JIMMA UNIVERSITY
INSTITUTE OF TECHNOLOGY
SCHOOL OF GRADUATE STUDIES
CIVIL AND ENVIRONMENTAL ENGINEERING

Evaluation on the Potential Use of Natural Subbase Dust as Alternative Filler Material for Hot Mix Asphalt Design, Jimma Town

A Thesis Submitted to the School of Graduate Studies of Jimma University in Partial Fulfilment of the Requirements for the Degree of Master of Science in Highway Engineering

By

Bereket Yohannes

March, 2017

Jimma Ethiopia

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March, 2017

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As a member of the examining board of the final Msc open defence, we certify that we have read and evaluated the thesis prepared by Bereket Yohannes Entitled: **Evaluation on the Potential Use of Natural Subbase Dust as Alternative Filler Material for Hot Mix Asphalt Design**; and it is approved as fulfilling the thesis requirement for the degree of master of science (M.Sc) in Highway Engineering.

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DECLARATION

I, the undersigned, declare that this thesis entitled "**Evaluation on the Potential Use of Natural Subbase Dust as Alternative Filler Material for Asphalt Mix Design, Jimma Town**" 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. Furthermore, all sources of material used for the thesis have been duly acknowledged.

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As Master research Advisors, we hereby certify that we have read and evaluated this Msc research prepared under our guidance by Bereket Yohannes entitled: **Evaluation on the Potential Use of Natural Subbase Dust as Alternative Filler Material for Asphalt Mix Design, Jimma Town.** We recommend that it can be submitted as fulfilling the MSc thesis requirements.

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ABSTRACT

A well-designed asphalt mixture is expected to serve effectively for many years under a variety of loading and environmental conditions. Bituminous concrete is one of the highest and costliest types of flexible pavement. One of the main problems in the construction of asphalt paving mixture is obtaining sufficient amount of filler material and high cost of the use of OPC, HL or marble dust as filler material. HL and OPC are active fillers which has high adhesion properties as the result Asphalt Institution restricted the use of only a maximum limit of 2%. Whereas inert fillers like marble dust and stone dust can be used with a proportion of up to 8% to improve the aggregate grading requirements. But these materials has a problem of issues like abundance, accessibility, high grinding effort cost, high transportation cost. To alleviate this problem it is important to come across alternative filler material that can address this gap.

The study has investigated the potential use of natural subbase dust (NSD) as alternative filler material and their characteristic on the effect of hot asphalt mixture was identified.

This research was conducted by using Experimental Research Design. In total, 48 samples were prepared according to ASTM D1559, of which 30 of them have been used to determine the OBC and the rest to find out the effects of adding different percentages of NSD to the asphalt mixture and for the control mixtures. For this purpose, five different bitumen contents were used (4%−6% with 0.5% increments). Aggregate mixtures blended without filler and with NSD filler were investigated to evaluate their Marshall properties on HMA mixtures. Four varying percentages of NSD ranging from (2% - 8% at 2% increments) was used for Marshall experiments. And for control mix 2% Hydrated Lime (HL) and 2% Ordinary Portland Cement (OPC) were used in the mixture besides, 4% Marble Dust was used as reference.

The aggregates were blended by using Job mix formula to obtain the percentage of material proportion. As the result for aggregates blended without filler G-1(26%), G-2(23%) and G-3(51%) proportion was used where as for aggregates blended with NSD filler, G-1 (26%), G-2 (22%), G-3 (46%) and G-4 (6%) was utilized. Where G-1 is Coarse Aggregate 3/4, G-2 is Intermediate Aggregate 3/8, G-3 is Fine Aggregate and G-4 is NSD filler. Based on Marshall test results the OBC was found 5.1% by the total asphalt mix. Furthermore, examining Marshall mixes containing different percentages of filler showed the optimum percentage of NSD was 6% by the total mix weight. All the Marshall properties of stability, flow, VFB, VMA & air voids parameters at 6% NSD filler by the total weight were consistent with in the range of the standard specifications.

The investigation of NSD filler has resulted good effects by improving the aggregate grading and filling the voids on the asphalt mixture. Furthermore, the outcome of Marshall parameters like stability, air voids and bulk density values were consistent with the standard specifications. Therefore, NSD filler can potentially be used an alternative filler material in HMA with optimum filler content of 6% by total weight of any surface aggregate mixtures. Besides, it is recommended to exercise the use of NSD as filler material in HMA projects in order to ensure the quality of works, save transportation cost and save time spend to import other filler materials from far away. It is also recommended combining NSD filler with other materials may produce better outcome on the effects on the asphalt mix properties.

Keywords: Aggregates, Natural Subbase Dust Filler, Bituminous Paving Mixes, Cement Hydrated Lime, Marble Dust, Marshall Mix Design, Optimum Filler Content.

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ACRONYMS

AASHTO	American Association of State Highways and Transport Officials
AC	Asphalt Concrete
ASTM	American Standard for Test Method
BC	Binder Content
BS	British Standard
CBR	California bearing ratio
DGA	Dense Graded Asphalt
DGM	Dense Graded Mix
ERCC	Ethiopian Road Construction Corporation
HMA	Hot Mix Asphalt
HMAC	Hot Mix Asphalt Concrete
HL	Hydrated Lime
JiT	Jimma Institute of Technology
JMF	Job Mix Formula
NP	Non Plastic
NSD	Natural Subbase Dust
OBC	Optimum Bitumen Content
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 Mastic Asphalt
VMA	Void in Mineral Aggregate

CHAPTER ONE

INTRODUCTION

1.1. Background of the Study

The construction and maintenance of highway pavement in Ethiopia requires a large amount of good quality materials. Fast growth of continual heavy axel traffic demands better quality of material for paving application. The development and use of modified asphalt mix can meet the needs of the communities. Asphalt modification, can be realized primarily through polymer modification. However, this method is expensive due to the high cost of raw polymer, skilled personnel and special equipment. In the other method, asphalt mix modification can be done by replacing common filler like lime, cement and other suitable materials [1].

