) and slate (formed from shale, a sedimentary rock). (ERA manual, 2002)

2.3.1.2 Aggregate Sources

Aggregate for APL are generally classified according to their sources, they includes Natural aggregate, Processed aggregates and synthetic rock aggregate.

- **Natural Aggregate**: Natural aggregates are those used with little or on processing. They are made up of particles produced by natural erosion and degradation, such as the action of wind, water, moving ice and chemicals. The shape of individual particles is largely a result of erosion. Glaciers, for example, often produced rounded boulders and pebbles. Similarly, flowing water produces smoothly rounded particles. The two major types of natural aggregate used in pavement constructions are gravel and sand. Gravel is usually defined as particles 6.35 mm (1/4 in) or larger in size. Sand is defined as particles smaller than 6.335 mm but larger than 0.075 mm (No. 200), Pericles smaller than 0.075 mm are mineral filler [3]. Gravels and sands are further classified by their source. Materials quarried from an open pit and used without further processing are referred to as pit run materials. Similarly, materials taken from stream banks are referred to as bank-run materials.
- **Processed Aggregate**: Processed aggregate have been quarried, crushed and /or screened in preparation for use. There are two basic sources of processed aggregate: natural gravel that is crushed to make them more suitable for use in HAM, and fragments of bedrock and large stones that must be reduced in size. Rock is crushed for three reasons: To reduce the size and improve the distribution and range (gradation) of particle size.
    - To change the surface texture of the particles from smooth to rough.
    - To change particles shape from round to angular.

Aggregates can either be natural or manufactured. Natural aggregates are generally extracted from larger rock formations through an open excavation (quarry). Extracted rock is typically reduced to usable by mechanical crushing. Manufactured aggregate is often the by-product of other manufacturing industries [3].The mineral aggregates used in this research were the manufactured one and subjected to various tests in order to assess their physical characteristic and suitability of the road construction. The aggregate were obtained from ERCC quarry and crusher site located in Unkulu of

Ana Manna. In order to obtain a representative samples for testing, all coarse and fine aggregates were riffled in accordance with AASHTO/ASTM/BS.

2.3.1.3 Aggregate gradation and Size

An aggregate's particle size distribution, or gradation, is one of its most influential characteristics. It determines almost every APL properties including stiffness, stability, durability, permeability, workability, fatigue resistance, frictional resistance, and resistance to moisture damage [12].

This makes gradation the primary factor in the asphalt mix design. Matthews and Mon smith investigated a study to evaluate aggregate gradation on the creep response of asphalt mixtures and pavement rutting estimates. They have used both methods of measuring rutting performance (stabile meter and creep tests). From their study, it was indicated that mixtures with aggregate particles size distribution around the mid band of gradation limits, termed as “medium graded”, provide significantly better resistance to rutting than the mixtures with aggregate gradation below the mid band of aggregate gradation, termed as “coarse graded”. However [29] have showed that changing the proportions of fine and coarse aggregates with the same nominal maximum aggregate size did not affect the permanent deformation significantly. This was verified by Kandhal and Allen that from their study on rutting potential of both coarse and fine graded mixtures. The statistical analysis of the test data revealed that there is no significant difference between the rutting resistance of coarse and fine graded super pave mixturesMineral aggregate, predominantly of coarse aggregate constitutes approximately 90–95% of hot-mix asphalt (HMA) by weight. Generally aggregate characteristics such as particle size, shape, and texture influence the performance and serviceability of hot-mix asphalt pavement. Aggregate shape is one of the important properties that are considered in the mix design of asphalt pavements to avoid premature pavement failure [1]

2.3.1.3.1 Coarse aggregate

Coarse Aggregate Should produces by crushing sound, un-weathered rock or natural gravel. The specifications for the aggregates are similar to those for granular base course. The aggregate must be clean and free of clay and organic material; the particles should be angular and not flaky. Gravel should be crushed to produce at least two fractured faces on each particle. Aggregates for wearing course must also be resistant to abrasion and polishing. Highly absorption of bitumen must be taken into account in the mix design procedure.

2.3.1.3.2 Fine aggregate:

Fine Aggregate can be crushed rock or natural sand and should be clean and free from organic impurities. It shall be fraction passing 600 microns and retained on 75 microns sieve and its function is to fill up the voids of the coarse aggregate.

2.3.2 Binder

Sometimes termed as bitumen or asphalt is a general description for the adhesive or glue used in asphalt pavements, either petroleum derived or naturally occurring material [6].The asphalt binder is what gives an asphalt pavement its flexibility, binds the aggregate together, and gives waterproofing properties to the pavement [24]. Even though the binder content is a key mixture design parameter, the binder grade plays a significant role on the performance of pavement. Bitumen acts as a binding agent to the aggregates, fines and stabilizers in bituminous mixtures. Binder provides durability to the mix.

The characteristics of bitumen which affects the bituminous mixture behaviour are temperature susceptibility, viscos-elasticity and aging [23]. The behaviour of bitumen depends on temperature as well as on the time of loading. It is stiffer at lower temperature and under shorter loading period. Bitumen must be treated as a viscos-elastic material as it exhibits both viscous as well as elastic properties at the normal pavement temperature. Selecting a binder grade is essential in insuring that the asphalt will not experience significant levels of distress at the prevailing climatic condition. Asphalt binders are viscoelastic materials in nature whose resistances to deformation under load are sensitive to loading time and temperature. Less viscous asphalts make the mixture less stiff and therefore more susceptible to irrecoverable deformations, i.e., rutting. On the other hand, if asphalt is too hard, it would be brittle at low temperatures ultimately leading to cracking under loading [13].

Though at low temperature it behaves like an elastic material and at high temperatures its behaviour is like a viscous fluid [33].Asphalt binder is material having a wide range of consistency from fluid to hard and brittle for flexible pavement construction. Asphalt binders are most commonly characterized by their physical properties. This is because an asphalt binder’s physical properties directly describe how it will perform as a constituent in Asphalt mix. Different quality tests were carried out on asphalt cement during this study to assess its physical properties through various laboratory steps.

2.3.3 Mineral Filler

Mineral fillers can be crushed rock fines, Portland cement or hydrated lime to assist the adhesion of the bitumen to aggregate and fill up the void. It should be inert material which pass 75 micron sieve. However, addition of mineral fillers has dual purpose when added to asphalt mixtures. A portion of the mineral filler that is finer than the asphalt film thickness mixed with asphalt binder forms a mortar or mastic and contributes to improved stiffening of mix [15]. This modification to the binder that may take place due to addition of mineral fillers could affect asphalt mixture properties such as rutting and cracking. The other portion of fillers larger than the asphalt film thickness behave as a mineral aggregate and serves to fill the voids between aggregate particles, thereby increasing the density and strength of the compacted mixture[21].

Mineral fillers have a significant impact on the properties of APL mixtures. Mineral fillers increase the stiffness of the asphalt mortar matrix. Mineral fillers also affect workability, moisture resistance, and aging characteristics of HMA mixtures [33]. Generally filler plays an important role in properties of bituminous mixture particularly in terms of air voids, voids in mineral aggregate. Different types of mineral fillers are used in the SMA mixes such as stone dust, ordinary Portland cement (OPC), slag cement, fly Ash, hydrated lime etc.

Aggregate shape is one of the important properties that are considered in the mix design of asphalt pavements to avoid premature pavement failure. Flat and elongated particles tend to break during mixing, compaction and under traffic loading [13].

It has been found a direct correlation between the rutting potential of HMA mixtures and the shape and texture of coarse aggregate particles. Some mixes with flaky aggregates have been found to exhibit higher fatigue life than mixes with non-flaky aggregates [12]The percentage of crushed coarse particles has a significant effect on laboratory permanent deformation properties. As the percentage of crushed coarse particles decreased, the rutting potential of the HMA mixtures increased. It is emphasized in literature that cubical, rough-textured aggregates have better interlocking mechanisms; reduce the potential for rutting and more resistant to the shearing action of traffic than rounded and smooth textured aggregates [13].

Some researches indicate that dense aggregate properties and gradations are desirable to mitigate the potential effects of rutting of asphalt concrete pavement. When properly compacted, mixtures with dense or continuous aggregate gradations have fewer voids [14]. The coarse aggregates for premixes should be produced by crushing sound, unweather rock or natural gravel. The specifications for the aggregates are similar to those for granular base courses. The aggregate must be clean and free of clay and organic material, the particles should be angular and not flaky. Gravel should be crushed to produce at least two fractured faces on each particle. Aggregates for wearing course must also be resistant to abrasion and polishing. Highly absorptive aggregates should be avoided where possible, but otherwise the absorption of bitumen must be taken into account in the mix design procedure [28]. Hydrophilic aggregates which have a poor affinity for bitumen in the presence of water should also be avoided. They may be acceptable only where protection from water can be guaranteed [3]

The main types of premix are asphaltic concrete, bitumen macadam and hot rolled asphalt. Each type can be used in surfacing or base courses. Their general properties and suitable specification described below [5].

2.4 Types of Asphalt Mix

2.4.1Asphaltic Concrete

Asphalt concrete (AC) is a dense, continuously graded mix which relies for its strength on both the interlock between aggregate particles and, to a lesser extent, on the properties of the bitumen and filler. The mix designed to have low air voids and low permeability to provide good durability and good fatigue behaviour but this makes the material particularly sensitive to errors in proportioning, and mix tolerance are therefore very narrow [5].

Hot mix asphalt concrete

Commonly abbreviated as HMAC or HMA is produced by heating the asphalt binder to decrease its viscosity, and drying the aggregate to remove moisture from it prior to mixing. Mixing is generally performed with the aggregate at about 300 °F(roughly 150 °C) for virgin asphalt and 330 °F (166 °C) for polymer modified asphalt, and the asphalt cement at 200 °F (95 °C). Paving and compaction must be performed while the asphalt insufficiently hot. In many countries paving is restricted to summer months because in winter the compacted base will cool the asphalt too much before it is packed to the optimal air content. HMAC is the form of asphalt concrete most commonly used on highly trafficked pavements such as those on major highways, racetracks and airfields.[5]

Warm mix asphalt Concrete

Commonly abbreviated as WMA is produced by adding zeolites waxes, asphalt emulsions, or sometimes even water to the asphalt binder prior to mixing. This allows significantly lower mixing and laying temperatures and results in lower consumption of fossil fuels, thus releasing less carbon dioxide, aerosols and vapours. Not only are working conditions improved, but the lower laying-temperature also leads to more rapid availability of the surface for use, which is important for construction sites with critical time schedules. The usage of these additives in hot mixed asphalt (above) may afford easier compaction and allow cold weather paving or longer hauls [5]

Cold mix asphalt

Concrete is produced by emulsifying the asphalt in water with (essentially) soap prior to mixing with the aggregate. While in its emulsified state the asphalt is less viscous and the mixture is easy to work and compact. The emulsion will break after enough water evaporates and the cold mix will, ideally, take on the properties of cold HMAC. Cold mix is commonly used as a patching material and on lesser trafficked service roads [5]

Cut-back asphalt concrete

Is produced by dissolving the binder in kerosene or another lighter fraction of petroleum prior to mixing with the aggregate. While in its dissolved state the asphalt is less viscous and the mix is easy to work and compact. After the mix is laid down the lighter fraction evaporates. Because of concerns with pollution from the volatile organic compounds in the lighter fraction, cut-back asphalt has been largely replaced by asphalt emulsion [5].

2.4.2Bitumen Macadam

This one is closed graded bitumen macadam are continuously graded mixes similar to asphaltic concrete but usually with a less dense aggregate structure. They have developed in the United Kingdom from empirical studies and are made to recipe specifications without reference to a format design procedure. Their suitability for different condition and with different materials may be questioned but, in practice, numerous materials including crushed gravels have been used successfully [24]

2.4.3Bituminous Surfacing

This is particularly important for surfacing laid on granular base courses. Mixes which are designed to have good durability rather than high stability are flexible and are likely to have " sand" and bitumen contents at the higher end of the permitted ranges. In areas where the production of sand- sized material is expensive and where there is no choice but to use higher stability mixes, additional stiffening through then aging and embrittlement of the bitumen must be prevented by applying a surface dressing [24].

2.5 Hot Mix Asphalt

HMA is a mixture of coarse and fine aggregates and asphalt binder. HMA, as the name suggests, is mixed, placed and compacted at higher temperature. HMA is typically applied in layers, with the lower layers supporting the top layer.

2.5.1 Types of Hot Mix Asphalt

They are Dense Graded Mixes (DGM), Stone Matrix asphalt (SMA) and various Open graded HMA (National centre for asphalt Technology, 1996).

2.5.1.1Dense-Graded Mixes

This type of bituminous concrete is a well-graded HMA has good proportion of all constituents are also called Dense bituminous macadam. When properly designed and constructed, a dense graded mix is relatively impermeable. Dense-graded mixes are generally referred to by their nominal maximum aggregate size and can further be classified as either fine-graded or coarse graded. Fine-graded mixes have more fine and sand sized particles than coarse-graded mixes. It is Suitable for all pavement layers and for all traffic conditions. It offers good compressive strength. Materials used are Well-graded aggregate, asphalt binder (with or without modifiers).

2.5.1.2Stone Matrix Asphalt (SMA)

Stone matrix asphalt (SMA), sometimes called stone mastic asphalt, is a gap-graded HMAoriginally developed in Europe to maximize rutting resistance and durability in heavy traffic road. SMA has a high coarse aggregate content that interlocks to form a stone skeleton that resists permanent deformation. The stone skeleton is filled with mastic of bitumen and filler to which fibres are added to provide adequate stability of bitumen and to prevent drainage of binder during transport and placement. Typical SMA composition consists of 70−80% coarse aggregate, 8−12% filler, 6.0−7.0% binder, and 0.3 per cent fibre. The deformation resistant capacity ofSMA stems from a coarse stone skeleton providing more stone-on-stone contact than with conventional dense graded asphalt (DGA) mixes [34]

2.5.1.3Open-Graded Mixes

Unlike dense-graded mixes and SMA, an open-graded HMA mixture is designed to be water permeable. Open-graded mixes use only crushed stone (or gravel) and a small percentage of manufactured sands. The two most typical open-graded mixes are:

Open-graded friction course (OGFC). Typically 15 per cent air voids and no maximum air voids specified. Used for surface courses only. They reduce tire splash/spray in wet weather and typically result in smoother surfaces than dense-graded HMA. Their high air voids reduce tire road noise by up to 50%

Asphalt treated permeable bases (ATPB). Less stringent specifications than OGFC since it is used only under dense-graded HMA, SMA or Portland cement concrete for drainage. Used as a drainage layer below dense-graded HMA, SMA. Material used aggregate (crushed stone or gravel and manufactured sands), asphalt binder (with modifiers). OGFC is more expensive per ton than dense-graded HMA, but the unit weight of the mix when in-place is lower, which partially offsets the higher per-ton cost. The open gradation creates pores in the mix, which are essential to the mix’s proper function. Anything that tends toclog these pores, such as low-speed traffic, excessive dirt on the roadway can degrade performance [5].

2.5.2 Properties of Hot Mix Asphalt (HMA)

The main objective of asphalt concrete mixture design is to determine an economical blend or mix of stone aggregate, sand and fillers such as brick dust gives a mix having or possess the following characteristics.Sufficient mix stability to satisfy the demands of traffic without displacement.High resistance to deformation. High resistance to fatigue and the ability to withstand high strains i.e. they need to be flexible. Sufficient stiffness to reduce the stresses transmitted to the underlying pavement layers. Sufficient void in total compaction mix to allow for a slight amount of additional compaction and traffic loading without flushing bleeding and loss of stability yet low enough to keep out harmful air and moisture.Sufficient work ability to permit sufficient placement of the mix without segregation [5].

2.5.2.1 Stability

Stability is defined as the resistance of the paving mix to deformation under traffic load. The stability of mixture depends on internal friction and cohesion. Inter particle friction among the aggregate particles is related to aggregate characteristics such as shape and surface texture. Cohesion result from the bonding ability of the asphalt, proper degree of both inter particle friction and cohesion in a mix prevent the aggregate articles from being moved past each other of extracted by traffic. Two examples of failure are:

Shoving - a transverse rigid deformation which occurs at areas subject to severe acceleration.
Grooving - longitudinal ridging due to channelization of traffic. Stability depends on the inter-particle friction, primarily of the aggregates and the cohesion offered by the bitumen. Sufficient binder must be available to coat all the particles at the same time should offer enough liquid friction. However, the stability decreases when the binder content is high and when the particles are kept apart. A stability value that is too high produces a pavement that is too stiff and therefore less durable

2.5.2.2 Durability

The durability of an asphalt pavement is the ability to resist factor such as aging of the asphalt, disintegration of the aggregate, stripping of the asphalt film from aggregate, and the resistance of the mix against weathering and abrasive actions. Weathering causes hardening due to loss of volatiles in the bitumen. Abrasion is due to wheel loads which causes tensile strains. Typical examples of failure are

Pot-holes, - deterioration of pavements locally and
Stripping, loss of binder from the aggregates and aggregates are exposed. Disintegration is minimized by high binder content since they causes the mix to be air and waterproof and the bitumen film is more resistant to hardening.
Source: Hot Asphalt Mix Manual, 2nd edition

2.5.2.3Impermeability

Impermeability prevents the passage of air and water into or through the asphalt pavement. This characteristic is related to the void content of the compacted mixture, and much of the discussion on voids in mix design relates to Impermeability. Even though void content is an indication of the potential for passage of air and water through a pavement, the character of these voids is more important than the number of voids. Although Impermeability is important for durability of compacted paving mixtures, virtually all asphalt mixtures used in highway construction are permeable to some degree.Source: Hot Asphalt Mix Manual, 2nd edition

2.5.2.4 Workability

Workability describes the ease with which a paving mixture can be placed and compacted. Mixture with good workability are relatively easy to place and compact, those with poor work ability are difficult to place and compact. And it can be improve by changing mix design parameters, aggregate source, or gradation. Mixtures that can be too easily worked or shoved are referred to as tender mixes. Tender mixes are too unstable to place and compact properly. They are often caused by: A shortage of mineral filler, too much medium-size particles, too much moisture in the mix.

Although not normally a major contributor to workability problems, asphalt does have some effect on workability. Because the temperature of the mix affects the viscosity of the asphalt, a temperature too low will make a mix unworkable, and a temperature that is too high may make it tender. Source: Hot Asphalt Mix Manual, 2nd edition

2.5.2.5 Flexibility

Flexibility is the ability of an asphalt pavement to adjust to gradual settlements and movements in the subgrade without cracking. Since virtually all subgrade either settle (under loading) or rise (from soil expansion), flexibility is a desirable characteristic for all asphalt pavement. An open graded mix or one with high asphalt content is generally more flexibility than a dense graded mix or one with low asphalt content. Sometimes the need of for flexibility conflicts with the need for stability, so that trade-offs have to be made in selecting the optimum asphalt content.Source: Hot Asphalt Mix Manual, 2nd edition

2.5.2.6 Fatigue Resistance

Fatigue resistance is the pavement's resistance to repeated bending under wheel load (traffic). Research shows air void and asphalt viscosity have a significant effect on fatigue resistance. As the percentage of air void in the pavement increases, either by design or lack of compaction pavement fatigue resistance is drastically reduced. Likewise a pavement containing asphalt that has aged and hardened significantly has reduced resistance to fatigue. The thickness and strength characteristics of the pavement and the support of the subgrade also have a great deal to do with determining pavement life and preventing load-associated cracking. Thick, well-supported pavements do not bend as much under loading as thin or poorly supported pavements do. Therefore, they have longer fatigue lives. Source: Hot Asphalt Mix Manual, 2nd edition

2.5.2.7 Skid Resistance

Skid resistance is the ability of an asphalt surface to minimize skidding or slipping of vehicle tires, particularly when wet. For good skid resistance, tire tread must be able to maintain contact with the aggregate particles instead of riding on a film of water on the pavement surface (hydroplaning). Source: Hot Asphalt Mix Manual, 2nd edition

Desirable properties

From the above discussion, the desirable properties of a bituminous mix can be summarized as follows: Stability to meet traffic demand, bitumen content to ensure proper binding and water proofing, voids to accommodate compaction due to traffic, flexibility to meet traffic loads, esp. in cold season, and sufficient workability for construction.

Source: Hot Asphalt Mix Manual, 2nd edition

CHAPTER THREE

METDOLOGY

3.1 Background

The goal of this study was to investigate the material quality of Asphalt Pavement Layer (APL) by using Marshal Mix Design properties in the laboratory. This study is start from preparation and investigation the properties of the row material for the marshal mix. The material used for the mixture includes coarse aggregate, Fine aggregate, Mineral filler and asphalt binder.

3.2 Study Area

This research was conducted in Jimma zone; the capital of the Zone is Jimma town. It is located in Oromia Region, South-western Ethiopia of about 355 km from Addis Ababa. Jimma zone has 18 districts. They are (Kersa, Seka-Chekorsa, Mana, Goma, Dedo, Gera, shebe-sombo, Nada, Sekoru, Tiroafeta, Gumey, Sigmo, Setema, Chorabotor, Limu-seka, Limu-kosa, Nonobenja and Mencho). Jimma Zone is known as a green gold coffee land. The city is located 7.6670 North latitude and 36.8330 East longitude and at an altitude range of 1,720-2011 Masl and experiencing an average annual rain fall amounting to 1503-1800 mm. The long wet period extends from late May to early June. In addition, July, August and September are months of rainy season. Most parts of the zone are bounded by three main rivers: Gibe, Didessa and Gojab. According to the 1997 National census, The 2007 Population and Housing Census of Ethiopia: Statically report for Oromia Region Page 8 the rural and urban population of Jimma is 2,486,155. About 49.7% of the rural inhabitants were females.

3.3 Research Design and period

The research design was formulated with problem identification which has been done through unstructured literature review and informal discussion with colleagues and professionals in the sector. The data and information sources were determined based on the formulated research design. On the basis of the data and information sources, the research instruments were decided; and available documentary sources relevant to the study were reviewed. The review includes books, journal, and internet sources.

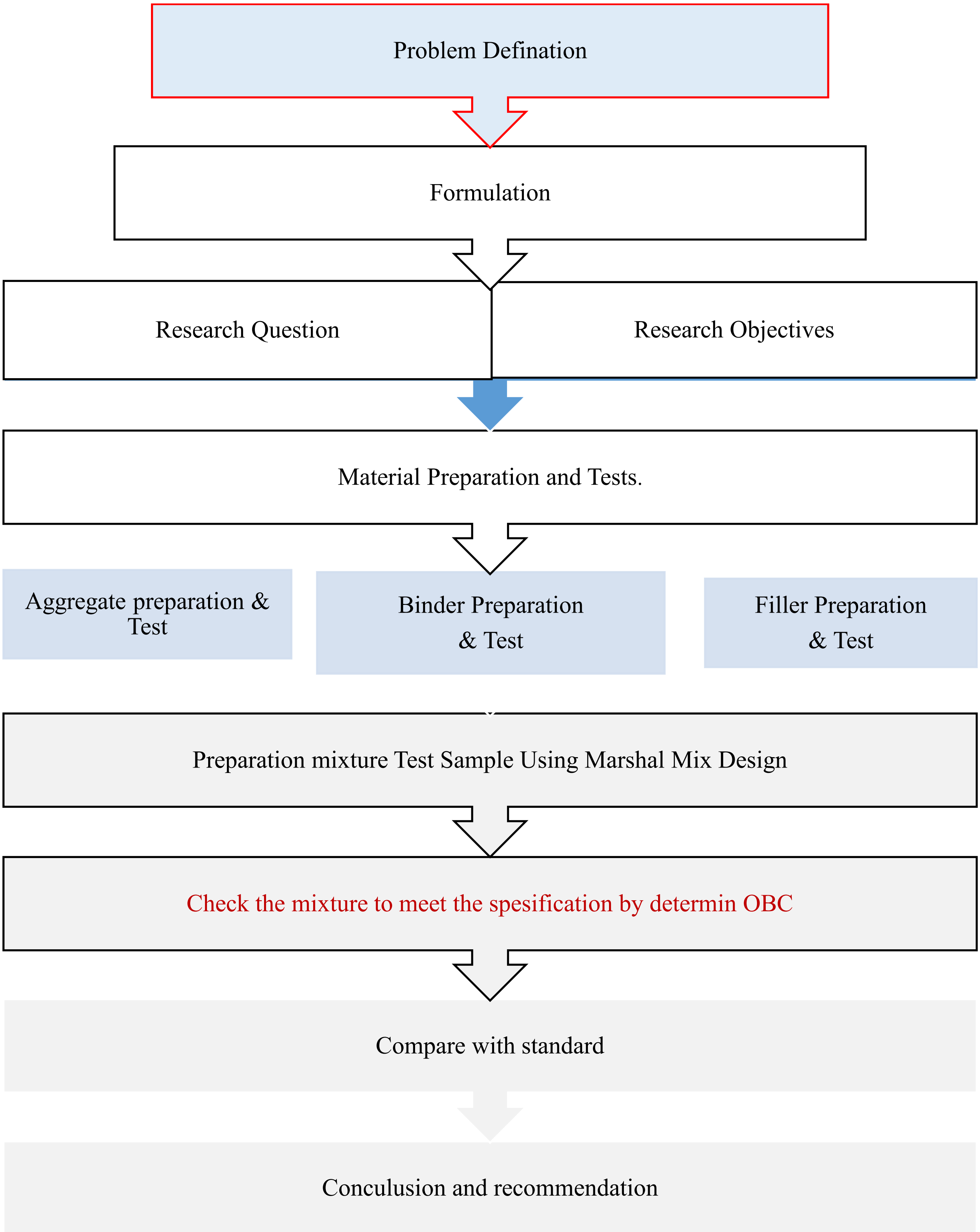

Figure: 3.1. Flow chart of study design

3.4 Material Selection

Several materials were required for producing asphalt specimens. Since the main objective of the study was to investigate the performance asphalt pavement layer respect to overall parameters asphalts pavement mix, it was important to evaluate also various aggregate and binder sources. The Row material used in this study, the crush stone coarse aggregate and fine aggregate are taken from ERCC quarry which the crusher site located in Unkulu of Ana ManaJimma Zone. The asphalt cement of 85/100 penetration grade was obtained from Ethiopian Road Construction Corporation.

3.5 Material Test Preparation

In this section, details of test procedures to determine the index properties and strength of materials are presented. The validity of the conclusions made at the end the study depends on the accuracy of the test procedures used. To improve the reliability of these conclusions, careful understanding of test procedures and better interpretation practice are required. In this case, attempt was made to obtain accurate laboratory results by careful following of proper testing procedures as described by ASTM, AASHTO and BS standards and share ideas with advisors and other experienced persons to properly conduct this research.

After preparing the sample by air drying and reducing to test size using mechanical splitter in accordance to procedures outlined in AASHTO T-248 various laboratory tests were conducted on the samples of CSA and cg. Most of the tests were conducted in ERCC.

3.5.1 Aggregate Type and Quality Selection

The properties of aggregates are very important to the performance of hot mix asphalt (HMA) pavements. Often pavement distress such as rutting\stripping, surface disintegration, and lack of adequate surface frictional resistance can be attributed directly to improper aggregate selection and use.

Thus, care has to be made while selecting the mineral aggregate and all quality test assurance has to be conducted to confirm whether they satisfy a definite project specification. The study conducted by [17] disclosed that aggregate type has a significant effect on the fatigue resistance and permanent deformation of asphalt mixtures. Aggregates are deemed to give the mixture stability after various traffic loads, resistance to wear due to abrasive action of traffic, and still resistant to frost action. Thus, to obtain a mixture having good performance, evaluation of various mineral aggregate physical properties is essential.

3.5.1.1 Sieve Analysis

The coarse and fine aggregate particles were separated into different sieve size and proportioned to obtain the desired gradation for bituminous mixtures of ASTM 3515 for 19mm nominal maximum aggregate size. Incorporating different amount of mineral fillers, the Job-Mix-Formula (JMF) for the aggregate particle size distribution that would be used for the preparation of mixtures is shown in Table 3-1 where keeping the coarse aggregate size distribution unchanged and varying distribution in the fines. The specified grading limits and that of obtained for this study are as shown in Table 3-1.

Table 3.1 Composition of Asphalt paving Mixture specification ASTM D 3515

Mix Designation and Nominal Maximum Size of Aggregate						
Sieve Size	2 in.	$1^{1}/_{2}$ in.	1 in.	¾ in.	½ in.	3/8 in.
	(50 mm).	(37.5mm).	(25.0mm).	(19.0mm).	(12.5mm).	(9.5mm).
$2^{1}/_{2}$ in.	100	-	-	-	-	-
2 in.	90-100	90-100	100	-	-	-
$1\,^{1}/_{2}$ in.	-	90-100	100	-	-	-
1 in.	60-80	-	90-100	100	-	-
3/4 in.	-	56-80	-	90-100	100	-
1/2 in.	35-65	-	59-80	-	90-100	100
3/8 in.	-	-	-	56-80	-	90-100
No. 4	17-47	23-53	29-59	35-65	44-74	55-85
No. 8	10-36	15-41	19-45	23-49	28-58	32-67
No. 16	-	-	-	-	-	-
No. 30	-	-	-	-	-	-
No. 50	3-15	4-16	5-17	5-19	5-21	7-23
No. 100	-	-	-	-	-	-
No. 200	0-5	0-6	1-7	2-8	2-10	2-10

Source: Asphalt institution of Hot Mix Asphalt pavement Manual, series No. 22, and second edition.

3.5.1.2 Particle Shape and Surface Texture

Rounded particles create less particle-to-particle interlock than angular particles and thus provide better workability and easier compaction. However, in HMA less interlock is generally a disadvantage as rounded aggregate will continue to compact, shove and rut after construction. Thus angular particles are desirable for HMA (despite their poorer workability), while rounded particles are desirable for PCC because of their better workability (although particle smoothness will not appreciably affect strength) (PCA, 1988).These particles tend to impede compaction or break during compaction and thus, may decrease strength.

These particles have a lower surface-to-volume ratio than rough-surfaced particles and thus may be easier to coat with binder. However, in HMA asphalt tends to bond more effectively with rough-surfaced particles. Thus, rough-surface particles are desirable for HMA. The flat and elongated particle test is used to determine the dimensional ratios for aggregate particles of specific sieve sizes. This characterization is used in the super pave specification to identify aggregate that may have a tendency to impede compaction or have difficulty meeting VMA specifications due to aggregate degradation.

3.5.1.3 Aggregate Impact Value

The aggregate impact value gives a relative measure of the resistance of an aggregate to sudden shock or impact, which in some aggregates differs from its resistance toas lowlyappliedcompressiveload. Withaggregateofaggregateimpactvaluehigherthan30the result may be anomalous. Also, aggregatesizeslargerthan12mmAASHTOarenotappropriatetotheaggregateimpacttest.Thest andardaggregate impact test shallbemade on aggregate passing 12.5-mmAASHTO testsieveandretainedona10.0mmAASHTOtestsieve.

Figure 3.2: Aggregate impact testing machine.

The material for the standard test shall consist of aggregate passing the 14.0 mm BS test sieve and retained on the 10.0 mm BS test sieve and shall be thoroughly separated o the these sieves before testing. The aggregate shall be tested in a surface-dry condition. The measure shall be filled one-third full with the aggregate by means of a scoop, the aggregate shall then be tamped with 25 blows, by allowing the tamping rod to fall freely from a height of about 50mm above the surface.

The ratio of the mass of fines formed to the tatal sample mass in each test shall be expressed as a percentage, the result being recorded to the first decimal place,

$$Percentage\ fines = {}^{B}\!/_{A} * 100$$

Where: A=the mass of surface-dry sample (g)

B=the mass of the friction passing the sieve for separating the fines (g)

3.5.1.4 Aggregate Crushing Value

The aggregate crushing value gives a relative measure of the resistance of an aggregate to crushing under a gradually applied compressive load. With aggregate of an aggregate crushing value higher than 30 than result may be anomalous, and in such cases the ten percent fines value should be determined instead. The standard aggregate crushing test shall be made on aggregate passing a 14.0mm BS (10mm ASTM) test sieve.

Figure 3.3: Major equipment used in Aggregate crushing value (Compression testing machine).

The material for the standard test shall consist of aggregate passing the 14.0 mm BS test sieve and retained on the 10.0 mm BS test sieve and shall be thoroughly separated o the these sieves before testing. The aggregate shall be tested in a surface-dry condition. If dried by heating the period of drying shall not exceed 4h, the temperature shall not exceed 110 ^{o}C and the aggregate shall be cooled to room temperature before testing. The quantity of aggregate for one test shall be such that the depth of the material in the cylinder shall be 100 mm after tamping.

The appropriate quantity may be found conveniently by filling the cylindrical measure in three layers of approximately 50 mm above the surface of the aggregate with the rounded end of the tamping rod and finally leveled off, using the tamping rod as straight edge. The mass of material comprising the test sample shall be determined (Mass A).

The ratio of the mass of fines formed to the total mass of the sample in each test shall be expressed as a percentage, the result being recorded to the first decimal place.

$$Percentage\ fines = \frac{B}{A}$$

Where: A= the mass of surface-dry sample (g)

B=the mass of the friction passing the 2.36mm BS test sieve (g)

3.5.1.5 Los Angles Abrasion test

The Los Angeles (L.A.) abrasion test is a common test method used to indicate aggregate toughness and abrasion characteristics. Aggregate abrasion characteristics are important because the constituent aggregate in HMA must resist crushing, degradation and disintegration in order to produce a high quality HMA. The L.A. abrasion test measures the degradation of a coarse aggregate sample that is placed in a rotating drum with steel spheres. As the drum rotates the aggregate degrades by abrasion and impact with other aggregate particles and the steel spheres (called the "charge"). Once the test is complete, the calculated mass of aggregate that has broken apart to smaller sizes is expressed as a percentage of the total mass of aggregate. Therefore, lower L.A. abrasion loss values indicate aggregate that is tougher and more resistant to abrasion.

Figure 3.4: Major equipment used in the L.A. abrasion test.

The Los Angeles abrasion value is the percentage of fines passing 1.18mm BS or 1.7mm ASTM sieve that gives the abrasion resistance of the aggregate. Soft aggregate are quickly ground to dust while hard aggregate lose little mass. The abrasion value of each test specimen shall be calculated as follows.

$$Abrasion\ value = \frac{(A-B)}{A}$$

Where: A=the mass of specimen before abrasion (g)

B=the mass of specimen after abrasion (g)

3.5.2 Asphalt Binder Selection and Test

Asphalt binders, sometimes referred to as asphalt cement binders or simply asphalt cement, are an essential component of asphalt concrete they are the cement that holds the aggregate together. Asphalt binders are a co-product of refining crude petroleum to produce gasoline, diesel fuel, lubricating oils, and many other petroleum products. Asphalt binder is produced from the thick, heavy residue that remains after fuels and lubricants are removed from crude oil. This heavy residue can be further processed in various ways, such as steam reduction and oxidation, until it meets the desired set of specifications for asphalt binders

3.5.2.1 Asphalt Binder Selection

For demanding, high-performance applications, small amounts of polymers are sometimes blended into the asphalt binder, producing a polymer-modified binder. In general asphalts can be classified into three general types:

- Asphalt cement
- Asphalt emulsion
- Cutback asphalt

Cutbacks and emulsions are used almost entirely for cold mixing and spraying and will not use for hot mix asphalt mixture. Because of its chemical complexities, asphalt specifications have been developed around physical property tests, such as penetration, viscosity and ductility. These tests are performed at standard test temperatures, and the results are used to determine if the material meets the specification criteria.

Asphalt binders have been mixed with crushed aggregate to form paving materials for over 100 years. They are a very useful and valuable material for constructing flexible pavement worldwide. However, asphalt binders have very unusual engineering properties that must be carefully controlled in order to ensure good performance. One of the most important characteristics of asphalt binders that must be addressed in test methods and specifications is that their precise properties almost always depend on their temperature.

Asphalt binders tend to be very stiff and brittle at low temperatures, thick fluids at high temperatures, and leathery/rubbery semi-solids at intermediate temperatures. Such extreme changes in properties can cause performance problems in pavements. At high temperatures, a pavement with a binder that is too soft will be prone to rutting and shoving.

On the other hand, a pavement that contains a binder that is too stiff at low temperatures will be prone to low-temperature cracking. There is an extreme change in modulus that occurs in asphalt binders over the range of temperatures. Specifications for asphalt binders must control properties at high, low, and intermediate temperatures. Furthermore, test methods used to specify asphalt binders usually must be conducted with very careful temperature control; otherwise, the results will not be reliable. Asphalt binders are also very sensitive to the time or rate of loading. When tested at a fast loading rate, an asphalt binder will be much stiffer than when tested at a slow loading rate. Therefore, time or rate of loading must also be specified and carefully controlled when testing.