Highway pavements are categorized into two groups rigid and flexible. Rigid pavements are composed of a cement concrete surface course and flexible pavements are those surfaced with bituminous materials. Asphalt concrete is a mixture of aggregate, bitumen and filler in different relative amount that set up the substantial property of mix. Pavement systems in Ethiopia are exposed to a multitude of severe environmental factors mainly heavy axle load applied on the road, high traffic and excessive high temperature [2].

Road usually exhibits excessive failures at early stage of the pavement life. A major step in the improvement of the existing performance of roads starts with modification of mix design. The strength, cost and stability of asphalt mixtures are influenced by several features together with gradation of aggregates, types and amount of filler materials. Ilan Ishai, et al. investigated the major role of fillers as they play crucial role in the properties and behavior of bituminous paving mixtures. The mechanical properties of bituminous road pavement depend decisively upon the properties of filler and bitumen. Modifications of asphalt paving materials that have high quality additives are quite expensive for the mass production of bituminous mixtures. A solution to solve this problem is by considering the influence of natural mixture ingredients, such as filler [3].

Kandhal et al. conducted various studies that the properties of mineral fillers especially the material passing 0.075mm (No. 200) sieve have a significant effect on the performance of asphalt paving mixture in terms of deformation, fatigue cracking and moisture susceptibility. Mineral fillers were originally added to dense-graded HMA paving mixtures to fill the voids in the aggregate skeleton and to reduce the voids in the mixture [4].

Asi Ibrahim and Assa'ad Abdullah studied fillers that are used in the asphalt mixture to affect the mix design especially the optimum asphalt content. The term filler is often used loosely to designate a material with a particle size distribution smaller than No. 200 sieve. The filler theory assumes that "the filler serves to fill voids in the mineral aggregate and thereby create dense mix". Filler particles are beneficial because of increased resistance to displacement resulting from the large area of contact between particles. It was found that fillers increase the required compactive effects of specimens to the same volume or air void content. The function of mineral filler is essentially to stiffen the binder [5].

Various conventional materials such as cement, lime, granite powder are normally used as filler in asphalt concrete mixture in other world. Cement, lime and granite powder are expensive and are used for other purposes more effectively. From the economic point of view, the researcher has investigated and evaluated the potential use of natural subbase dust as alternative filler material in hot asphalt concrete mixture and compared with the conventional fillers and with standard specifications [6]. The study also evaluated the effects of natural subbase dust filler on the Marshall properties. Based on the experimental results, the feasibility of natural subbase dust as alternative filler with optimum proportion was assessed by comparing with the control mixtures and standard specifications.

1.2. Statement of the Problem

Fillers have traditionally been used in asphalt mixtures to fill the voids between the larger aggregate particles [7]. Bahia et al. investigated the influence of different types of fillers on the properties of asphalt concrete mixture as it varies with the particle size, shape, surface area, surface texture and other physical - chemical properties [8].

Conventionally in Ethiopia fine sand, cement, hydrated lime, crushed stone and marble dust are used as filler material in bituminous mix. One of the main problems in the construction of asphalt paving mixture is obtaining sufficient amount of filler material and high cost of the use of cement or marble dust as filler material. Since OPC and HL are restricted by Asphalt Institution the use of a maximum limit of 2% proportion to improve the adhesion property of the aggregates only, which is not sufficient quantity to achieve the grading requirements. On the other hand, marble dust is obtained from a waste product of marble industries far away and with long period waiting for obtaining sufficient quantity. If these dusts are not deposited with care by avoiding moisture absorption, it require long period to get dry. In this study an attempt was made to find effective types of cheap and non-conventional filler on the behavior of bituminous mixes. For this purpose, natural subbase dust was used as non-conventional filler. The characteristics of the mixtures containing different types of filler were evaluated by examining fundamental material properties and by performing various laboratory tests. Then the results obtained for mix type containing non-conventional fillers were compared with the conventional fillers.

Therefore, it is important to come across an alternative type of filler materials. This study has investigated the potential use of natural subbase dust on the Marshall properties of HMA.

1.3. Objectives of the Study

1.3.1. General Objective

The general objective of the study was to evaluate the potential use of natural subbase dust as alternative filler material for asphalt mix design.

1.3.2. Specific Objectives

- To identify the characteristics of natural subbase dust as alternative filler material on hot mix asphalt.
- To investigate the effect of natural subbase dust filler on the Marshall properties.
- To compare the Marshall test results with standard specifications.

1.4. Research Questions

The researcher formulated the following research questions to conduct the study:

1. What are the characteristics of natural subbase dust as filler material for hot mix asphalt?
2. What are the effects of natural subbase dust as filler on the Marshall properties?
3. What will be the outcome when we compare with the standard specifications?

1.5. Scope of the Study

The scope of the study was to evaluate the potential use of natural subbase dust as alternative filler material in hot asphalt concrete mix design. This study was done by using natural subbase material sampled from selected quarry site.

1.6. Significance of the Study

Since Jimma town has abundance of available natural subbase material quarry sites that can be used as filler material after screening and grinding it. Because, it can minimize transportation cost we offer to import other filler materials like cement, lime and marble dust etc.

Owners, contractors and consultants will benefit from the study as a source of information for highway projects implementing it throughout Ethiopia and particularly around Jimma area where there is a shortage of filler material. The findings can also be referenced as source of information and as an inputs for further researches.

1.7. Research Gap

There are ample source of natural subbase material quarry sites available around Jimma and the fact that there is a shortage of filler material for the newly constructed asphalt road in Jimma town has initiated the researcher to study further in this area. Besides, there have been no researches conducted in this area so far has motivated the researcher to study further so as to address the problems like abundance, cost and accessibility issues in the hot mix asphalt design.

CHAPTER TWO

LITERATURE REVIEW

2.1. Theoretical Review

Roads are built up in several layers, consisting of sub-grade, sub-base, base and surface layer; these layers together constitute the pavement. Because asphalt concrete is much more flexible than Portland cement concrete, asphalt concrete pavements are sometimes called flexible pavements. Asphalt concrete is composed primarily of aggregate and asphalt binder. Aggregate typically makes up about 95% of a Hot Mix Asphalt (HMA) mixture by weight, whereas asphalt binder makes up the remaining 5%. By volume, a typical HMA mixture is about 85% aggregate, 10% asphalt binder and 5% air voids. Asphalt binder glues the aggregate together and that means without asphalt binder HMA would simply be screened and grinded stone or gravel. Small amounts of additives and admixtures are added to many HMA mixtures to enhance their performance or workability [9].