3.5.2.2 Asphalt Binder Test

For this research experimental works bitumen of penetration grade 85/100 is used and collected from ERCC Ethiopian Road Construction Corporation. The main reason of using this grade is because of its common type of asphalt that widely use in most road projects in our country.

3.5.2.2.1 Softening Point

Softening point test may be classed as a consistency test in that it measures the temperature at which the bituminous materials reach a given consistency as determined by the test conditions while it is applicable to semi-solid materials and is useful in characterizing bitumen.

The test was performed by forming a sample in a brass ring, cooling it in a melting ice bath and then placing the sample within the ring in a 5 ^{o}C water bath. After placing a steel ball on a sample surface, the water bath temperature was raised at the rate of 5 ^{o}C per minute. The temperature at which the sample sagged under the weight of the steel ball and touches the bottom of the container surface 2.5 cm below the sample was the softening point temperature.

3.5.2.2.2 Flash point

The flashpoint of asphalt cement is the lowest temperature at which volatile gases separate from a sample to “flash” in the presence of an open flame. Flashpoint must not be fire point, the lowest temperature at which the asphalt cement will burn. The asphalt flashpoint is determined to identify the maximum temperature at which it can be handled and stored without danger of flashing. The basic procedure for determining flashpoint is to gradually heat a sample of asphalt cement in brass cup while periodically moving a small flame over the sample. The temperature at which an instantaneous flashing of vapors occurs across the surface is the flashpoint.

3.5.2.2.3 Penetration

The penetration test is an empirical measure of the hardness of asphalt at room temperature. The standard penetration test begins with conditioning a sample of asphalt cement to a temperature of 25 ^{o}C in a temperature controlled water bath. A standard needle is then brought to bear on the surface of the asphalt under a load of 100 gm. for exactly five seconds. The distance that the needle penetrates into the asphalt cement is recorded in units of 0.1 mm. The distance the needle travel is called "penetration" of the sample.

3.5.2.2.4 Specific Gravity

Specific gravity is the ratio of the weight of any volume of a material to the weight of an equal volume of water both at specified temperature. There are two reasons that needed to know about the specific gravity of asphalt cement. One's asphalt expands when heated and contracts when cooled. This means that the volume of a given amounts of asphalt cement will be grater at higher temperatures than at lower ones. Specific gravity measurements provide a yardstick for making temperature volume correction. Second specific gravity of asphalt is essential in the determination of the effective asphalt content and the percentage of air voids in compacted mix specimens and compacted pavement.

3.5.2.2.5 Ductility

Ductility is a measure of how far a sample of asphalt cement can stretch before it breaks into two parts. It is used in the penetration and viscosity classification systems. It is measured by an "extension" test in which a briquette of asphalt cement is extended or stretched, at a specific rate and temperature. Extension is continued until the thread of asphalt cement joining the two halves of the sample breaks. The length in centimeters of the specimen at the moment breaks is the ductility.

3.5.2.2.6 Solubility

The solubility test measures the purity of asphalt cement. A sample is immersed in a solvent to dissolve the asphalt. Impurities such as salt, free carbon and non-organic contaminants do not dissolve. These insoluble impurities are filtered out of the solution and measured as a proportion of the original sample.

3.6 Asphalt Mix Design

In the production of hot mix asphalt, asphalt and aggregate are blended together in precise proportion. The relative proportions of the materials determine the physical properties of the materials determine the finished pavement. There are three commonly used design procedures for determining suitable proportion of asphalt and aggregate in a mixture. They are Marshall Method, the Hveem method, and the Super pave system method.

3.6.1 Objective of Mix Design

The design of asphalt mix is largely a matter of selecting and proportioning materials to obtain the desired properties in the finished construction. The overall objective of the design procedure is to determine an economical blend and gradation of aggregates (within the limit of project specification or research specifications) and asphalt that yield a mix having:

Sufficient asphalt to ensure a durable pavement
Adequate mix stability to satisfy the demands of traffic without distortion or displacement
Void content high enough to allow for a slight amount of additional compaction under traffic loading without flushing, bleeding, and loss of stability, yet low enough to keep out harmful air and moisture.
Sufficient workability to permit efficient placement of the mix without segregation.The selected mix design is usually the one that best meets all of the established criteria. It should be accomplished with well trained personnel using the proper materials and calibrated equipment and following the specified procedures. For this study the Marshall Mix Design method for HMA mixtures was used to identify the optimum asphalt binder contents for all mixtures

3.6.2 Marshall Mix Design

The Marshall method of designing paving mixtures was developed by Bruce Marshall he is Bituminous Engineer with the Mississippi State Highway Department. The Marshall method is applicable only to hot mix asphalt using penetration, viscosity or PG graded asphalt binder or cement and containing aggregate with maximum size of 25.0 mm (1 in.) or less. The method is used for both laboratory design and field control. The purpose of marshal method is to determine the optimum asphalt content for a particular blend of aggregate. And also provide information about the properties of the resulting pavement mix, including density and void content, which are used during pavement constriction.

The Marshall method uses standard test specimen 64 mm (2.5 in) high and 102 mm (4 in.) internal diameter. A series of specimens, each containing the same aggregate blend but varying in asphalt content from 4 % to 6 % with increment of 1/2 % is prepared using a specific procedure to heat, mix and compact the asphalt aggregate mixture.

The procedure for the Marshall method starts with the preparation of test specimens, and steps preliminary to specimen preparation are:

All material proposed for use of meet the physical requirement of the project specification. Aggregate blend combination meets the graduation requirements of the project specification.

Determine the bulk specific gravity of all aggregate used in the blend and the specific gravity of asphalt cement for performing density and void analyses.

There was a significant amount of testing conducted throughout the progression of this study and there were several procedures followed for mix design, sample preparation, sample conditioning, and physical testing.

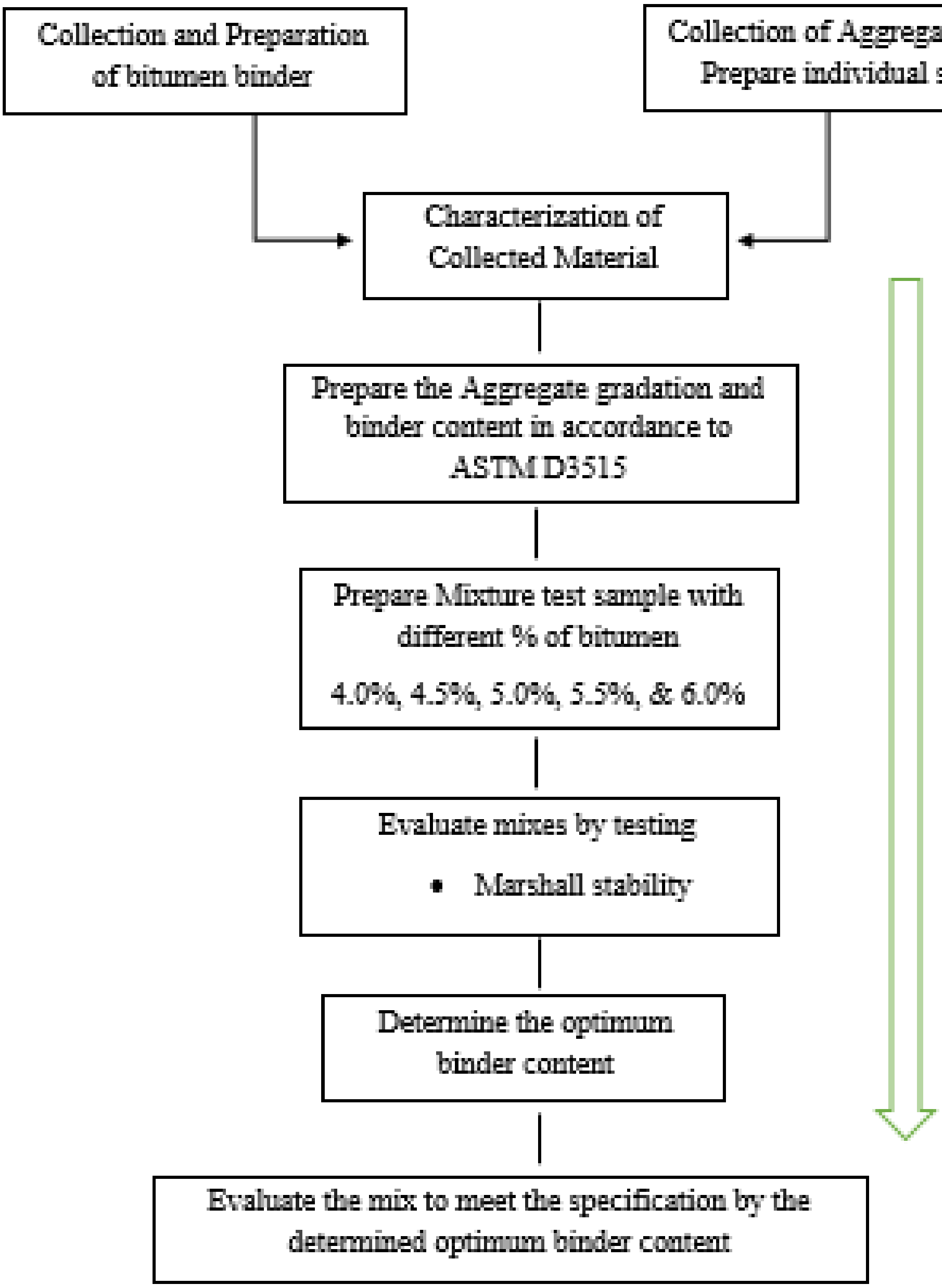

Figure 3.5: Flow chart of the Marshall Asphalt mix design.

3.6.3 Specimen Preparation

In determining the design asphalt content for a particular blend or gradation of aggregate by the Marshall method, a series of test specimens is prepared for a range of different asphalt contents so the test data curve show well defined relationships. The steps recommended for preparing Marshall Test specimens are:

A) Prepare number of Specimens.

Preparing Marshall Specimens using the Marshall procedures for individual specimens are necessary. Dry and sieve aggregates into sizes (preferably individual sizes) and store in clean salable containers. Separate enough material to make 2 (types of aggregate) × 15 (samples for five bitumen and three samples for each bitumen) = 30 specimens of approximately 1200 gm each.

B) Preparation of Aggregate

There are two types of aggregate is one the normal aggregate which the study used as control without blending with brick filler and the second one is the mixed or blending aggregate with brick filler shown in figure 3.4 Next weigh out aggregate for each conditions of specimens placing each in a separate container and heat to mixing temperature determined from the asphalt property. Then heat sufficient asphalt cement to prepare the total specimens on each step. Asphalt contents should be selected at 1/2 % percent increments with at least two asphalt contents above "optimum" and at least two below "optimum."

C) Determination of Mixing and compacting temperature.

It is necessary to mix asphalt cement and aggregate until all the aggregate is coated. It is helpful to work on a heated table. Mixing can be mechanical mixer shown in Figure 3.5. Also it is essential to check temperature of freshly mixed material; if it is above the compaction temperature, allow it to cool to compaction temperature; if it is below compaction temperature, discard the material and make a new mix.

The temperature to which the asphalt must be heated to produce viscosities of 170 ± 20 centistokes kinematics and 280 ± 30 centistokes kinematic shall be established as a mixing temperature and compaction temperature, respectively.

D) Preparation of Mold and Hammer

Thoroughly clean the specimen mold assembly and face of compaction hammer and heat them on the hot plate to a temperature between 95 ^{o}C and 150 ^{o}C (200 ^{o}F and 300 ^{o}F).as shown in figure 3.6. And place a piece of filter or waxed paper, in the bottom of the mold before the mixture is placed in the mold.

E) Preparation of mixtures

Weight into separate pans for each test specimen in the amount of each size fraction required to produce a batch that will result in compacted specimen 63.5 ± 1.227 mm (2.5 ± 0.05 in) in height, this is normally 1200 gm. (1.2 kg). Place the pan in the oven and heat to a temperature not exceeding 28 ^{o}C above the mixing temperature specified in (c). From the crater in the dry blended aggregate weight the required amount of asphalt binder into the mixture in accordance with the calculated batch weight, then mix the aggregate and the asphalt binder with mechanical mixer as quickly and thoroughly as possible to yield a mixture having a uniform distribution of asphalt as shown in figure.

F) Packing the Mold

Place a paper disk and entire batch shown in the figure to the mold, spade the mixture vigorously with a heated spatula 15 times around the perimeter and 10 times over the interior. Smooth the surface to a slightly rounded shape as shown in figure 3.8. The temperature for the compaction should be within the limit of compaction temperature, otherwise it shall be discarded.

G) Compaction of Specimens

Place a paper on top of the mix and place the mold assembly on the compaction pedestal in the mold holder. As specified according to the design traffic category these studies used by the maximum traffic flow of 75 blows with the compaction hammer using free fall of 457 mm. Then remove the plate and collar and reverse and reassembly the mold, apply the same number of compaction blows to the face of the reversed specimen as shown in Figure 3.7.

Figure 3.6.Compaction of hot specimen

3.6.4 Mixture characteristics and Behaviour

When a sample paving mixture is prepared in the laboratory, it can be analyzed to determine its probable performance in a pavement structure. The analysis focuses on four characteristics of the mixture and the influence those characteristics are likely to have on mix behavior. They are:

- Mix Density
- Air Void
- Void in the mineral aggregate
- Asphalt content

3.6.4.1 Mix Density

The density of the compacted mix is its unit weight or the weight of a specific volume of mix. Density is particularly important because high density of the finished pavement is essential for lasting pavement performance. In mix design testing and analysis, density of the compacted specimen is usually expressed in kilograms per cubic meter (kg/m3). It is calculated by multiplying the bulk specific gravity of the mix by the density of water [(1,000 kg/m^3) (62.43 lbs. $/ft^3$].

The bulk specific gravity of a mixture refers to the specific gravity of a specimen of compacted mixture, including the volume of air voids within the mixture. It is equivalent to the mass of a given specimen in grams, divided by its total volume in cubic centimeters. The bulk specific gravity of an asphalt concrete mixture can be determined using either laboratory compacted specimens or cores or slabs cut from a pavement.
The standard procedure for determining the bulk specific gravity of compacted asphalt concrete involves weighing the specimen in air and in water. The following formula is used for calculating bulk specific gravity of a saturated surface-dry specimen:

$$Gmb = A/(B - C)$$

.... Eq. 3.1

Where: Gmb= Bulk specific gravity of compacted specimen, A = Mass of the dry specimen in air, g, B = Mass of the saturated surface-dry specimen in air, g, and C = Mass of the specimen in water, g.

The specimen density and the maximum theoretical density, both of which are determined in the laboratory, are each used as standards to determine if the density of the finished pavement meets specification requirements.

3.6.4.2 Air voids

Air voids are small pockets of air between the coated aggregate particles in the final compacted HMA. Air void content does not include pockets of air within individual aggregate particles, or air contained in microscopic surface voids or capillaries on the surface of the aggregate. A certain percentage of air voids is necessary in the finished HMA to allow for a slight amount of compaction under traffic and a slight amount of asphalt expansion due to temperature increases. The allowable percentage of air voids in laboratory specimens is between 3 percent and 5 percent for surface and base courses, depending on the specific design.

The durability of an asphalt pavement is a function of the air void content. Therefore designing and maintaining the proper air void content in HMA and other mix types is important for several reasons. When air void contents are too high, the pavement may be too permeable to air and water, resulting in significant moisture damage and rapid age hardening. When air void contents are too low, the asphalt binder content may be too high, resulting in a mixture prone to rutting, bleeding and shoving.
Determining air void content is one of the main purposes of volumetric analysis. Unfortunately, there is no simple direct way to determine the air void content of an asphalt concrete specimen. Air void content is determined by comparing the specific gravity (or density) of a compacted specimen with the maximum theoretical density of the mixture used to make that specimen.

Density and air void content are directly related. The higher the density is the lower the void in the mix will be, and reversal. Job specifications usually require the pavement compaction achieve an air void content of less than 8 percent and more than 3 percent. Air void content is calculated from the mixture bulk and theoretical maximum specific gravity:

$$Va = \left[100[1 - \left[\frac{Gmb}{Gmm}\right]\right] \qquad \text{E.q 3.2}$$

Where; Va = Air void content, volume %,Gmb = Bulk specific gravity of compacted mixture and Gmm = Theoretical maximum specific gravity of loose mixture

3.6.4.3 Voids in the Mineral Aggregate (VMA)

It is the inter-granular void spaces that exist between the aggregate particles in a compacted paving mixture. VMA includes air voids and spaces filled with asphalt. VMA is a volumetric measurement expressed as a percentage of the total bulk volume of a compacted mix.

VMA represents; the space that is available to accommodate the effective volume of asphalt (i.e., all of the asphalt except the portion lost by absorption into the aggregate) and the volume of air voids necessary in the mixture. The more VMA in the dry aggregate, the more space is available for the films of asphalt. The durability of the mix increases with the film thickness on the aggregate particles. Therefore, specific minimum requirements for VMA are recommended and specified as a function of the aggregate size.

Minimum VMA is necessary to achieve an adequate asphalt film thickness, which results in a durable asphalt pavement. Increasing the density of the gradation of the aggregate to a point where below minimum VMA values are obtained leads to thin films of asphalt and a low-durability mix. Therefore, economizing in asphalt content by lowering VMA is actually counter-productive and detrimental to pavement quality. Table 3.2shows specification for VMA in ERA manual.

Table 3.2: Void in the mineral aggregate (ERA manual)

Nominal maximum particle size (mm)	7.5	28	20	14	10	5
Minimum void in mineral aggregate, %	12	12.5	14	15	16	18

$$VMA = (Va - Vbe) \quad \text{E.q 3.3}$$

Where:VMA =Voids in the mineral aggregate, % by total mixture volume, VA = Air void content, % by total mixture volume, be = Effective binder content, % by total mixture volume.