2.1.1. Flexible Pavement Layers

Asphalt concrete pavements are not a thin covering of asphalt concrete over soil, they are engineered structures composed of several different layers.

A. Subgrade:

The natural soil surface is the boundary between the base soil (subgrade) and the upper layers of pavement, and it's called the formation. The in-place soils, called the subgrade, serve as the foundation that supports the road. After removal of topsoil and other organic materials, the subgrade may be stabilized by compaction alone, or by compaction after mixing in asphalt emulsion, foamed asphalt, portland cement, lime, or other proprietary stabilizing materials. The properties and characteristics of the subgrade soil determine the pavement thickness needed to carry the expected traffic loads [10].

B. Sub-base Layer:

The sub-base course is the layer of material beneath the subgrade and the base course. It provides structural support, improve drainage and reduce the intrusion of fines from the subgrade in the pavement structure. Moreover if the base course is open graded the natural subbase course with more fines can serve as filler between subgrade and the base course [11]. Sometimes the subbase course is omitted from a pavement and a relatively thick base course is placed directly on the subgrade soil.

C. Base Course Layer:

The base course is the layer of a specified material of designed thickness placed immediately beneath the surface or binder course. It provides additional load distribution. It may be composed of screened and grinded stone, screened and grinded slag and other untreated or stabilized materials.

D. Asphalt Binder Course:

Binder course is a hot mix asphalt (HMA) course between the wearing course and either a granular base course or stabilized base course of an existing pavement or another HMA binder course. Its purpose is to distribute traffic loads so that stresses transmitted to the pavement foundation will not result in permanent deformation of that layer. Additionally, it facilitates the construction of the surface layer.

E. Grading of aggregates

It complies with American Society for Testing and Materials (ASTM D3515-01) that indicates international gradation limits for the asphalt binder course. Table (1) and Figure (1) indicates international gradation limits for the dense graded asphalt binder course (ASTM D3515-01) [12].

Table 1: Gradation Limits of Dense Graded Asphalt Binder Course (ASTM D3515)

Sieve size (mm)	Percentage by Weight Passing	
	Min	*Max*
25.00	100	100
19.00	90	100
12.50	67	85
9.50	56	80
4.75	35	65
2.36	23	49
0.30	5	19
0.15	3	14
0.075	2	8

Fig. 1: Gradation Limits of Dense Graded Asphalt Binder Course (ASTM D3515)

E. Asphalt Wearing Course:

It is the top layer of the pavement and it is directly exposed to traffic and environmental forces. Wearing course provides characteristics such as friction, smoothness, noise control, rut and shoving resistance, and drainage. In addition, it serves to prevent the entrance of excessive quantities of surface water into the underlying HMA layers, bases, and subgrade.

F. Screened and Grinded Natural Subbase

A number of studies have been made on the use of different types of fillers in various types of paving mixes which will be presented briefly below.

Zulkati et al. identified that filler exerts a significant effect on the characteristics and performance of asphalt concrete mixture. Besides, good packing of the coarse aggregates, fine aggregates and filler provides a strong backbone for the mixture [13].

Bituminous roads are defined as the roads in the construction of which bitumen is used as binder. It consists of an intimate mixture of aggregates, mineral filler and bitumen. The quality and durability of bituminous road is influenced by the type and amount of filler material is used [11]. The filler tends to stiffen the asphaltic cement by getting finely dispersed in it. Various materials such as cement, lime, granite powder, stone dust and fine sand are normally used as filler in bituminous mixes. Cement, lime and granite powder are expensive and used for other purposes more effectively. Fine sand, ash, waste concrete dust etc finer than 0.075 mm sieve size appears to be suitable as filler material. The use of waste powder as filler in asphalt mixture has been the focus of several research efforts over the past few years. Phosphate waste filler [14], Jordanian oil shale fly ash [15], bag house fines [16], recycled waste lime [17], municipal solid waste incineration ash [18] and waste ceramic materials [19] have been investigated as filler. It was proved that these types of recycled filler could be used in asphalt mixture and gave improved performance. So the present study has been taken in order to investigate the behavior of bituminous mixes with different types of filler materials locally available.

If filler is mixed with less bitumen than it is required to fill its voids, a stiff dry product is obtained which is practically not workable. Overfilling with bitumen, on the contrary, imparts a fluid character to the mixture [20]. The filler has the ability to increase the resistance of particle to move within the mix matrix and/or works as an active material when it interacts with the asphalt cement to change the properties of the mastic [7]. Elastic modulus of asphalt concrete mixture can increases by the addition of mineral filler. But excessive amount of filler may weaken the mixture by increasing the amount of asphalt needed to cover the aggregates [21]. The effects of these fillers are also dependent on gradations.

The objective of this study was to produce an aggregate-asphalt mix with a controlled void. If the void of the mixed aggregate is too low, the mix will be unable to carry sufficient asphalt and therefore will be difficult to compact due to insufficient lubrication. It will not be sufficiently durable as the film on the aggregate particles will be too thin.

On the other hand, if the void is too high, it is probable that the mix will be lacking in stability because each aggregate will receive less support from those surrounding it [4]. Fillers could improve the temperature susceptibility and durability of the asphalt binder and asphalt-concrete mixture. The effects of these fillers are also dependent on gradations. To have a good mixture, aggregates and filler should bind properly [22]. A strong backbone for the mixture can provided by the good packing of the coarse, fine, and filler aggregates.

The performance of bituminous mix also depends on amount of filler in the mix [23]. The workability of a mix depends, to some extent, on the amount and type of the filler present in the mix [24]. The mixture performance also affected by the interactions between asphalt and filler because of the larger surface area, filler may absorb more asphalt and its interaction with asphalt may lead to different performance of asphalt-concrete mixture [25]. The size distribution, particle shape, surface area, surface texture, voids content, mineral composition, and other physiochemical properties vary for several fillers. Therefore, their effect on the properties of asphalt-concrete mixture also varies.

Brown and Mallick investigated about the type of filler, type of stabilizer and amount of stabilizer affect not only optimum bitumen content (OBC) of paving mixes, but also affect the property like Marshall stability, tensile strength and retain stability of mixes. Besides, the OBC of dense graded mix is less than stone matrix asphalt [1]. Mogawer et al. investigated on the property of eight different types of mineral filler materials in Europe that indicated the filler quality does not affect the performance of mixture [26].

Muniandy and Aburkaba investigated four types of industrial by-product wastes filler namely, limestone, ceramic waste dust, coal fly ash and steel slag dust as they increase the stiffness and fatigue life of stone mastic asphalt (SMA) mixtures. Filler obtained from waste marble dust shaping process of marble blocks and lime stone are used as filler in hot mix asphalt and optimum bitumen content was determined by Marshall Test and it showed good result [27].

Bahia et al. studied waste filler powder as mineral filler on Marshall property of bituminous mix by comparing with bituminous where lime stone, ordinary portland cement was taken as filler with varying content (4-7%). Optimum filler powder content was found 7%. By using filler powder as filler in bituminous, its stability increases up to 13% and its flow value decreases density also decreases as compared to bituminous contains lime stone and cement filler of the major constituents in asphalt paving mixture. Fillers not only fill voids in coarse and fine aggregates but also affect the aging characteristics of the mix. Generally, the aggregate materials those are finer than 75 μm in size is referred to as filler. Filler is defined as consisting of finely divided mineral matter, such as rock dust , slag dust , hydrated lime, hydraulic binder, fly ash, or other suitable mineral matter [10].

Anderson et al. investigated filler in an asphalt-concrete mixture, whether artificial or natural may stiffen the asphalt concrete, extend the asphalt cement and affect the workability and compaction characteristics of the mix. Filler imparts a considerable importance on the properties of asphalt-concrete mixture. The amount of filler influences the optimum asphalt content [6].

Zulkati et al. studied the workability of mixing during the operation and compaction of asphalt-concrete mixture are consequential property of asphalt-filler mastic also affected by filler materials Filler provides better resistance to micro cracking so that it can increase the fatigue life of asphalt-concrete mixture. They proved also the structural characteristics of asphalt-concrete mixture could be improved by using hydrated lime and phosphor gypsum as filler material. [13] Asi and A. Assad investigated a significant improvement in fatigue life of the asphalt-concrete mixtures can be obtained by using fly ash from oil shale [28]. Ahmed and Othman proved the use of waste cement dust as filler on the asphalt concrete mixture enhances the mechanical properties of the mix and the laboratory results indicate that the cement dust can totally replace limestone powder in the asphalt paving mixture. Besides the use and application of mineral filler in asphalt mixtures are intended to improve the properties of binder by reducing the binder's inherent temperature susceptibility [29]. Harris B.M and Stuart K.D investigated that mineral fillers play a dual role in asphalt mixtures; primarily, they act as a part of mineral aggregate by filling the voids between the coarser particles in the mixtures and by strengthening the asphalt mixture; secondly, when mixed with asphalt fillers form mastic a high-consistency binder that cement slager binder particles together. They also identified the type and amount of filler used in hot asphalt mixtures would affect the properties of the mixes. The use of industrial and by–product wastes as replacement of mineral fillers in asphalt mixtures enhances the properties and performance of asphalt concrete pavements [30].

Anderson et al. identified filler as one of the components of asphalt concrete mixture that plays a significant role on the characteristics and performance of the asphalt mixtures. For modification of asphalt paving materials, the high quality of additives are quite expensive for the mass producing of bituminous mixture. A solution to this problem can be obtained by considering the influence of natural mixture ingredient such as filler. Hydrated lime and stone dust fillers have influence on fatigue performance of bituminous concrete mixes. Among the two filler lime was found to have substantial influence on the fatigue properties, although static strength remained more or less the same for both fillers. The marshal and plastic deformation test showed that lime stone dust and marble dust gave almost the same results. Marble dust had higher values of plastic deformation and hence was suggested for low traffic volume roads [6].

Different types and quantity of filler have an effect on the performance of asphalt concrete mixture. Filler provides batter resistance to micro cracking so that it can increase the fatigue life of asphalt concrete mixture. Various conventional materials such as cement, lime, granite powder are normally used as filler in asphalt concrete mixture in other world. Cement, lime and granite powder are expensive and are used for other purposes more effectively. With the economic point of view, my present investigation has been taken in order to study the performance of asphalt concrete mixture with abundantly available natural subbase dust and compare with conventional filler materials.

2.2. Components of Mix and Functions

2.2.1. Aggregate Type and Quality Selection

The properties of aggregates are very important for the performance of hot mix asphalt (HMA) pavements. 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 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.

2.2.2. Aggregate Classification

Aggregate for HMA are generally classified according y to their formation is divided into three general types: sedimentary, igneous and metamorphic [2].

A. **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)
- Combination of these types of material

B. Igneous: Igneous rock consists of molten material (magma) that has cooled and solidified. There are two types: extrusive and intrusive. ERA manual defines 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 filler-like appearance and structure. Rhyolite 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 gabbros. Earth movement and erosion process bring intrusive rock to the earth's surface where it is quarried and used [2].

C. 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. ERA manual explains many types of metamorphic rock have a distinct characteristic feature; the mineral are arranged in parallel planes or layers. Example of foliated rock is gneisses, schist (formed from igneous material) and slate (formed from shale, a sedimentary rock) [2].

2.2.3. Aggregate Sources

Aggregate for HMA are generally classified according to their sources. It includes natural aggregate, processed aggregates and synthetic rock aggregate.

Natural Aggregates are those used with little or no 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 6.35mm or larger in size. Sand is defined as particles smaller than 6.335mm but larger than 0.075mm (No. 200), Pericles smaller than 0.075mm are mineral filler.