3.6.4.4. Binder Content

Binder content is one of the most important characteristics of asphalt pavement mix. Use of the proper amount of binder is essential to good performance in asphalt concrete mixtures. Too little binder will result in a dry stiff mix that is difficult to place and compact and will be prone to fatigue cracking and other durability problems. Too much binder will be uneconomical, since asphalt binder is, by far, the most expensive component of the mixture and will make the mixture susceptible to rutting and shoving.
Asphalt binder content can be calculated in four different ways: total binder content by weight, effective binder content by weight, total binder content by volume, and effective binder content by volume. Total asphalt content by volume is calculated as the percentage of binder by total mix mass:

$$Pb = 100\left[\frac{Mb}{Ms + Mb}\right]$$ .... E.q 3.4

Where

Pb = Total asphalt binder content, % by mix mass

Mb = Mass of binder in specimen

Ms = Mass of aggregate in specimen

Total asphalt binder content by volume can be calculated as a percentage of total mix volume using the following formula:

$$Vb = \left(\frac{Pb * Gmb}{Gb}\right)$$ ....,... E.q 3.5

Where

Vb = Total asphalt binder content, % by total mix volume

Pb = Total asphalt binder content, % by mix mass

Gmb = Bulk specific gravity of the mixture

Gb =Specific gravity of the asphalt binder

The absorbed asphalt binder content by volume is also calculated as a percentage of total mix volume:

$$Vba = Gmb\left[\left(\frac{Pb}{Gb}\right) + \left(\frac{Ps}{Gsb}\right) - \left(\frac{100}{Gmm}\right)\right]$$ ………………………................................ E.q 3.6

Where

Vba = Absorbed asphalt content, % by total mixture volume

Gmb= Bulk specific gravity of the mixture

Pb= Total asphalt binder content, % by mix mass

Gb= Specific gravity of the asphalt binder

Ps = Total aggregate content, % by mix mass = 100 – Pb

Gsb= Average bulk specific gravity for the aggregate blend

Gmm= Maximum specific gravity of the mixture

The effective asphalt by volume is found by subtracting the absorbed asphalt content from the total asphalt content:

$$Vbe = (Vb - Vba)$$ ….. E.q 3.7

Where

Vbe= Effective asphalt content, % by total mixture volume

V**b**= Total asphalt binder content, % by mixture volume

Vba, = Absorbed asphalt content, % by total mixture volume

The effective and absorbed asphalt binder contents can also be calculated as percentages by weight, once the volume percentage has been calculated:

$$Pba = Pb - Pbe \quad \text{.........E.q 3.8}$$

$$Pbe = Pb\left(\frac{Vbe}{Vb}\right) \quad \text{.........E.q 3.9}$$

Where

Pbe = Effective asphalt binder content, % by total mass

Pb = Asphalt binder content, % by total mass (see Equation 5-5)

Vbe = Effective asphalt binder content, % by total mixture volume (see Equation 5-8)

Vb = Asphalt binder content, % by total mixture volume (see Equation 5-6)

Pba = Absorbed asphalt binder, % by total mixture mass

3.6.4.5 Voids Filled with Asphalt

Voids filled with asphalt (VFA) are the percentage of inter-granular void space between the aggregate particles (VMA) that contains or is filled with asphalt. VFA is used to ensure that the effective asphalt part of the VMA in a mix is not too little (dry, poor durability) or too great (wet, unstable). The acceptable range of VFA varies depending upon the traffic level for the facility. Higher traffic requires a lower VFA, because mixture strength and stability is more of a concern. Lower traffic facilities require a higher range of VFA to increase HMA durability. A VFA that is too high, however, will generally yield a plastic mix. VFA is the effective binder content expressed as a percentage of the VMA:

$$VFA = 100\left(\frac{VMA - Va}{VMA}\right) \quad \text{.........E.q 3.10}$$

Where

VFA = voids filled with asphalt, as a volume percentage

VMA =Voids in the mineral aggregate, % by total mixture volume

Va = Air void content, % by total mixture volume

3.7 Test procedure

In Marshall Method of pavement mix design after preparation of test specimen, the next step is each compacted test specimen is subjected to these test and analysis those are listed below:

- Bulk Specific gravity determination.
- Stability and flow test.
- Density and Void analysis.

The equipment required for the testing the specimen of the 102 mm (4 in.) diameter x 64 mm (2.5 in.) height is:

Marshall testing Machine:

It is compression testing device, designed to apply loads to test specimens through cylindrical segment testing heads (inside radius of curvature of 51 mm (2 in)) at constant rate of vertical strain of 51 mm (2 in.) per minute. Two perpendicular guide posts are included to allow the two segments to maintain horizontal positioning and free vertical movement during the test. It is equipped with a calibrated proving ring for determining the applied testing load, a Marshall stability testing head for use in testing the specimen, and a Marshall flow meter for determining the amount of strain at the maximum load in the test.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Aggregate

The aggregate used in this research work is provided by Ethiopian Road Construction Corporation Jimma District.

Table 4.1: Aggregate Physical properties

No	Test Descriptions	Unit	Test Method	Result	Specification ERA (2002)
1	Particles shape, Flakiness	%	BS812, P110	14.8	<45
2	C.AggSp.Gravity (Bulk)	kg/m^3	AASHTO T85	2.81	N/A
3	F.AggSp.Gravity (Bulk)	kg/m^3	AASHTO T84	2.75	N/A
4	C.AggSp.Gravity (Apparent)	kg/m^3	AASHTO T85	2.88	N/A
5	F.AggSp.Gravity (Apparent)	kg/m^3	AASHTO T84	2.82	N/A
6	Aggregate crushing value	%	BS812, P104	13.6	<25
7	Los Angeles Abrasion	%	AASHTO T96	12.5	<30
8	Water Absorption	%	ASTM C127	1.72	<2
9	Durability & Soundness	%	ASTM C 128	6.2	<12
10	Aggregate impact value	%	BS812	16	<25
11	Cleanliness(materialpassing0.425mm)	%	BS1377	3	<4
12	Polished stone value	%	BS812	41	<50

From the figure above we observe that the aggregate material used for the construction is well and pass for the specification for ERA standard 2002.

4.1.1 Aggregate Gradation of Mix Design

HMA is graded by percentage of different-size aggregate particles it contains.

Those three types of hot-bins may combined together for gating the most well graded material for the asphalt layer material, and it is shown below in figure 4.1

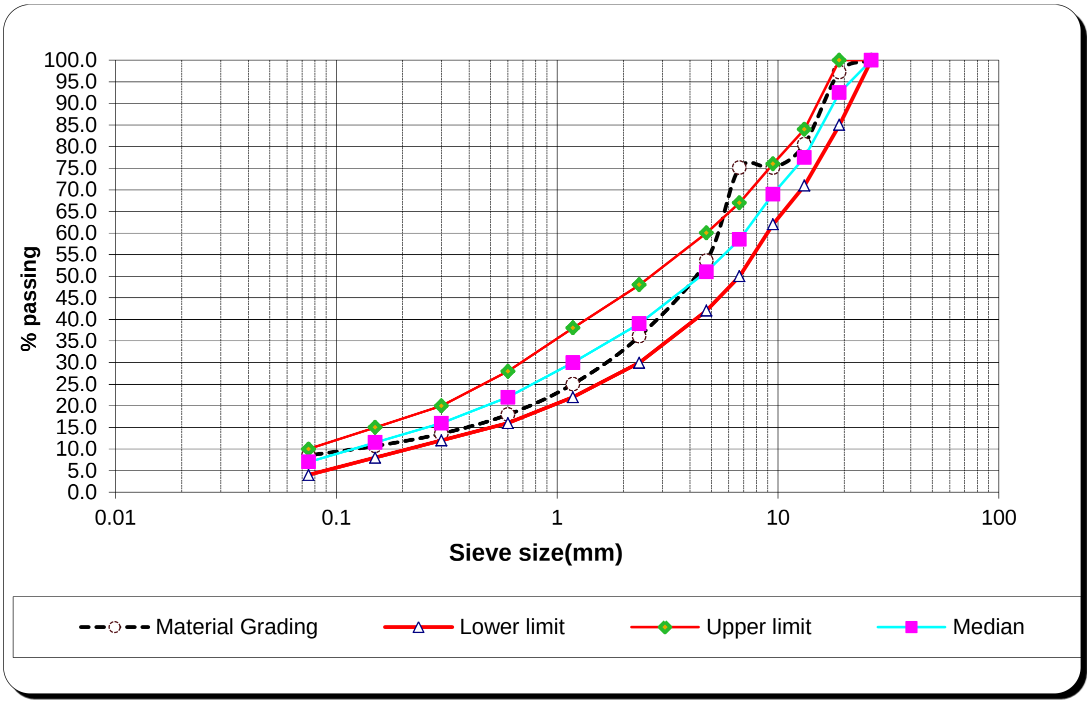

Figure 4.1: Combined Gradation of Hot-bin Aggregate

The above shown figure mention as the blending result of the material for the course aggregate is out of the upper and the lower limit, this means the material need to modify using Job mix design to get the blend in the limit of upper and lower.

4.2 Asphalt Binder Test Result

. The test results are shown in Table 4.2, which complies with the requirement of ERA specifications.

Table 4.2: Laboratory result of Asphalt Binder

No	Test Descriptions	Unit	Test Method	Result	Specification ERA (2002) for 85/100
1	Softening Point	^oC	AASHTO T 53	46	42-51
2	Solubility	%	AASHTO T 44	99.6	Min 99
3	Ductility	^oC	AASHTO T 51	100+	100+
4	Specific gravity	kg/m^3	AASHTOT228	1023	1020±
5	Penetration	^oC	AASHTO T49	90	85-100
6	Loss on Heating	%	AASHTO T47	23	Max 100
7	Flash Point	^oC	AASHTO T48	562	Min 232

4.3 Preparation of blending aggregate

The Job-Mix-Formula (JMF) for the aggregate particle size distribution that would be used for the preparation of mixtures shown in Table4.3. Where keeps the coarse aggregate size distribution varying distribution in the fines which means with different hot-bin types as shown there combined in Table 4.3.

Table 4.3: Over all, % passing of Blending aggregate of Job mix

AASHTO Sieve Size mm	20/13.2 mm	13.2/5.0 mm	5.0/0.0 mm	Plant Dust	Blending Result	Specification		Mix Tolerances	Job Mix Formula	
						lower	upper			
26.5	100.0	100.0	100.0	100.0	100.0	100	100	±5.0	95.0	100
19.0	89.5	100.0	100.0	100.0	97.3	85	100	±5.0	92.3	102.3
13.2	25.2	100.0	100.0	100.0	80.5	71	84	±5.0	75.5	85.5
9.50	4.5	99.6	100.0	100.0	75.1	62	76	±5.0	70.1	80.1
6.70	0.0	99.6	100.0	100.0	73.9	50	67	±5.0	68.9	78.9
4.75	0.3	21.3	95.3	100.0	53.6	42	60	±4.0	49.6	57.6
2.36	0.2	10.3	66.0	100.0	36.1	30	48	±4.0	32.1	40.1
1.18	0.1	7.1	45.8	100.0	25.0	22	38	±4.0	21.0	29.0
0.600	0.1	5.2	32.9	100.0	18.0	16	28	±4.0	14.0	22.0
0.300	0.1	4.0	24.7	100.0	13.6	12	20	±3.0	10.6	16.6
0.150	0.1	3.2	19.5	100.0	10.7	8	15	±2.0	8.7	12.7
0.075	0.0	2.4	15.6	100.0	8.5	4	10	±2.0	6.5	10.5
Blending proportion	26	23	51	0.0	100					

The specified grading limits and batching weight that of obtained for this study are as shown in Table 4.3.The aggregate gradation is normally expressed as the percentage (by weight) of total sample that passes through each sieve. It is determined by weight the contents of each sieve following the sieve analysis and then calculating the percentage passing each sieve by one of several mathematical procedures. One method is to subtract the weight of the contents of each sieve from the weight of the material passing the previous sieve, resulting in the total weight passing each sieve.

HMA is graded by percentage of different-size aggregate particles it contains. Table 4.3 illustrates three different HMA gradations. Certain terms are used in referring to aggregate fractions:

- Hot-Bin one -G-1 , 20/13.2
- Hot- Bin two -G-2 , 13.2/5.00

- Hot- Bin three - G-3 5.0/0.00

Note: - Mineral filler and Mineral Dust occur naturally with many aggregates and are produced as a by-product of crushing many types of rock.

Figure 4.2: Combined Gradation of aggregate for Wearing course

Figure 4.2 shows that the aggregate blend without filler for the Marshall Mixture preparation, which shows the blend G-1, 26%, G-2, 23%, and G-3, 51%. From the graph we conclude the blend needs somehow hot-bin two 13.2/5.0 mm materials to be in the specification lower and upper limit.

Table 4.4: Over all Batch weight for Marshall mix

AC,% by weight of total mix	AC in gm.	Total batch weight in gm.
4.0	43.8	1093.8
4.5	49.5	1099.5
5.0	55.3	1105.3
5.5	61.1	1111.1
6.0	67.0	1117.0

The first step in evaluation of test result from marshal design method is prepared the total batch weight of material including binder content as shown in above Table 4.4.

4.3.2 Measuring the Stability

It is a processing of measuring the stability values from the standard 63.5 mm (2 1/2 in) thickness shall be converted to an equivalent 63.5 mm (2 1/2 in) value by means of conversion factor. The applicable correlation ratio to convert the measured stability values are set in Table 4.5. The conversion may be made on the basis of either measured thickness or measured volume.

4.3.3 Measuring Flow Values

The flow values also read from the Marshall machine during the applied load fort stability check. So after reading the flow values the average the flow values and the final converted stability values for all specimens of given asphalt content listed in Table 4.6.

Table 4.5: Stability Correlation Ratios

Volume of Specimen cm^3	Approximate Thickness of Specimen		Correlation Ratio
	mm	in	
200 to 213	25.4	1	5.56
214 to 225	27	1 1/16	5
226 to 237	28.6	1 1/8	4.55
238 to 250	30.2	1 3/16	4.17
251 to 264	31.8	1 1/4	3.85
265 to 276	33.3	1 5/16	3.57
277 to 289	34.9	1 3/8	3.33
290 to 301	36.5	1 7/16	3.03
302 to 316	38.1	1 1/2	2.78
317 to 328	39.7	1 9/16	2.5
329 to 340	41.3	1 5/8	2.27
341 to 353	42.9	1 11/16	2.08
354 to 367	44.4	1 3/4	1.92
368 to 379	46	1 13/16	1.79
380 to 392	47.6	1 7/8	1.67
393 to 405	49.2	1 15/16	1.56
406 to 420	50.8	2	1.47

421 to 431	52.4	2 1/16	1.39
432 to 443	54	2 1/8	1.32
444 to 456	55.6	2 3/16	1.25
457 to 470	57.2	2 1/4	1.19
471 to 482	58.7	2 5/16	1.14
483 to 495	60.3	2 3/8	1.09
496 to 508	61.9	2 7/16	1.04
509 to 522	63.5	2 1/2	1
523 to 535	64	2 9/16	0.96
536 to 546	65.1	2 5/8	0.93
547 to 559	66.7	2 11/16	0.89
560 to 573	68.3	2 3/4	0.86
574 to 585	71.4	2 13/16	0.83
586 to 598	73	2 7/8	0.81
599 to 610	74.6	2 15/16	0.78
611 to 625	76.2	3	0.76

Source: Hot Asphalt Mix Manual, 2^{nd} edition

It is possible while making the specimen the thickness slightly vary from the standard specification of 63.5 mm. Therefore, measured stability values need to be corrected to those which would have been obtained if the specimens had been exactly 63.5 mm. This is done by multiplying each measured stability value by an appropriated correlation factors as a given Table 4.5

Gmb= Bulk specific gravity,

Gmm= Theoretical maximum specific gravity,

Va= Air Void in the total mix,

VMA= Voids in the mineral aggregate and

VFA = Void filled with asphalt

Table 4.6: Marshall Test result

% AC by wt. of mix,Spec.No.		Specimen Mass, gm			Bulk Volume, cc	Bulk S.G of Specimen	Th. Max. S.G. (Loose Mix)	Unit Weight, Mg/m³	% Air Void	% VMA	% VFB	Stability			Flow,mm
		In Air	In Water	SSD In Air								Measured, div	Factor	Adjusted, KN	
4.0	A	1239.4	753.5	1246.8	493.3	2.512	2.683	2.512	6.4	13.91	54.0	1095.0	1.09	14.64	3.20
4.0	B	1241.5	753.7	1248.8	495.1	2.508	2.683	2.508	6.5	14.04	53.7	1165.0	1.09	15.58	3.15
4.0	C	1247.2	762.8	1251.0	488.2	2.555	2.683	2.555	4.8	12.43	61.4	1170.0	1.09	15.65	3.15
Average						2.525	2.683	2.525	5.9	13.46	56.2			15.29	3.17
4.5	A	1248.6	762.1	1252.2	490.1	2.548	2.679	2.548	4.9	13.13	62.7	1040.0	1.09	13.91	3.15
4.5	B	1248.8	760.8	1249.5	488.7	2.555	2.679	2.555	4.6	12.89	64.3	1075.0	1.09	14.38	3.25
4.5	C	1247.6	759.7	1248.7	489.0	2.551	2.679	2.551	4.8	13.02	63.1	1005.0	1.09	13.44	3.38
Average						2.551	2.679	2.551	4.7	13.01	63.9			13.91	3.26
5.0	A	1248.9	764.0	1249.6	485.6	2.572	2.686	2.572	4.2	12.77	67.1	900.0	1.09	12.04	3.41
5.0	B	1248.3	763.4	1248.4	485.0	2.574	2.686	2.574	4.2	12.70	66.9	1100.0	1.09	14.71	3.48
5.0	C	1248.2	764.0	1248.2	484.2	2.578	2.686	2.578	4.0	12.56	68.2	955.0	1.09	12.77	3.59
Average						2.575	2.686	2.575	4.1	12.68	67.7			13.17	3.49
5.5	A	1246.1	763.0	1246.1	483.1	2.579	2.690	2.579	4.1	12.99	68.4	740.0	1.09	9.90	3.57
5.5	B	1247.2	762.9	1247.2	484.3	2.575	2.690	2.575	4.3	13.12	67.2	845.0	1.09	11.30	3.83
5.5	C	1244.6	761.3	1244.7	483.4	2.575	2.690	2.575	4.3	13.12	67.2	868.0	1.09	11.61	3.64
Average						2.576	2.690	2.576	4.2	13.08	67.9			10.94	3.68
6.0	A	1228.0	747.7	1228.4	480.7	2.555	2.689	2.555	5.0	14.26	64.9	580.0	1.14	8.11	3.71
6.0	B	1236.8	753.7	1237.0	483.3	2.559	2.689	2.559	4.8	14.12	66.0	750.0	1.09	10.03	4.40
6.0	C	1242.0	757.6	1242.2	484.6	2.563	2.689	2.563	4.7	13.99	66.4	755.0	1.09	10.10	5.22
Average						2.559	2.689	2.559	4.8	14.12	66.0			9.41	4.44

4.4 Analysis of physical properties of compacted HMA

4.4.1 Stability

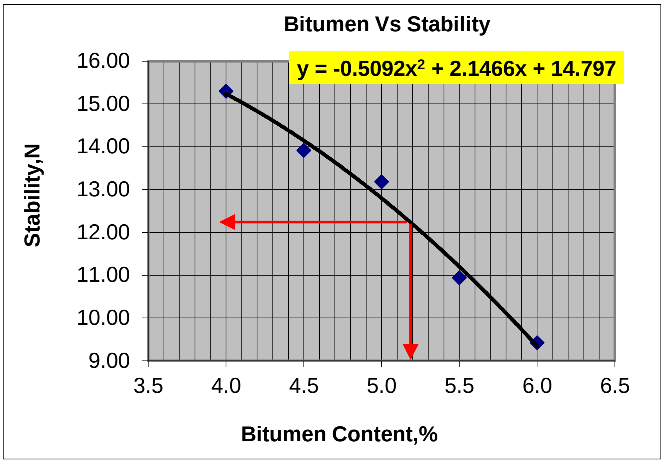

Figure 4.3: Comparison between Bitumen vs. Stability.