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 are quarried, screened and grinded and /or screened in preparation for use. There are two basic sources of processed aggregates which are natural gravel that are screened and grinded suitable for use in HMA, and fragments of bedrock and large stones that must be reduced in size. Rock is screened and grinded for three reasons;

- To reduce the size and improve the distribution and range 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. Extracted rock is typically reduced to usable by mechanical crushing. Manufactured aggregate is often the byproduct of other manufacturing industries.

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 Mana woreda. In order to obtain a representative samples for testing, all coarse and fine aggregates were riffled in accordance with AASHTO/ASTM/BS [9].

2.2.4. Aggregate Gradation and Size

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

This makes gradation the primary factor in the asphalt mix design to evaluate aggregate gradation on the creep response of asphalt mixtures and pavement rutting estimates. It is 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”. Kandhal and Allen studied 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 mixtures. [31]

A) Coarse Aggregate

Coarse aggregate should be produced by crushing sound, unweathered 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 screened and grinded 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.

B) Fine Aggregate:

Can be screened and grinded 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.

C) Fillers

Mineral fillers can be screened and grinded 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. 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.

Mineral fillers have a significant impact on the properties of HMA mixtures. Mineral fillers increase the stiffness of the asphalt mortar matrix. Mineral fillers also affect workability, moisture resistance, and aging characteristics of HMA mixtures. 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. Waste marble dust obtained from shaping process of marble blocks and lime stone as filler and optimum binder content was determined by Marshall Test and showed good result. They utilized municipal solid waste incinerator (MSWI) fly ash as a partial replacement of fine aggregate or mineral filler in stone matrix asphalt mixtures. They made a comparative study of the performance of the design mixes using Super pave and Marshall Mix design procedures.

2.2.5. Asphalt Binder

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 behavior are temperature susceptibility, visco-elasticity and aging. The behavior 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 visco-elastic material as it exhibits both viscous as well as elastic properties at the normal pavement temperature. Though at low temperature it behaves like an elastic material and at high temperatures its behavior is like a viscous fluid.

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. Common Types of Premix

Hot Asphalt Mix Manual states 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.

2.3.1. Asphaltic Concrete

Hot Asphalt Mix Manual also explains as 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 behavior but this makes the material particularly sensitive to errors in proportioning, and mix tolerance are therefore very narrow. 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 (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 is sufficiently 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.

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 vapors.

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 [32].

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.

Asphalt Mix Manual defines 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.

2.3.2. Bitumen 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 screened and grinded gravels have been used successfully [33].

2.3.3. Bituminous 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 [33].

2.4. 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. They are Dense Graded Mixes (DGM), Stone Matrix asphalt (SMA) and various Open graded HMA [34].

2.4.1. Dense-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.

2.4.2. Stone Matrix Asphalt (SMA)

Stone matrix asphalt (SMA) sometimes called stone mastic asphalt, is a gap-graded HMA originally 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 fibers 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% fiber. The deformation resistant capacity of SMA stems from a coarse stone skeleton providing more stone-on-stone contact than with conventional dense graded asphalt (DGA) mixes [34].

2.4.3. Open-Graded Mixes

Unlike dense-graded mixes and SMA, an open-graded HMA mixture is designed to be water permeable. Open-graded mixes use only screened and grinded 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% air voids and no maximum air voids specified.
- 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 [33].

2.5. 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 natural subbase 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.

2.5.1. Stability

Stability is defined as the resistance of the paving mix to deformation under traffic load. There are two examples of failure;

(i) **Shoving** - a transverse rigid deformation which occurs at areas subject to severe acceleration.

(ii) **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.

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. Table (2) lists some causes and effects of insufficient stability.

Table 2: Causes and Effects of Pavement Instability

Causes	Effects
Excess asphalt in mix	Wash boarding, rutting and flushing or bleeding
Excess medium size sand in mixture	Tenderness during rolling and for period after constriction , difficulty in compacting
Rounded aggregate, little or no screened and grinded surface	Rutting and channeling

Source: Hot Asphalt Mix Manual, 2nd edition

2.5.2. 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. A lack of sufficient durability in a pavement can have several causes and effects as shown in Table (3).

Table 3: Causes and Effects of Pavement Durability

Causes	Effects
Low Asphalt content	Dryness or raveling
high void content through design or lack of compaction	Early hardening of asphalt followed by cracking or disintegration
Water susceptible (hydrophilic) aggregate in mixture	Asphalt film strips from aggregate leaving an abraded, reveled or mushy

Source: Hot Asphalt Mix Manual, 2nd edition.

2.5.3. Impermeability

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. This is acceptable as long as it is within specified limits. Causes and effects of poor impermeability values in dense graded HMA are shown in table (4).

Table 4: Causes and Effects of Pavement Permeability

Causes	Effects
Low Asphalt content	Thin asphalt films will cause early aging and raveling
High voids content in design mix	Water and air can easily enter pavement, causing oxidation and disintegration
Inadequate compaction	Will result in high voids in pavement, leading to water infiltration and low strength

Source: Hot Asphalt Mix Manual, 2nd edition.

2.5.4. 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 very unstable to place and compact properly. They are often caused by shortage of mineral filler, too much medium-size particles and 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. Table (5) lists some of the causes and effects to workability of paving mixtures.

Table 5: Causes and Effects of Pavement Workability

Causes	Effects
Large maximum-size particles	Rough surface, difficult to place
Excessive coarse aggregate	May be hard to compact
A mix temperature too low	Uncoated aggregate, not durable, rough surface, hard to compact
Too much medium-size sand	Mix shoves under roller, remains tender
Low mineral Filler	Tender mix, highly permeable
High mineral filler content	Mix may be dry or gummy, hard to handle, not durable

Source: Hot Asphalt Mix Manual, 2nd edition.

2.5.5. 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.

2.5.6. Fatigue Resistance

Fatigue resistance is the pavement's resistance to repeated bending under wheel load. 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. Table (6) present a list of causes and effects of poor fatigue resistance.

Table 6: Causes and Effects of Poor Fatigue Resistance.