Anything that increases the viscosity of the asphalt cement increases the Marshall stability. Thestability of HMA versus bitumen content is given in Figure 4.3.

So the result shows that as the bitumen content increases from 3.5 to 6.5 percent. There may be a maximum value at a bitumen content of approximately 5.2 percent this show the material blending is give good percentage of optimum content of bitumen.

4.4.2 Unit Weight

The density of the compacted mix is the unit weight of the mixture (the weight of a specific volume of asphalt mixture). Density is important because proper density in the finished product is essential for lasting pavement performance. Mix properties are required to be measured in volumetric terms as well as weight is shown in Figure 4.4.

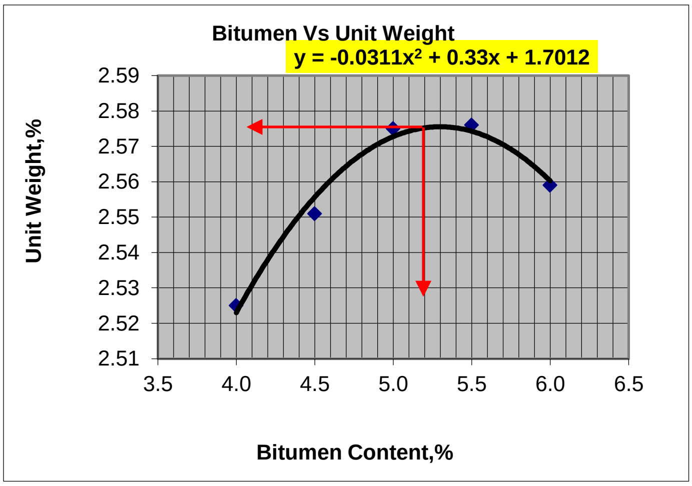

Figure 4.4: Comparison between Bitumen vs. Unit Weight

The above figure tells as the trend of unit weight verses bitumen content is usual trend which it gives the maximum unit weight given by the formula of second quadrant

$Y=-0.0311X^2 + 0.33X +1.7012 = 2.576$ by using bitumen content of 5.2 % which is very good when we compare with standard specification.

4.5.3 Voids in Mineral Aggregate (VMA)

VMA is the total volume of voids within the mass of the compacted aggregate. This total amount of voids significantly affects the performance of a mixture because if the VMA is too small, the mix may suffer durability problems, and if the VMA is too large, the mix may show stability problems and be uneconomical to produce. It is a common trend that, as filler content in the mixes increase, the voids in mineral aggregate decrease up to minimum value then increases at higher content.

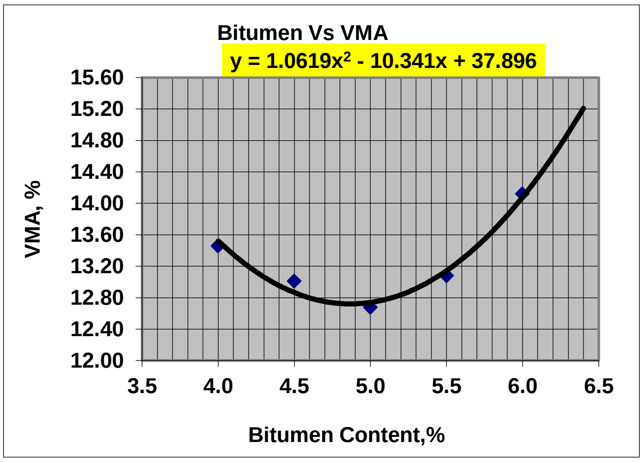

Figure 4.5: Comparison between Bitumen vs. VMA

It is a common trend that, as bitumen or a filler content in the mixes increase, the voids in mineral aggregate decrease up to minimum value then increases at higher content. So figure 4.5 tells as the result of void filled with aggregate is 14.90 % which is the middle of the specification which is the upper limit is 16 % and lower limit is 10 %.

4.5.4 Voids Filled with Bitumen (VFB)

A void filled with asphalt (VFB) is the percentage of inter-granular void space between the aggregate particles (VMA) that contains or is filled with asphalt.

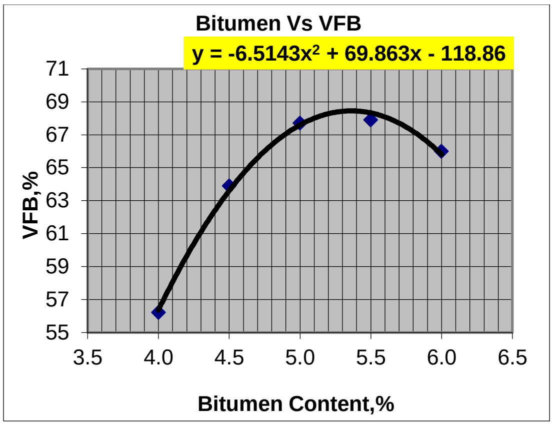

Figure 4.6: VFB, Comparison between Bitumen vs VFB

Most specifications include percent VFA requirements range from 65 - 80 percent. Since VFB depends on both VMA and Va, the cumulative effects shown on Figure 4.6.This gives 68.28 % which means the middle below the average of the upper and lower limit of the specification.

4.5.4 Air Void in the mix (Va)

Air voids may be increased or decreased by lowering or raising the binder content. They may also be increased or decreased by controlling the amount of material passing the No. 200 sieve in the asphalt mixture.

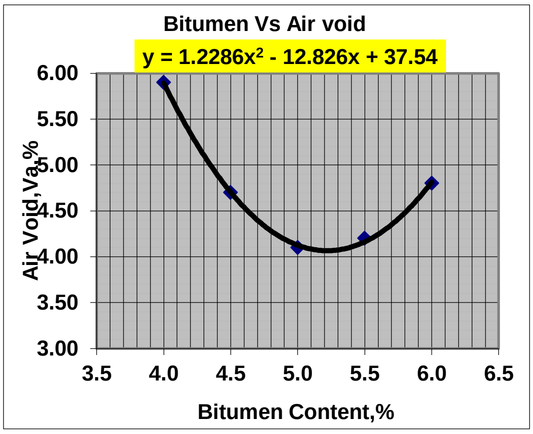

Figure 4.7: Air Void Comparison

The more fines added to the asphalt mixture generally the lower the air voids. If a plant has a bag house dust collection system, the air voids may be controlled by the amount of fines which are returned to the asphalt mixture. Finally, the air voids may be changed by varying the aggregate gradation in the asphalt mixture. In our case the air void is 4.07 % that is result of aggregate which it gives good dust material in default in the hot-binis.

4.5.5 Flow

Flow refers that the vertical deformation of the sample (measured from start of loading to the point at which stability begins to decrease) in 0.25 mm.

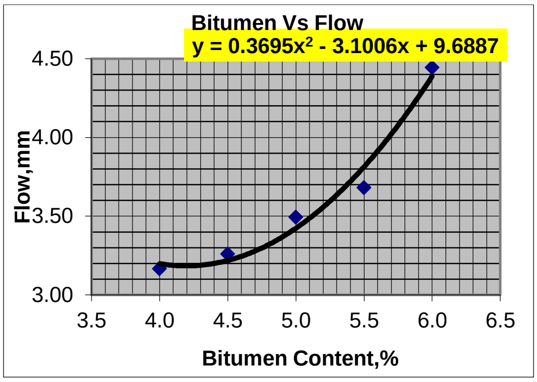

Figure 4.8: Flow Comparison between Bitumen vs flow

High flow values generally indicate a plastic mix that will experience permanent deformation under traffic, whereas low flow values may indicate a mix with higher than normal voids and insufficient asphalt for durability and one that may experience premature cracking due to mixture brittleness during the life of the pavement. Our result gives that the flow of the material in this study is good which gives 3.6 % which is approach to the upper limit this means it may be affected for permanent deformation under traffic.

4.5.6 Optimum Asphalt Content Determination

It is considered that the effective asphalt content in the mixture determines the performance of mixtures. This can be explained as that it is the effective asphalt binder content that makes the asphalt film around the aggregate particles.

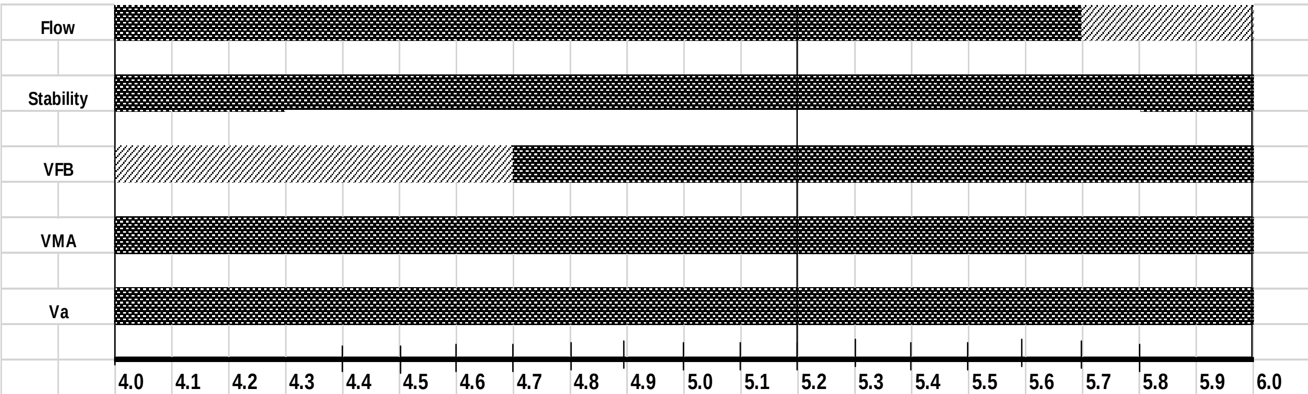

Figure 4.9: Flow Comparison optimum bitumen content

If the asphalt film thickness around the aggregate particles is thick enough, various desirable characteristics such as better durability, more fatigue resistance, and higher resistance to moisture induced damage can be achieved from bituminous mixtures. But, there should be a maximum limit where up on an increase in temperature and loading, the asphalt content in the mix gets increased and results bleeding on the surface of paved road.

Table 4.7 Summary of Marshal Mix design of the study

No.	**Marshall Mix Property**	**Unit**	**Marshall Mix result**	**Specification ERA manual 2**
1	OBC	%	5.2	5 to 7
2	Flow	%	3.6	2 to 4
3	Stability	KN	12.19	Min 9 KN
4	VFB	%	68.28	60 to 85
5	Va	%	4.07	3 to 6
6	VMA	%	14.90	10 to 16
7	Unit weight	Mg/m^3	2.75	-

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

This study investigate the material quality of asphalt layer by Using standardized testing procedures, aggregate was tested for all the necessary quality tests including specific gravity, absorption, abrasion resistance, void content, and gradation. Similarly important quality tests of bitumen were conducted in a laboratory and all the results were pass the necessary specifications.

This analysis will try to answer the question of whether the problem happen due to the quality of material or the performance the HMA mixtures irrespective of which application method is used. On the basis of test results and analysis obtained in a controlled laboratory, the following conclusions and recommendations are presented.

5.1 Conclusions

- The laboratory investigation showed that Physical property of aggregate is strong material with an ACV <25 in percent butalso has medium water absorptioncapacity because in most moderate but not bad, of its little bit porosity. The gradation fulfill the requirement, but lacking sufficient fines and having coarser particles but not more than upper limit of gradation in the blending of the three Hot-Bin types.
- The optimum asphalt content value were required to fulfill the Marshall requirement is 5.2% this give moderate asphalt content and it is between the lower and upper limit of the specification.
- The void filled with bitumen (VFB) values obtained indicate relatively high trend that is 68.28% which is not the average of upper and lower limit this is b/c of the insufficient of fine material.
- The others property are on good median of upper and lower limit of specification which are air void and void field by bitumen.
- But the flow gives 3.6 % which is so approach of the Upper limit which is 4% this may result permanent deformation under traffic to the road.
- So the pavement condition along the study area has been affected by different failure types such as cracks, surface defect and disintegrating.

5.2 Recommendation

- Because of approach result of flow the road may be giver deformation to the future so it is butter to see take remedial action or prepare them self to the future for the problem occur.
- Since the flow is proportional relationship with bitumen content and dust material, it is butter to minimize the bitumen content and add some amount of filler material to those Hot-bines for gating good performance of flow.
- It is recommended further or detail investigation on the subgrade and sub-base material of the road including the geological properties of the rout.

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APPENDIX I

Table I.1:- Hot-bin Three (5/0 mm) Aggregate gradation Trial 1

Material Type:	**AC aggregate (5/0 mm)**				
Sampling location:	**Asphalt Plant**			Total Wt.of sample before wash in gm	**1032.0**
Sample taken	**from Hot bin**	**Trial :-**	**1**	Total Wt. of sample after wash in gm	**934.9**

Sieve Opening, mm	Wt. Retained, gm	% Retained	JOB GRADE % Pass	Specification Limit		Median of the Specific. Limit
				LOWER LIMIT	UPPER LIMIT	
26.5	0.0	0.0	100.0	100.0	100.0	100.0
19.0	0.0	0.0	100.0	85.0	100.0	92.5
13.2	0.0	0.0	100.0	71.0	84.0	77.5
9.5	0.0	0.0	100.0	62.0	76.0	69.0
6.7	0.0	0.0	100.0	50.0	67.0	58.5
4.75	61.9	6.0	94.0	42.0	60.0	51.0
2.36	233.2	22.6	71.4	30.0	48.0	39.0
1.18	177.5	17.2	54.2	22.0	38.0	30.0
0.600	160.0	15.5	38.7	16.0	28.0	22.0
0.300	116.6	11.3	27.4	12.0	20.0	16.0
0.150	87.7	8.5	18.9	8.0	15.0	11.5
0.075	98.0	9.5	9.4	4.0	10.0	7.0
Pan	97.1	9.4	0.0			
Total	1032.0	100				

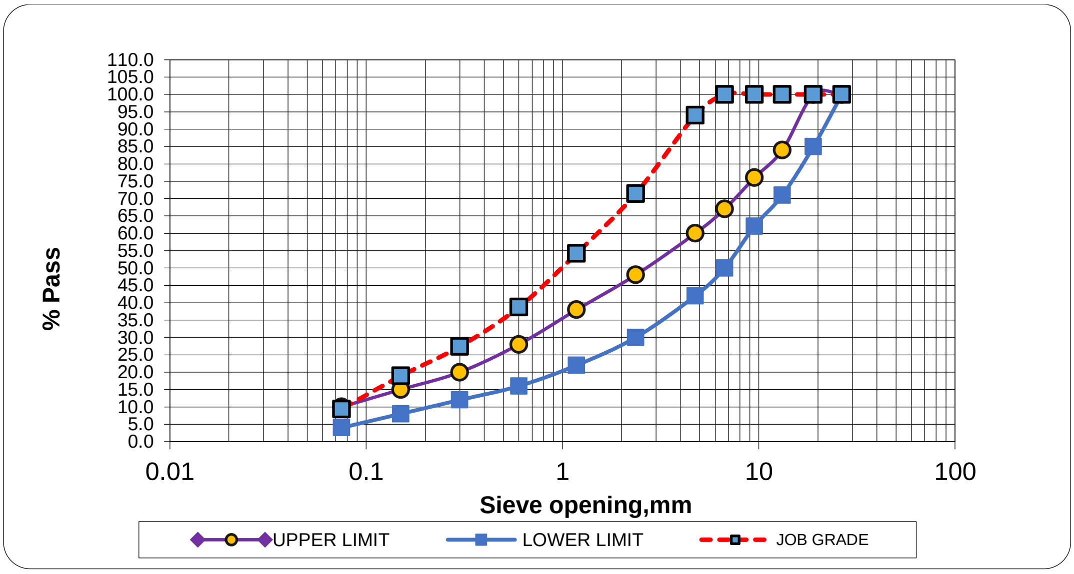

Figure I.1: hot-bin three (5/0 mm) Aggregate gradations Trial 1

Table I.2:- Hot-bin three (5/0 mm) Aggregate gradation Trial 2

Material Type: **AC aggregate (5/0 mm)**			
Sampling location: **Asphalt Plant**		Total Wt.of sample before wash in gm	**1532.0**
Sample taken from **Hot bin**	**Trial :-** **2**	Total Wt. of sample after wash in gm	**1385.0**

Sieve Opening, mm	Wt. Retained, gm	% Retained	JOB GRADE % Pass	Specification Limit		Median of the Specific. Limit
				LOWER LIMIT	UPPER LIMIT	
26.5	0.0	0.0	100.0	100.0	100.0	100.0
19.0	0.0	0.0	100.0	85.0	100.0	92.5
13.2	0.0	0.0	100.0	71.0	84.0	77.5
9.5	0.0	0.0	100.0	62.0	76.0	69.0
6.7	0.0	0.0	100.0	50.0	67.0	58.5
4.75	90.4	5.9	94.1	42.0	60.0	51.0
2.36	344.7	22.5	71.6	30.0	48.0	39.0
1.18	266.6	17.4	54.2	22.0	38.0	30.0
0.600	234.4	15.3	38.9	16.0	28.0	22.0
0.300	171.6	11.2	27.7	12.0	20.0	16.0
0.150	131.8	8.6	19.1	8.0	15.0	11.5
0.075	145.5	9.5	9.6	4.0	10.0	7.0
Pan	147.0	9.6	0.0			
Total	1532.0	100				

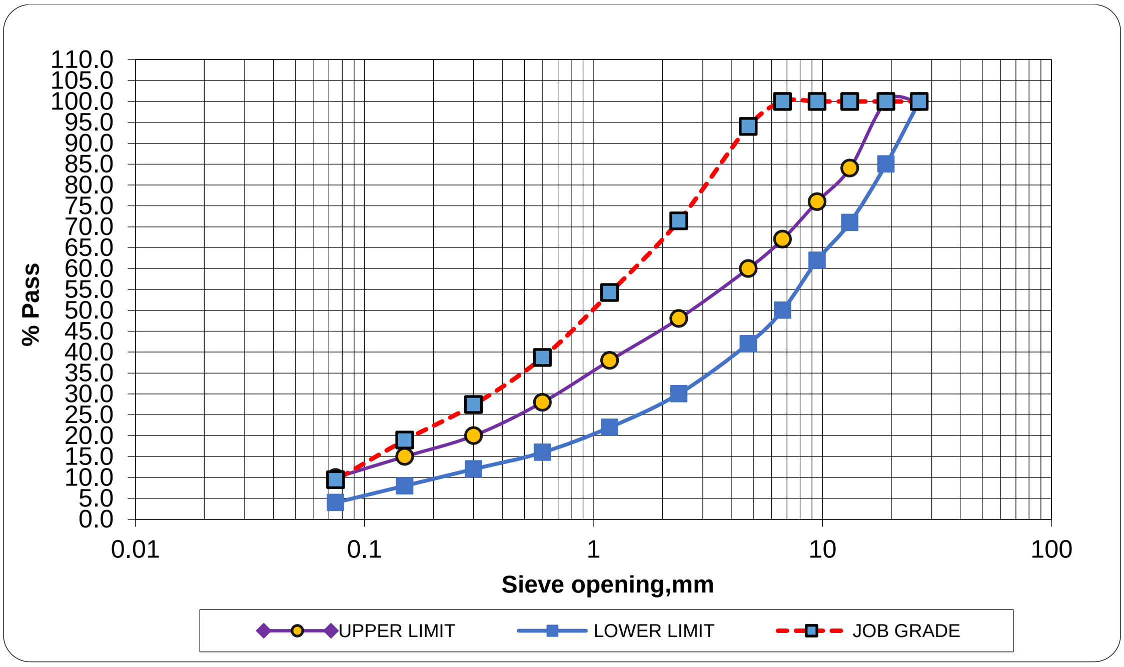

Figure I.2: Hot-bin three (5/0 mm) Aggregate gradation Trial 2

Table I.3:- Hot-bin three (5/0 mm) Aggregate gradation Trial 3

Material Type: **AC aggregate (5/0 mm)**			
Sampling location: **Asphalt Plant**		Total Wt.of sample before wash in gm	**1728.0**
Sample taken from **Hot bin**	**Trial :-** **3**	Total Wt. of sample after wash in gm	**1563.8**

Sieve Opening, mm	Wt. Retained, gm	% Retained	JOB GRADE % Pass	Specification Limit		Median of the Specifi. Limit
				LOWER LIMIT	UPPER LIMIT	
26.5	0.0	0.0	100.0	100.0	100.0	100.0
19.0	0.0	0.0	100.0	85.0	100.0	92.5
13.2	0.0	0.0	100.0	71.0	84.0	77.5
9.5	0.0	0.0	100.0	62.0	76.0	69.0
6.7	0.0	0.0	100.0	50.0	67.0	58.5
4.75	103.7	6.0	94.0	42.0	60.0	51.0
2.36	388.8	22.5	71.5	30.0	48.0	39.0
1.18	298.9	17.3	54.2	22.0	38.0	30.0
0.600	266.1	15.4	38.8	16.0	28.0	22.0
0.300	193.5	11.2	27.6	12.0	20.0	16.0
0.150	148.6	8.6	19.0	8.0	15.0	11.5
0.075	164.2	9.5	9.5	4.0	10.0	7.0
Pan	164.2	9.5	0.0			
Total	1728.0	100				

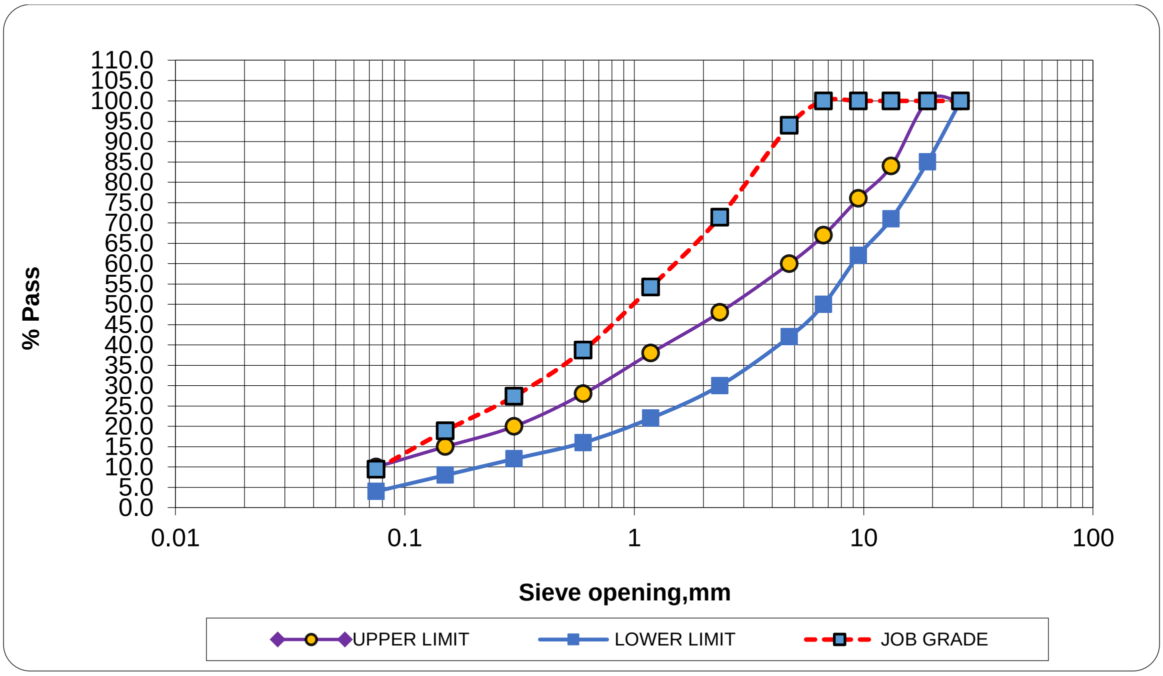

Figure I.3: Hot-bin three (5/0 mm) Aggregate gradation Trial 3

Table I.4:- Hot-bin three (13/5 mm) Aggregate gradation Trial 1

Material Type:	**AC aggregate (13 /5 mm)**				
Sampling location	**Asphalt Plant**			Total Wt.of sample before wash in gm	**3168.0**
Sample taken	**from Hot bin**	**Trial :-**	**1**	Total Wt. of sample after wash in gm	**3118.0**

Sieve Opening, mm	Wt. Retained, gm	% Retained	JOB GRADE % Pass	Specification Limit		Median of the Specific. Limit
				LOWER LIMIT	UPPER LIMIT	
26.5	0.0	0.0	100.0	100.0	100.0	100.0
19.0	0.0	0.0	100.0	85.0	100.0	92.5
13.2	0.0	0.0	100.0	71.0	84.0	77.5
9.5	1109.0	35.0	65.0	62.0	76.0	69.0
6.7	1413.0	44.6	20.4	50.0	67.0	58.5
4.75	539	17.0	3.4	42.0	60.0	51.0
2.36	47.5	1.5	1.9	30.0	48.0	39.0
1.18	9.5	0.3	1.6	22.0	38.0	30.0
0.600	0	0.0	1.6	16.0	28.0	22.0
0.300	0	0.0	1.6	12.0	20.0	16.0
0.150	0.0	0.0	1.6	8.0	15.0	11.5
0.075	0.0	0.0	1.6	4.0	10.0	7.0
Pan	50.0	1.6	0.0			
Total	3168.0	100				

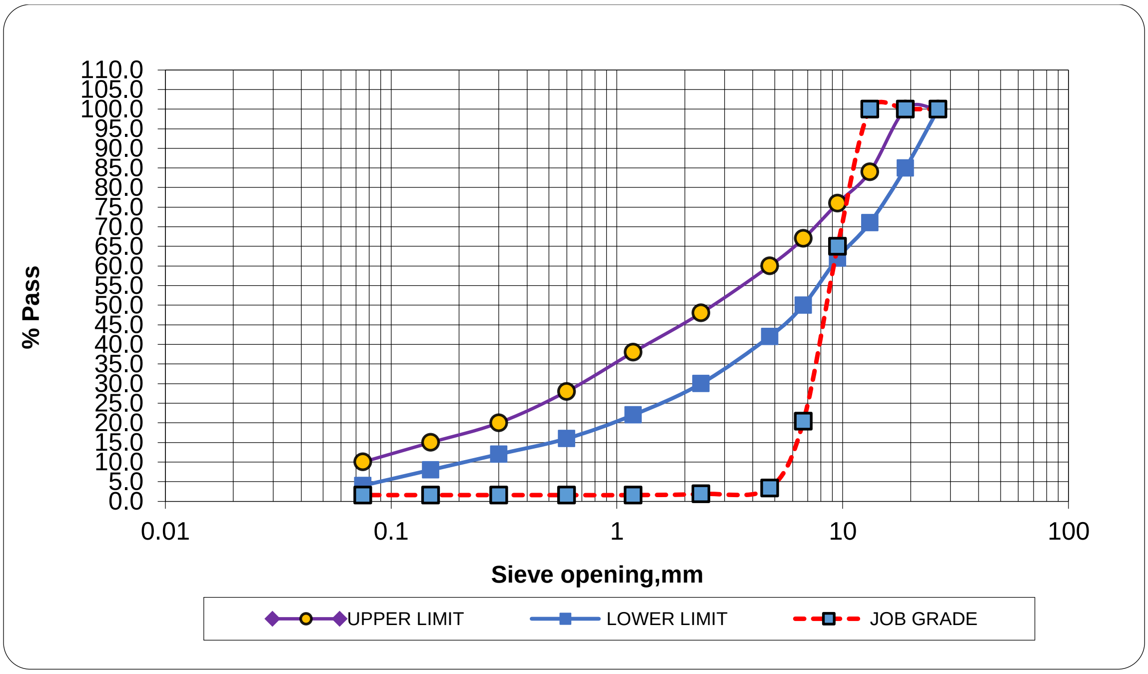

Figure I.4: Hot-bin two (13/5 mm) Aggregate gradation Trial 1

Table I.5:- Hot-bin two (13/5 mm) Aggregate gradation Trial 2

Material Type:	**AC aggregate (13 /5 mm)**			
Sampling location:	**Asphalt Plant**		Total Wt.of sample before wash in gm	**3552.0**
Sample taken from **Hot bin**	**Trial :-**	**2**	Total Wt. of sample after wash in gm	**3501.8**

Sieve Opening, mm	Wt. Retained, gm	% Retained	JOB GRADE % Pass	Specification Limit		Median of the Specific. Limit
				LOWER LIMIT	UPPER LIMIT	
26.5	0.0	0.0	100.0	100.0	100.0	100.0
19.0	0.0	0.0	100.0	85.0	100.0	92.5
13.2	0.0	0.0	100.0	71.0	84.0	77.5
9.5	1245.0	35.1	64.9	62.0	76.0	69.0
6.7	1586.0	44.7	20.3	50.0	67.0	58.5
4.75	604	17.0	3.3	42.0	60.0	51.0
2.36	55.1	1.6	1.7	30.0	48.0	39.0
1.18	11.7	0.3	1.4	22.0	38.0	30.0
0.600	0	0.0	1.4	16.0	28.0	22.0
0.300	0	0.0	1.4	12.0	20.0	16.0
0.150	0.0	0.0	1.4	8.0	15.0	11.5
0.075	0.0	0.0	1.4	4.0	10.0	7.0
Pan	50.2	1.4	0.0			

Total	3552.0	100				

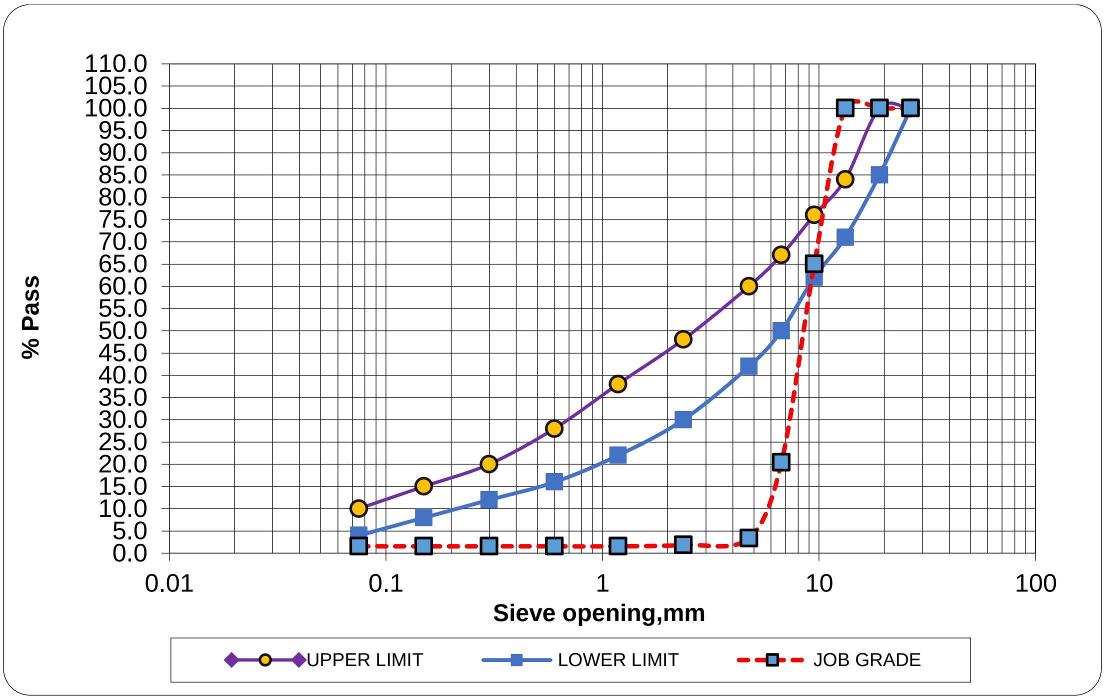

Figure I.5: Hot-bin two (13/5 mm) Aggregate gradation Trial 2

Table I.6:- Hot-bin two (13/5 mm) Aggregate gradation Trial 3

Material Type:	**AC aggregate (13 /5 mm)**				
Sampling location:	**Asphalt Plant**			Total Wt.of sample before wash in gm	**3112.0**
Sample taken from **Hot bin**		**Trial :-**	**3**	Total Wt. of sample after wash in gm	**3075.9**

Sieve Opening, mm	Wt. Retained, gm	% Retained	JOB GRADE % Pass	Specification Limit		Median of the Specific. Limit
				LOWER LIMIT	UPPER LIMIT	
26.5	0.0	0.0	100.0	100.0	100.0	100.0
19.0	0.0	0.0	100.0	85.0	100.0	92.5
13.2	0.0	0.0	100.0	71.0	84.0	77.5
9.5	1092.0	35.1	64.9	62.0	76.0	69.0
6.7	1391.0	44.7	20.2	50.0	67.0	58.5
4.75	532.2	17.1	3.1	42.0	60.0	51.0
2.36	49.5	1.6	1.5	30.0	48.0	39.0
1.18	11.2	0.4	1.2	22.0	38.0	30.0
0.600	0.0	0.0	1.2	16.0	28.0	22.0
0.300	0.0	0.0	1.2	12.0	20.0	16.0
0.150	0.0	0.0	1.2	8.0	15.0	11.5

0.075	0.0	0.0	1.2	4.0	10.0	7.0
Pan	36.1	1.2	0.0			
Total	3112.0	100				

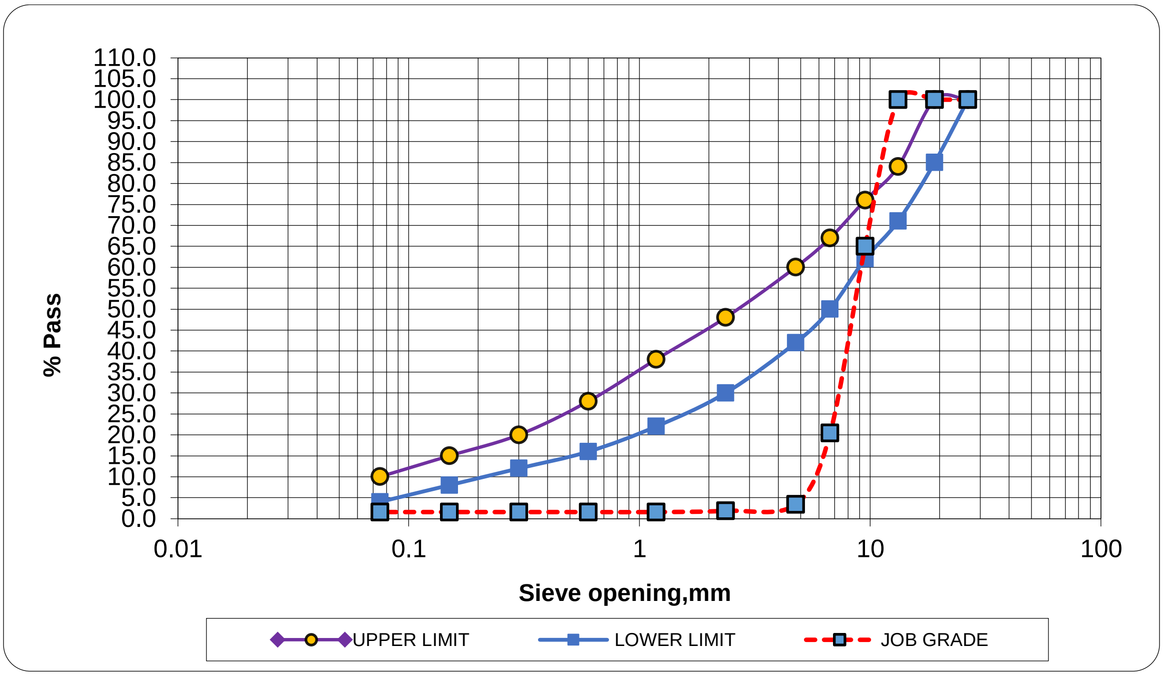

Figure I.6: hot-bin two (13/5 mm) Aggregate gradations Trial 3

Table I.7:- Hot-bin one (20/13 mm) Aggregate gradation Trial 1

Material Type:	**AC aggregate (20/13.2 mm)**				
Sampling location:	**Asphalt Plant**			Total Wt.of sample before wash in gm	**5646.0**
Sample taken	**from Hot bin**	**Trial :-**	**1**	Total Wt. of sample after wash in gm	**5589.2**