Causes	Effects
Low Asphalt Content	Fatigue cracking
High Design Voids	Early aging of asphalt followed by fatigue cracking
Inadequate Pavement Thickness	Excessive bending followed by fatigue cracking
Lack of Compaction	Early aging of asphalt followed by fatigue cracking

Source: Hot Asphalt Mix Manual, 2nd edition

2.5.7. 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. A list of causes and effects relating to poor skid resistance is shown in table (7).

Table 7: Causes and Effects of Poor Skid Resistance.

Causes	Effects
Excess asphalt	Bleeding, low skid resistance
Poorly textured or graded aggregate	Smooth pavement
Polishing aggregate in mixture	low skid resistance

Source: Hot Asphalt Mix Manual, 2nd edition

2.6. Desirable Properties of HMA

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, especially in cold season
- Sufficient workability for construction

CHAPTER THREE

RESEARCH METHDOLOGY

3.1. Project Location and Topography

The study was conducted at Jimma town, southwestern Ethiopia which is located 355km away from Addis Ababa. Its geographical coordinates are between 7° 13’- 8° 56N latitude and 35°49’-38°38’E longitude with an estimated area of 19,506.24. Jimma town is found in an area of average altitude of about 1780m above mean sea level. It lies in the climatic zone locally known as Woyna-Dega.

Fig. 2: Jimma Town Location Map

3.2. Research Design

This research was conducted by using laboratory experimental research design. After organizing literature review of different previously published researches, the study evaluated the performance of the natural subbase dust as filler for asphalt mix design. In particular, for all materials (asphalt binder, coarse aggregate, fine aggregate and fillers) AASHTO (T49, T53, T228 and T179) and for binder (ASTM D854) laboratory procedures were performed. For the accomplishment of this research goal the applicable practice work, research findings and other information on the filler material for the asphalt pavement mixture were reviewed.

In this study, the Marshall mix design method was used to design the HMA mixes. The standard Marshall specimens were prepared by applying 75 blows on each face according to ASTM: D6926 (ASTM D6926, 2010) having five different bitumen content between 4% and 6% by total weight of aggregate at 0.5% increments. For control mixes 2% HL and 2% OPC were used. Besides, 4% of Marble dust filler which is the mix design of Jimma town HMA project was used as reference. Furthermore mixes containing 2, 4, 6 and 8% natural subbase dust filler were used for investigation.

The data processing and analysis consisted of **four** stages:

I. Characterizing the materials;
   - Asphalt binder, Aggregates, Fillers

II. Design the mixtures with NSD filler;
   - Marshal Mix Design for the fillers

III. Evaluation of NSD;
   - Suitability Evaluation in HMA concrete mixtures

IV. Data analysis
   - Results were **analyzed** with Microsoft Office Excel 2007 Program.

In the first stage the properties of materials i.e. bitumen, fillers and aggregates were determined. In the second stage the optimum asphalt content for each mixture were determined according to the Marshall mix design method and in the final stage the suitability of the natural subbase dust was evaluated.

3.3. Materials

The row materials used for this study like 85/100 penetration grade of asphalt cement were obtained from ERCC laboratory and coarse, intermediate and fine aggregates were obtained from ERCC crusher site located in Unkulu woreda, Jimma Zone. Natural subbase material was purposively screened and sampled from Red Cross and Merewa quarry sites towards Jimma - Addis Ababa roadway.

3.4. Tests and Materials Preparation

3.4.1. Mineral Aggregate

Aggregate generally accounts for 92% to 96% of HMA by volume and about 70% to 80% of Portland cement concrete. Aggregate is also used for base and sub-base courses for both flexible and rigid pavements. Locally available aggregates having a specific gravity of 2.72 and 2.59 for coarse and fine aggregate respectively were used in this study. The continuous aggregate gradation for HMA set by ERA & AASHTO specifications was selected.

3.4.2. Physical Properties of Aggregates

The required laboratory tests were conducted to evaluate the physical properties of the aggregates. Gradation tests were conducted to determine the size distribution for each aggregate type.

3.4.2.1 Sieve Analysis

The particle size distribution of aggregate is one of the most influential characteristics in determining how a HMA mixture that performs as a pavement material. Aggregate gradation influences almost every important HMA property including stiffness, stability, durability, permeability, workability, fatigue resistance, skid resistance and resistance to moisture damage. The gradation of a combination of aggregates is one of the key aspects when studying the behavior of asphalt mixes. Anderson and Bahia stated specifications on gradation are aimed to assure the designer chooses the best possible combination of materials to obtain desirable responses (e.g. stability, flux, voids, young modulus, rutting resistance and permeability) [6]. Aggregate gradations are compared to a universal specification ASTM D3515 and a gradation test according to specification (ASTM

C136) was performed on a sample of used aggregate for each type of aggregate in a laboratory and the results are presented below in Table 8.

The Job-Mix-Formula (JMF) for the aggregate particle size distribution that was used for the preparation of mixtures before and after blending are shown in Table (8 and 9) respectively. The aggregate gradation is expressed as the percentage by weight of total sample that passes through each sieve. It is determined by weighing the contents of each sieve following the sieve analysis and then calculating the percentage passing in each sieve by one of several mathematical procedures. The method used here was subtracting 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.