Sieve Opening, mm	Wt. Retained ,gm	% Retained	JOB GRADE % Pass	Specification Limit		Median of the Specific. Limit
				LOWER LIMIT	UPPER LIMIT	
26.5	0.0	0.0	100.0	100.0	100.0	100.0
19.0	1372.0	24.3	75.7	85.0	100.0	92.5
13.2	3161.8	56.0	19.7	71.0	84.0	77.5
9.5	993.7	17.6	2.1	62.0	76.0	69.0
6.7	50.8	0.9	1.2	50.0	67.0	58.5
4.75	5.3	0.1	1.1	42.0	60.0	51.0
2.36	5.6	0.1	1.0	30.0	48.0	39.0
1.18	0	0.0	1.0	22.0	38.0	30.0
0.600	0	0.0	1.0	16.0	28.0	22.0
0.300	0	0.0	1.0	12.0	20.0	16.0
0.150	0.0	0.0	1.0	8.0	15.0	11.5

0.075	0.0	0.0	1.0	4.0	10.0	7.0
Pan	56.8	1.0	0.0			
Total	5646.0	100				

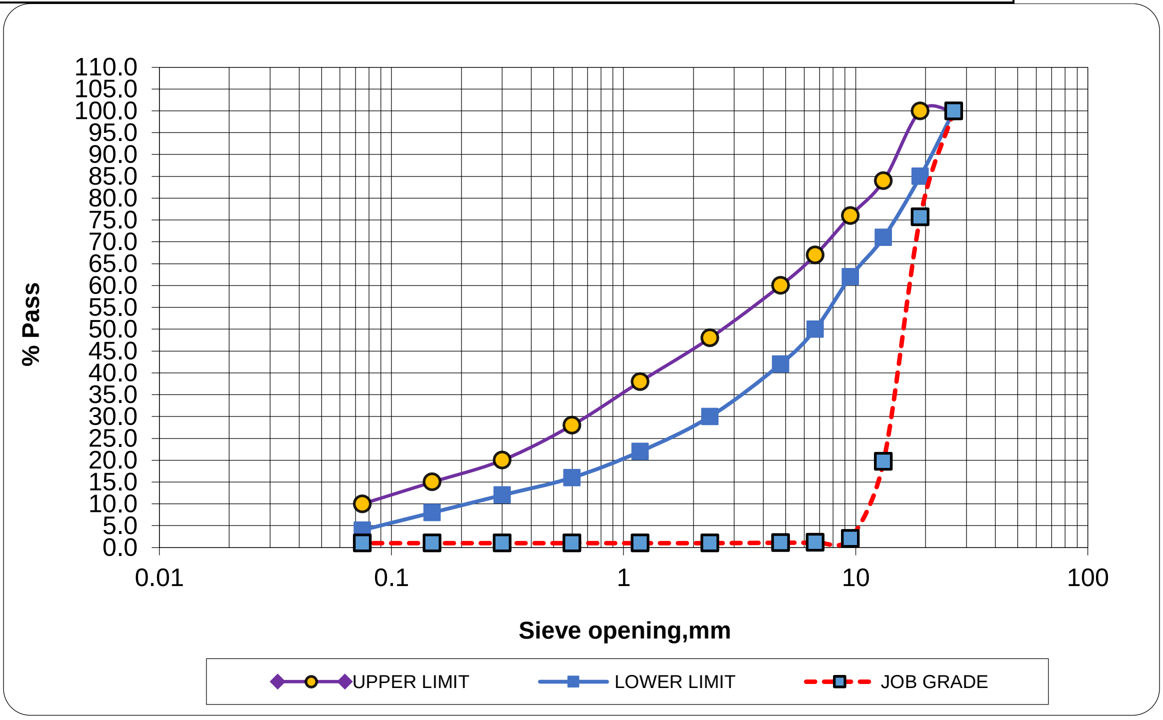

Figure I.7: Hot-bin one (20/13 mm) Aggregate gradation Trial 1

Table I.8: Hot-bin one (20/13 mm) Aggregate gradation Trial 2

Material Type:	**AC aggregate (20/13.2 mm)**				
Sampling location:	**Asphalt Plant**			Total Wt.of sample before wash in gm	**5556.0**
Sample taken from **Hot bin**		**Trial :-**	**2**	Total Wt. of sample after wash in gm	**5506.0**

Sieve Opening, mm	Wt. Retained, gm	% Retained	JOB GRADE % Pass	Specification Limit		Median of the Specific. Limit
				LOWER LIMIT	UPPER LIMIT	
26.5	0.0	0.0	100.0	100.0	100.0	100.0
19.0	1345.0	24.2	75.8	85.0	100.0	92.5
13.2	3122.0	56.2	19.6	71.0	84.0	77.5
9.5	972.3	17.5	2.1	62.0	76.0	69.0
6.7	50.0	0.9	1.2	50.0	67.0	58.5
4.75	5.6	0.1	1.1	42.0	60.0	51.0
2.36	11.1	0.2	0.9	30.0	48.0	39.0
1.18	0	0.0	0.9	22.0	38.0	30.0
0.600	0	0.0	0.9	16.0	28.0	22.0
0.300	0	0.0	0.9	12.0	20.0	16.0

0.150	0.0	0.0	0.9	8.0	15.0	11.5
0.075	0.0	0.0	0.9	4.0	10.0	7.0
Pan	50.0	0.9	0.0			
Total	5556.0	100				

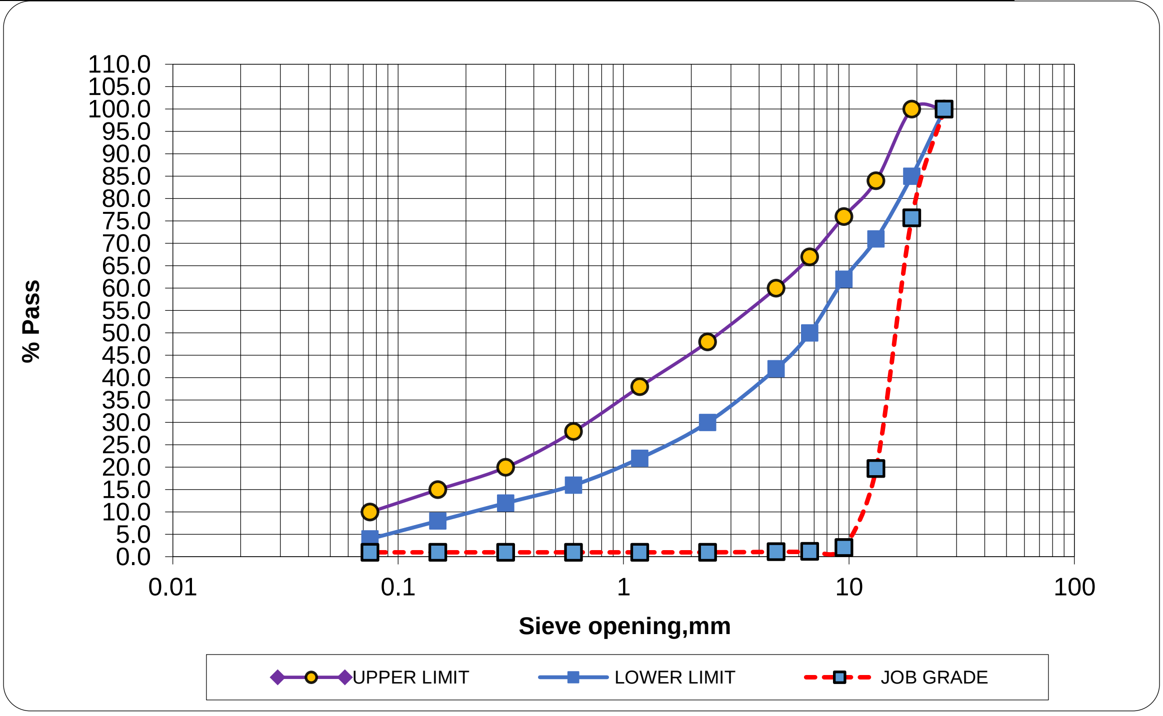

Figure I.8: Hot-bin one (20/13 mm) Aggregate gradation Trial 2

Table I.9: Hot-bin one (20/13 mm) Aggregate gradation Trial 3

Material Type:	**AC aggregate (20/13.2 mm)**			
Sampling location:	**Asphalt Plant**		Total Wt.of sample before wash in gm	**5550.0**
Sample taken from **Hot bin**		**Trial :-** **3**	Total Wt. of sample after wash in gm	**5527.8**

Sieve Opening, mm	Wt. Retained, gm	% Retained	JOB GRADE % Pass	Specification Limit		Median of the Specific. Limit
				LOWER LIMIT	UPPER LIMIT	
26.5	0.0	0.0	100.0	100.0	100.0	100.0
19.0	1354.2	24.4	75.6	85.0	100.0	92.5
13.2	3152.4	56.8	18.8	71.0	84.0	77.5
9.5	960.2	17.3	1.5	62.0	76.0	69.0
6.7	50.0	0.9	0.6	50.0	67.0	58.5
4.75	5.6	0.1	0.5	42.0	60.0	51.0
2.36	5.4	0.1	0.4	30.0	48.0	39.0
1.18	0.0	0.0	0.4	22.0	38.0	30.0
0.600	0.0	0.0	0.4	16.0	28.0	22.0
0.300	0.0	0.0	0.4	12.0	20.0	16.0

0.150	0.0	0.0	0.4	8.0	15.0	11.5
0.075	0.0	0.0	0.4	4.0	10.0	7.0
Pan	22.2	0.4	0.0			
Total	5550.0	100				

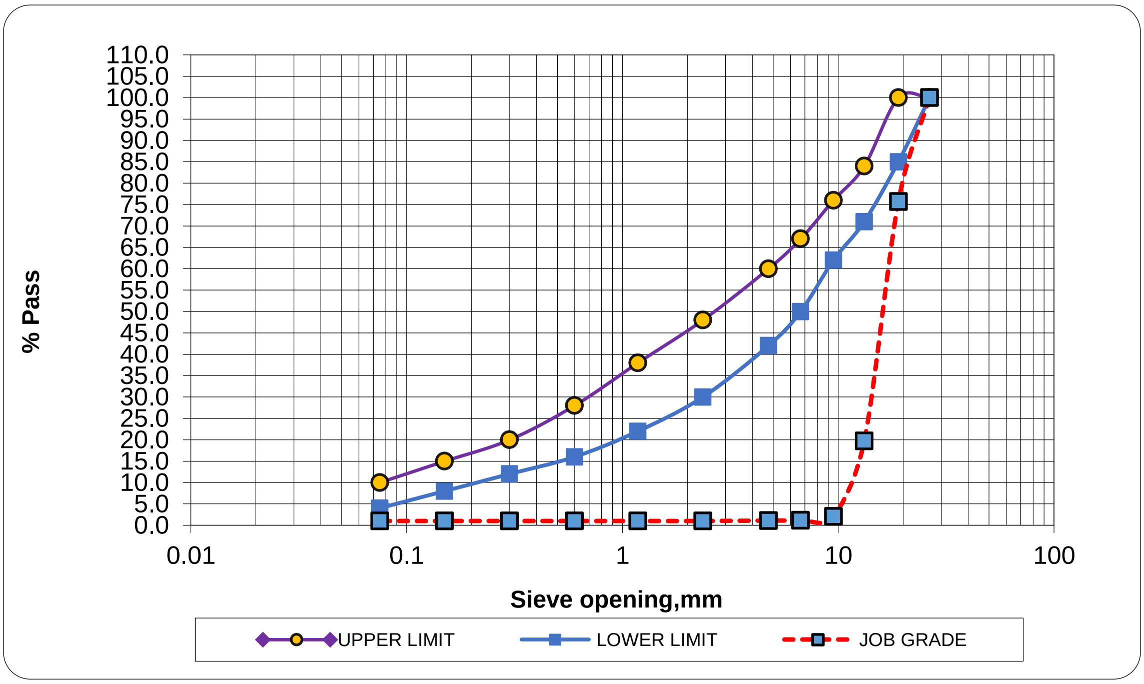

Figure I.9: Hot-bin three(20/13 mm) Aggregate gradation Trial 3

Table I.10: combined Hot-bin three (5/0 mm) Aggregate gradation

Material Type:	**AC aggregate (5/0mm)**		
Sampling location:	**Asphalt Plant**	Total Wt.of sample before wash in gm	**3242.1**
Sample taken	**Crusher Plant Hot Bin**	Total Wt. of sample after wash in gm	**2735.6**

Sieve Opening, mm	Wt. Retained, gm	% Retained	% Pass	Specification Limit		Median
				Minimum	Maximum	
26.5	0.0	0.0	100.0	100	100	100.0
19.0	0.0	0.0	100.0	85	100	92.5
13.2	0.0	0.0	100.0	71	84	77.5
9.5	0.0	0.0	100.0	62	76	69.0
6.70	0.0	0.0	100.0	50	67	58.5
4.75	153.9	4.7	95.3	42	60	51.0
2.36	947.5	29.2	66.0	30	48	39.0
1.18	655	20.2	45.8	22	38	30.0
0.600	419.4	12.9	32.9	16	28	22.0
0.300	264	8.1	24.7	12	20	16.0
0.150	169.8	5.2	19.5	8	15	11.5

0.075	126.0	3.9	15.6	4	10	7.0
Pan	36.5	1.1	14.5			
Total	2772.1	86				

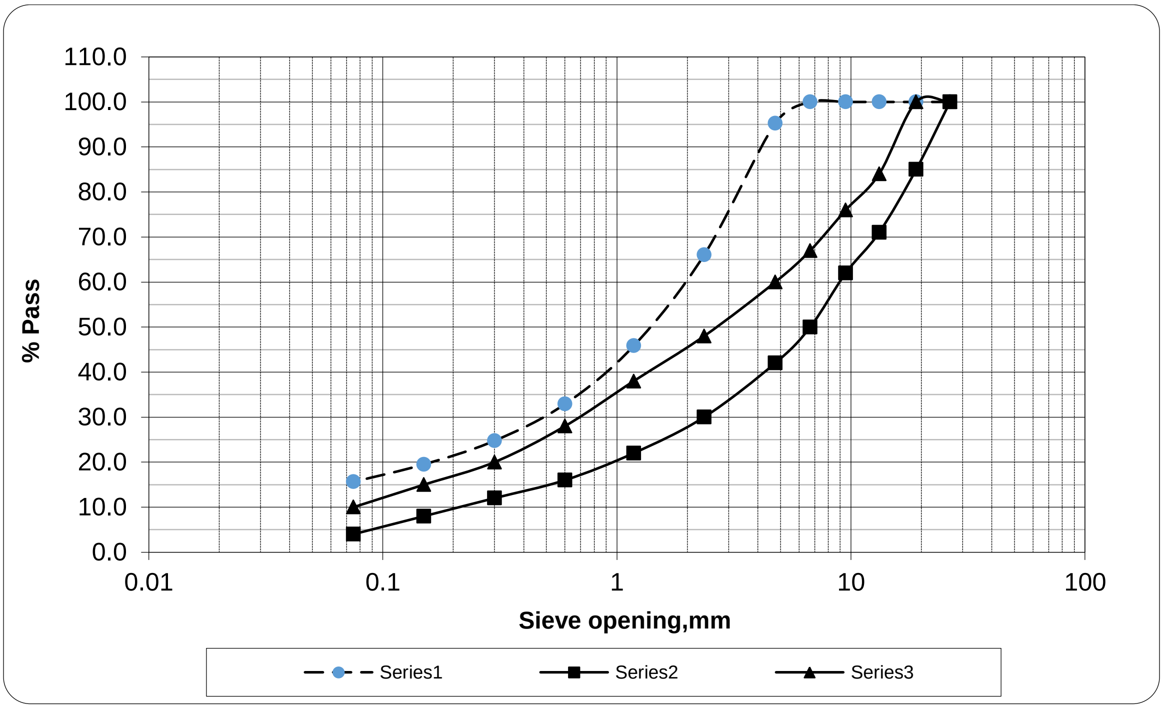

Figure I.10: Combined Hot-bin three (5/0 mm) Aggregate gradation

Table I.11: Combined Hot-bin two (13/5 mm) Aggregate gradation

Material Type:	**AC aggregate (13.2/5 mm)**		
Sampling location:	**Asphalt Plant**	Total Wt.of sample before wash in gm	**4313.8**
Sample taken	**Crusher Plant Hot Bin**	Total Wt. of sample after wash in gm	**4208.9**

Sieve Opening, mm	Wt. Retained, gm	% Retained	% Pass	Specification Limit		Median
				Minimum	Maximum	
26.5	0	0.0	100.0	100	100	100.0
19.0	0	0.0	100.0	85	100	92.5
13.2	0	0.0	100.0	71	84	77.5
9.5	15.5	0.4	99.6	62	76	69.0
6.70	0	0.0	99.6	50	67	58.5
4.75	3378	78.3	21.3	42	60	51.0
2.36	474.2	11.0	10.3	30	48	39.0
1.18	140	3.2	7.1	22	38	30.0
0.600	83.5	1.9	5.2	16	28	22.0
0.300	50.1	1.2	4.0	12	20	16.0
0.150	35.2	0.8	3.2	8	15	11.5