Table 8: Composition of Asphalt Paving Mixture Specification ASTM D3515

Mix Designation and Nominal Maximum Size of Aggregate								
Sieve Size		2in (50mm)	1 1/2in (37.5mm)	1in (25.0 mm)	3/4 in (12.5mm)	1/2 in (12.5mm)	3/8in (9.5 mm)	No. 4 (4.75 mm)
2 1/2"	63 mm	100	......	......	......	......	......	......
2"	50 mm	90 -- 100	100	......	......	......	......	......
1 1/2"	37.5 mm	......	90 --100	100	......	......	......	......
1"	26.5 mm	60 -- 80	......	90 -- 100	100	......	......	......
3/4"	19 mm	......	56 -- 80	......	90 --100	100	......	......
1/2"	12.5 mm	35 -- 65	......	56 -- 80	......	90 --100	100	......
3/8'	9.5 mm	......	......	......	56 --80	......	90 --100	100
No.	4.75	17 --	23 --	29 -- 59	35 -- 65	44 --74	55 -- 85	80 --
No.8	2.36	10 --	15 --	19 -- 45	23 -- 49	28 --58	32 -- 67	65 --
No.	1.18	......	......	......	......	......	......	40 -- 80
No.	0.6 um	......	......	......	......	......	......	25 -- 65
No.	0.3 um	3 -- 15	4 -- 16	5 -- 17	5 -- 19	5 -- 21	7 -- 23	7 -- 40
100	0.15 um	......	......	......	......	......	......	3 -- 20
0.07	0.075	0 -- 5	0 -- 6	1 -- 7	2 -- 8	2 -- 10	2 -- 10	2 -- 10
Bitumen, Weight % of Total Mixture								
		2--7	3--8	3--9	4 -- 10	4 -- 11	5 -- 12	6 -- 12

Source: Asphalt institution of Hot Mix Asphalt Pavement Manual, Series No.22, 2nd edition

3.4.2.2. Los Angeles Abrasion

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.

Fig. 3: Equipment Used for the L.A. Abrasion Test

The L.A abrasion test measures the degradation of a coarse aggregate sample that is placed in a rotating drum with steel spheres as shown in Figure(3). 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 completed, the mass of aggregate was calculated that has broken apart to smaller sizes are expressed as a percentage of the total mass of aggregate. Therefore, lower L.A. abrasion loss values indicate aggregate is tougher and more resistant to abrasion.

Table 9: Los Angeles Abrasion Lab Result

LOSS IN ABRASION AND IMPACT BY LOS ANGELES ABRASION MACHINE (AASHTO T-96)					
Sieve Size		Weight of Sample before test ,gm	Weight of Retained on SieveNo.12 ,gm	Weight of passing SieveNo.12 ,gm	% Loss %
Passing	Retained				
37.5 mm	25.0 mm				
25.0 mm	19.0 mm				
19.0 mm	12.5 mm	2500.45			
12.5 mm	9.5 mm	2500.45			
9.5 mm	6.3 mm				
6.3 mm	4.75 mm				
4.75 mm	2.36 mm				

Total	**5000.9**	**4262.3**	**738.6**	**14.8%**

3.4.2.3. Aggregate Crushing Value (ACV)

Aggregate crushing value gives a relative measure of the resistance of an aggregate to crushing under a gradually applied wheel load as compressive load. The standard aggregate crushing test was done on aggregates passing on No. 12.5mm and retained on No. 9.5mm AASHTO test sieves as shown below in table (10).

Table 10: Aggregate Crushing Value Lab Result

AGGRGATE CRUSHING VALUE TEST	BS 812 Part 110:1990	
Sample No.	1	2
Size of aggregates ,mm	10 - 14	10 – 14
Maximum load applied ,KN	400	400
Duration of testing ,mm	10	10
Weight of sample tested ,gm	2656.3	2633.8
Wt. of sample ret. on 2.36 sieve ,gm	2201.2	2204.1
Aggregate crushing Value ,%	17.1	16.3
Average aggregate. crushing value,%	16.7	

3.4.2.4. 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 to a slowly applied compressive load. Also aggregate sizes larger than 12mm are not appropriate for aggregate impact test. The standard aggregate impact test is done on aggregates passing on No. 12.5mm and retained on No. 10.0mm AASHTO test sieves.

3.4.2.5. Particle Shape and Surface Texture

Rounded particles create less particle-to-particle interlock than angular particles and thus providing 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. These particles tend to impede compaction or break during compaction and thus may decrease strength.

3.4.3. Asphalt Binder Selection and Test

Asphalt binders also referred as asphalt cement binders, are an essential component of asphalt concrete that holds the aggregate together.

In general asphalts can be classified into three general types:

- Asphalt cement
- Asphalt emulsion
- Cutback asphalt

For this experimental research works bitumen of penetration grade 85/100 was used and collected from ERCC Ethiopian Road Construction Corporation laboratory. The main reason of using this grade is because it is common type and based on the temperature and heavy traffic condition of the specification for Jimma zone.

A) 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.

B) Flashpoint

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. The asphalt flashpoint is determined to identify the maximum temperature at which it can be handled and stored without danger of flashing.

C) 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 needed to know about the specific gravity of asphalt cement. On one hand asphalt expands when heated and contracts when cooled. This means the volume of a given amounts of asphalt cement are grater at higher temperatures than at lower ones. On the other hand, 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.

D) 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.

E) Solubility

The solubility test measures the purity of asphalt cement. A sample was 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.

F) Softening Point

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

3.4.4. Mineral Fillers

The fillers used for the study was screened and grinded natural subbase material. The natural subbase samples were collected from the selected quarry site according to ERA and

AASHTO standards. This study had followed purposive sample selection process. The sample selections were dependant on the types of tests required as per standards and for each tests quartering and weighting sampling technique were used.

The natural subbase material was sampled, screened, grinded and sieved. The samples were grinded and sieved to obtain the dust part that pass on number 200 sieve. Then the corresponding Marshall laboratory tests were conducted after blending the dust filler with the aggregates at different mix proportions. Besides, for all materials such as asphalt binder, aggregate and filler material laboratory tests were carried out to determine the physical properties affecting the bituminous mixture property such as gradation parameters and plasticity index.   The works carried out are shown in the figure (4) below.

Fig. 4: Preparation for Lab Test of Physical Property of Natural subbase Material

3.5. 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 in 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.

3.5.1. Objectives of Mix Design

The overall objective of the design procedure is to determine an economical blend and gradation of aggregates 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.
- Sufficient workability to permit efficient placement of the mix without segregation.

3.5.2. Marshall Mix Design

The Marshall method of designing paving mixtures was developed by Bruce Marshall, who is Bituminous Engineer at Mississippi State Highway Department. The Marshall method is applicable only to hot mix asphalt using penetration, viscosity, asphalt binder and containing aggregate with maximum size of 25mm or less.