0.075	32.4	0.8	2.4	4	10	7.0
Pan	104.9	2.4	0.0			
Total	4313.8	100				

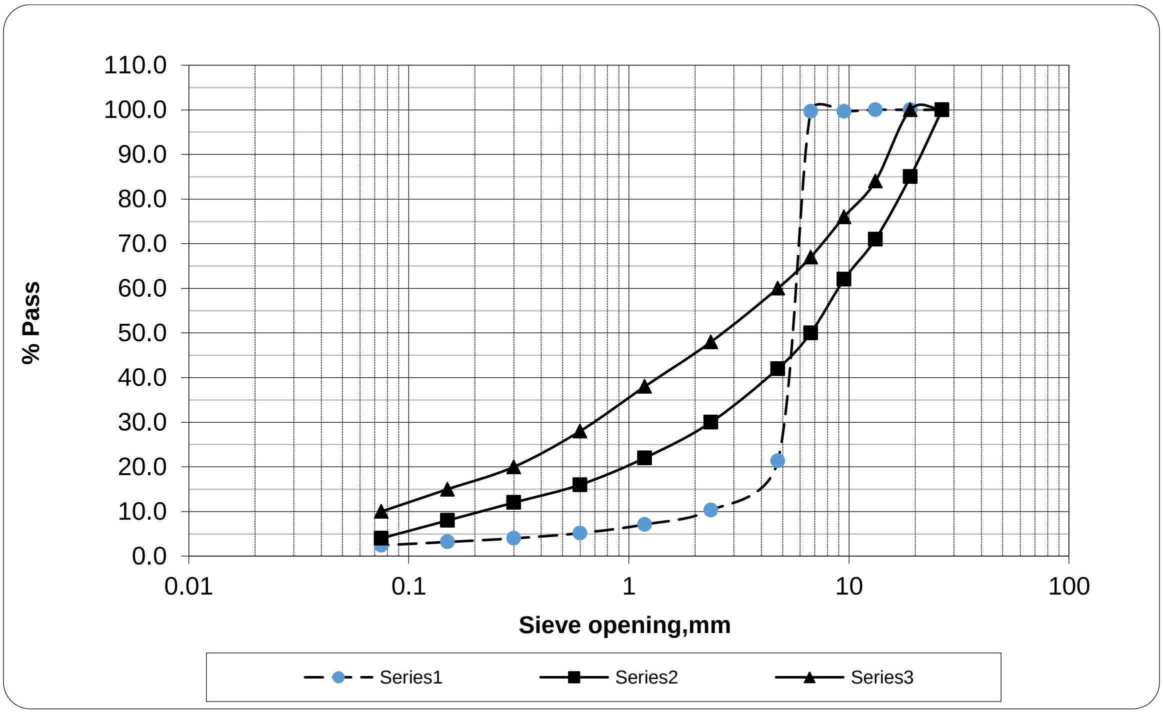

Figure I.11: Combined Hot-bin two (13/5mm) Aggregate gradation

Table I.12: Combined Hot-bin three (20/13 mm) Aggregate gradation

Material Type:	**AC aggregate (20/13.2 mm)**		
Sampling location:	**Asphalt Plant**	Total Wt.of sample before wash in gm	**3700.4**
Sample taken	**Crusher Plant Hot Bin**	Total Wt. of sample after wash in gm	**3700.0**

Sieve Opening, mm	Wt. Retained, gm	% Retained	% Pass	Specification Limit		Median
				Minimum	Maximum	
26.5	0.0	0.0	100.0	100	100	100.0
19.0	389	10.5	89.5	85	100	92.5
13.2	2380	64.3	25.2	71	84	77.5
9.5	765	20.7	4.5	62	76	69.0
6.70	0	0.0	4.5	50	67	58.5
4.75	155	4.2	0.3	42	60	51.0
2.36	4.0	0.1	0.2	30	48	39.0
1.18	2.0	0.1	0.1	22	38	30.0
0.600	1.0	0.0	0.1	16	28	22.0
0.300	1.0	0.0	0.1	12	20	16.0
0.150	1.0	0.0	0.1	8	15	11.5

0.075	2.0	0.1	0.0	4	10	7.0
Pan	0.4	0.0	0.0			
Total	3700.4	100				

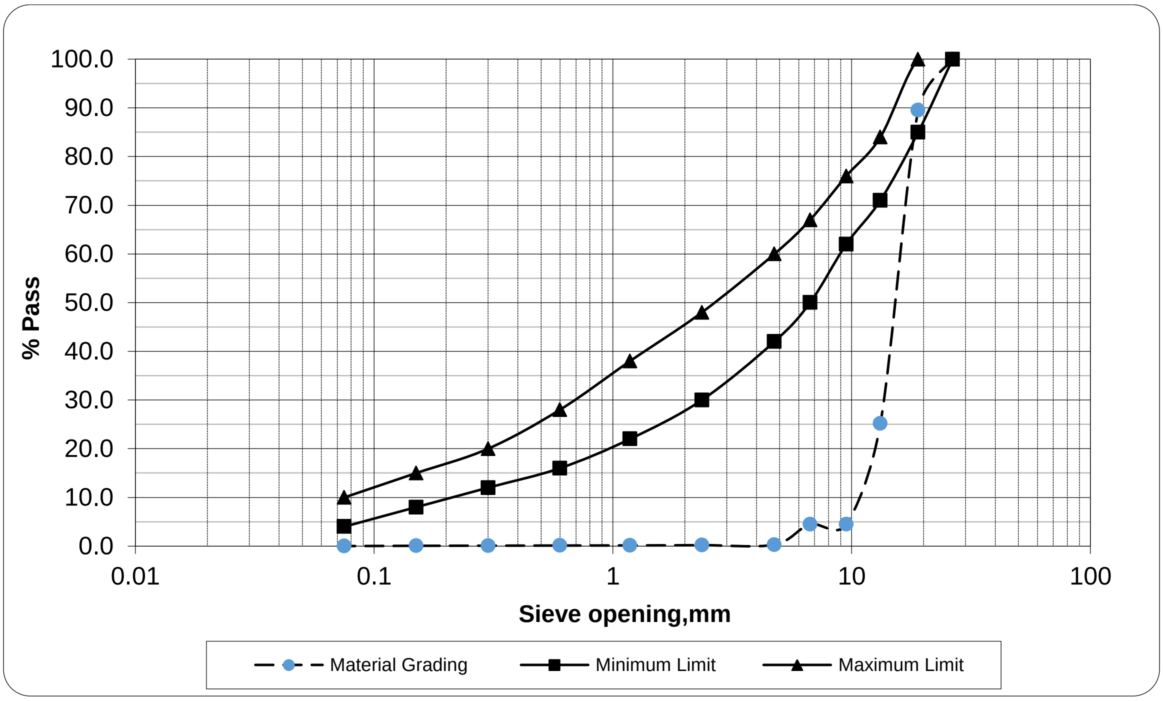

Figure I.12: Combined Hot-bin one (20/13mm) Aggregate gradation

Table I.12: All Combined Hot-bin Aggregate gradation for wearing course

AASHTO Sieve Size mm	20/13.2 mm	13.2/5.0mm	5.0/0.0mm	Plant Dust	Blending Result	Specification		Median
						lower	upper	
26.5	100.0	100.0	100.0	100.0	100.0	100	100	100.0
19.0	89.5	100.0	100.0	100.0	97.3	85	100	92.5
13.2	25.2	100.0	100.0	100.0	80.5	71	84	77.5
9.50	4.5	99.6	100.0	100.0	75.1	62	76	69.0
6.70	4.5	99.6	100.0	100.0	75.1	50	67	58.5
4.75	0.3	21.3	95.3	100.0	53.6	42	60	51.0
2.36	0.2	10.3	66.0	100.0	36.1	30	48	39.0
1.18	0.1	7.1	45.8	100.0	25.0	22	38	30.0
0.600	0.1	5.2	32.9	100.0	18.0	16	28	22.0
0.300	0.1	4.0	24.7	100.0	13.6	12	20	16.0
0.150	0.1	3.2	19.5	100.0	10.7	8	15	11.5
0.075	0.0	2.4	15.6	100.0	8.5	4	10	7.0
Blending proportion	26	23	51	0.0	100			

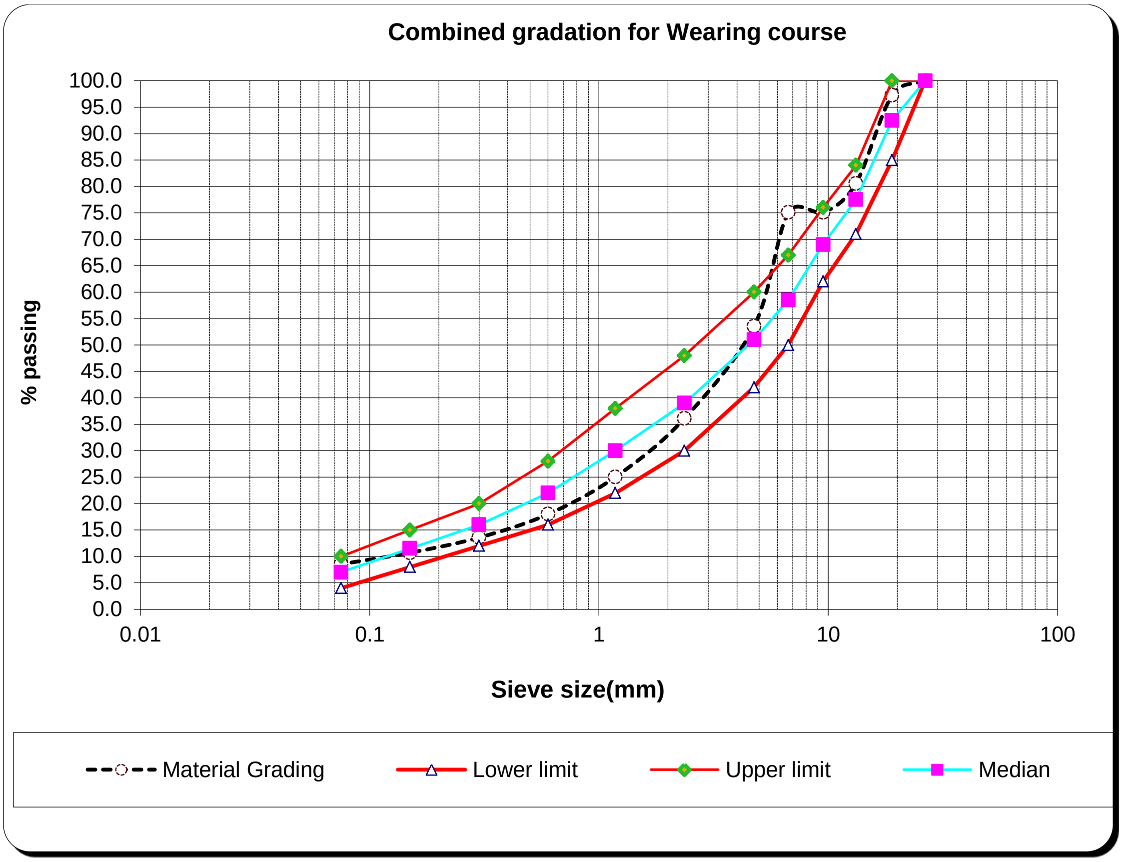

Figure I.12: All Combined Hot-bin Aggregate gradation for wearing course

APPENDIX II

Specific Gravity and Water Absorption of Course Aggregate (AASHTO T85 - 91)

Table II.1: Hot-bin one (0/5mm) Aggregate Specific gravity & Water Absorption

Description	1	2	3	Average
A. Mass of Oven Dry Sample in air gm	496.0	494.7	494.7	
B. Mass of Saturated Surface Dry in Air gm	500	500.0	500	
C. Mass of Flask + Water gm	760.5	762.3	759.9	
D. Mass of Flask + Water +Sample gm	1080.6	1082.3	1080	
Absorption of water (B - A)*100/A	0.806	1.071	1.071	0.983
Temperature , ^{o}C	23±1.7	23±1.7	23±1.7	
Apparent Specific gravity, A/(A-(D-C))	2.820	2.832	2.833	2.828
Bulk specific gravity, A/(B-(D-C))	2.757	2.748	2.750	2.752
Bulk specific gravity, SD basis B/(B-(D-C))	2.779	2.778	2.779	2.779

Table II.2: Hot-bin two (5/13mm) Aggregate Specific gravity& Water Absorption

Description	1	2	3	Average
A. Mass of Oven Dry Sample in air gm	2098.2	2011.9	2326.6	

B. Mass of Saturated Surface Dry in Air, SSD gm	2117.3	2030.2	2350.1	
C. Mass of Sample in Water gm	1364.7	1307.5	1515.2	
Absorption of water (B - A)*100/A	0.910	0.910	1.010	0.943
Temperature , °C	23±1.7	23±1.7	23±1.7	
Apparent Specific gravity, A/(A-C)	2.861	2.856	2.867	2.861
Bulk specific gravity, A/(B-C)	2.788	2.784	2.787	2.786
Bulk specific gravity, SSD basis B/(B-C)	2.813	2.809	2.815	2.812

Table II.3: Hot-bin three (13/20 mm) Aggregate Specific gravity& Water Absorption

Description	1	2	3	Average
A. Mass of Oven Dry Sample in air gm	2837.7	3065.9	2868.8	
B. Mass of Saturated Surface Dry in Air, SSD, gm	2864.0	3093.7	2895.7	
C. Mass of Sample in Water gm	1853.3	2002	1875.8	
Absorption of water (B - A)*100/A	0.927	0.907	0.938	0.924
Temperature , °C	23±1.7	23±1.7	23±1.7	
Apparent Specific gravity, A/(A-C)	2.883	2.882	2.889	2.884
Bulk specific gravity, A/(B-C)	2.808	2.808	2.813	2.810
Bulk specific gravity, SSD basis B/(B-C)	2.834	2.834	2.839	2.836

APPENDIX III

THEORETICAL MAXIMUM SPECIFIC GRAVITY OF HOT-MIX ASPHALT PAVING MIXTURES (AASHTO T 209-05)

Table III.1: Theoretical Maximum Specific Gravity for BC 4%

Sample Taken From Laboratory prepared

Bitumen content of the Sample ,%, 4.0

	Description	Sample-1	Sample-2	Sample-3	Average
°C	Temprature of Test Water	**20.9**	**20.9**		
A	Mass of Pycnometer filled with water , g	**9978.5**	9978.53		
D	Mass of Oven Dry Sample in air, g	**1244.00**	**1248.00**		
E	Mass of Pycnometer filled with Sample and water , g	**10759.0**	**10761.0**		
Gmm	**Theoretical Maximum Specific Gravity**	**2.684**	**2.681**		2.683

Effective Specfic Gravity of Combined Aggregate,Gse:

$$\textbf{Gse=} \frac{100-Pb}{(100/Gmm)-(Pb/Gb)} \qquad 2.874$$

Where :- Gse = Effective Specific Gravety of Combined Aggregete 2.874

Pb = % AC by wt.of Total Mixtures 4.00

Gb= Specific Gravity of Bitumen 1.033

Gmm=Maximum Specific Gravity 2.683

Table III.2: Theoretical Maximum Specific Gravity for BC 4.5%

	Sample Taken From Laboratory prepared	**Date sample :-**			
	Bitumen content of the Sample ,%, 4.5	**Date Testing :-**			

	Description	**Sample-1**	**Sample-2**	**Sample-3**	**Average**
°C	Temprature of Test Water	**20.5**	**22.3**		
A	Mass of Pycnometer filled with water , g	**9978.8**	9977.98		
D	Mass of Oven Dry Sample in air, g	**1250.00**	**1216.00**		
E	Mass of Pycnometer filled with Sample and water , g	**10762.0**	**10740.0**		
Gmm	**Theoretical Maximum Specific Gravity**	**2.678**	**2.679**		2.679

Effective Specfic Gravity of Combined Aggregate,Gse:

$$Gse = \frac{100 - Pb}{(100/Gmm) - (Pb/Gb)}$$ 2.896

Where :-		
Gse	= Effective Specific Gravety of Combined Aggregete	2.896
Pb	= % AC by wt.of Total Mixtures	4.50
Gb	= Specific Gravity of Bitumen	1.033
Gmm	=Maximum Specific Gravity	2.679

Table III.3: Theoretical Maximum Specific Gravity for BC 5.0%

Sample Taken From Laboratory prepared **Date sample :-** **0-Jan-00**

Bitumen content of the Sample ,%, **5.0** **Date Testing :-** **0-Jan-00**

	Description	Sample-1	Sample-2	Sample-3	Average
°C	Temprature of Test Water	**22.3**	**21.6**		
A	Mass of Oven Dry Sample in air, g	**9978.0**	**9978.3**		
D	Mass of Pycnometer filled with water , g	**1256.00**	**1240.00**		
E	Mass of Pycnometer filled with Sample and water , g	**10766.0**	**10757.0**		
Gmm	**Theoretical Maximum Specific Gravity**	**2.684**	**2.688**		2.686

Effective Specfic Gravity of Combined Aggregate,Gse:

$$Gse = \frac{100-Pb}{(100/Gmm)-(Pb/Gb)} \qquad 2.933$$

Where :-	Gse = Effective Specific Gravety of Combined Aggregete	2.933
	Pb = % AC by wt.of Total Mixtures	5.00
	Gb= Specific Gravity of Bitumen	1.033
	Gmm=Maximum Specific Gravity	2.686

Table III 4.:Theoretical Maximum Specific Gravity for BC 5.5%

	Sample Taken From Laboratory prepared	**Date sample :-**	**0-Jan-00**		
	Bitumen content of the Sample ,%, 5.5	**Date Testing :-**	**0-Jan-00**		
	Description	**Sample-1**	**Sample-2**	**Sample-3**	**Average**
°C	Temprature of Test Water	**22.0**	**22.1**		
A	Mass of Oven Dry Sample in air, g	**9978.3**	**9978.2**		
D	Mass of Pycnometer filled with water , g	**1266.00**	**1264.00**		
E	Mass of Pycnometer filled with Sample and water , g	**10774**	**10772**		
Gmm	**Theoretical Maximum Specific Gravity**	**2.692**	**2.688**		2.690

Effective Specfic Gravity of Combined Aggregate,Gse:

$$\textbf{Gse}= \frac{100-Pb}{(100/Gmm)-(Pb/Gb)} \qquad 2.967$$

Where :-	Gse = Effective Specific Gravety of Combined Aggregete	2.967
	Pb = % AC by wt.of Total Mixtures	5.50
	Gb= Specific Gravity of Bitumen	1.033
	Gmm=Maximum Specific Gravity	2.690

Table III 4: Theoretical Maximum Specific Gravity for BC 6.0%

Sample Taken From Laboratory prepared **Date sample :-** **0-Jan-00**

Bitumen content of the Sample ,%, 6.0 **Date Testing :-** **0-Jan-00**

	Description	**Sample-1**	**Sample-2**	**Sample-3**	**Average**
°C	Temprature of Test Water	**22.4**	**22.3**		
A	Mass of Oven Dry Sample in air, g	**9977.9**	**9978.0**		
D	Mass of Pycnometer filled with water , g	**1249.0**	**1251.0**		
E	Mass of Pycnometer filled with Sample and water , g	**10762**	**10764**		
Gmm	**Theoretical Maximum Specific Gravity**	**2.687**	**2.690**		2.689

Effective Specfic Gravity of Combined Aggregate,Gse:

$$\textbf{Gse=} \frac{100-Pb}{(100/Gmm)-(Pb/Gb)} \qquad 2.995$$

Where :- Gse = Effective Specific Gravety of Combined Aggregete 2.995

Pb = % AC by wt.of Total Mixtures 6.00

Gb= Specific Gravity of Bitumen 1.033

Gmm=Maximum Specific Gravity 2.689