The purpose of Marshal method is to determine the optimum asphalt content for a particular blend of aggregate. And also it provides information about the properties of the resulting pavement mix including density and void content which are used during pavement construction.

The Marshall method uses standard test specimen 64mm high and 102mm internal diameter. A series of specimens, each containing the same aggregate blend but varying in asphalt content from 4% to 6% with increment of 0.5% was prepared using a specific procedure to heat, mix and compact the asphalt aggregate mixtures.

3.5.3. Experimental Work

After evaluating the properties of used materials that are bitumen, aggregates and natural subbase dust sieve analysis was performed. Then for each types of aggregates blending was carried out to obtain the binder course gradation curve which were used in the preparation of the asphalt mixture. After that, with different bitumen contents asphalt mixes were prepared to obtain optimum bitumen content by Marshall test. Then the optimum bitumen content was used to prepare asphalt mixes with various percentages of natural subbase dust filler. Finally, Marshall test was used to evaluate the properties of these natural subbase dust filler in the mixtures and the corresponding laboratory test results obtained were analyzed with Microsoft Office Excel 2007 Program. Figure (5) shows a **flowchart** of experimental work for this study.

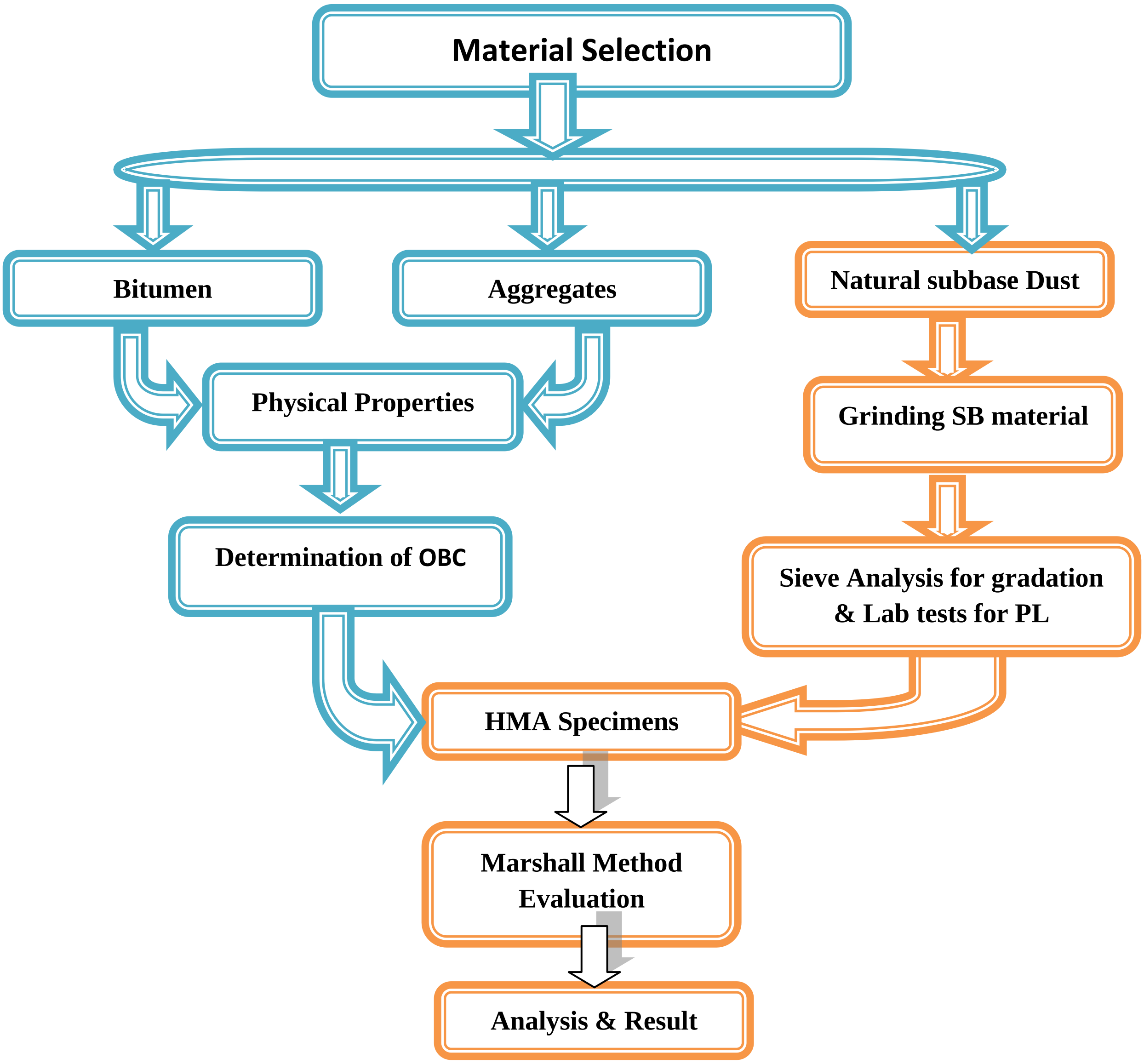


Fig. 5: Flow Chart of Experimental Work

3.5.4. Preparation of Mixtures

In determining the design asphalt content for a particular blend or gradation of aggregate by the Marshall method, a series of test specimens were prepared for a range of different asphalt contents.

According to ASTM specifications using mathematical trial method aggregates were blended together in order to get a proper gradation. Mathematical trial method depends on suggesting different trial proportions for each type of aggregate. The percentage of each type of aggregate was computed and compared with the specification limits. The figure (6) below shows preparation of aggregates for Marshall tests.

Fig. 6: Preparation of Aggregate for Specimen of Marshall Test

3.5.5. Marshall Test Method

Marshall Stability test was used in this study for both determining the optimum binder content (OBC) and evaluating the specimens of natural subbase dust filler. This method covers the measurement of the resistance to plastic flow of cylindrical specimens of bituminous paving mixture loaded on the lateral surface by means of the Marshall apparatus according to ASTM D1559-89. The prepared mixture was placed in preheated mold (101.6mm) in diameter by (63.5mm) in height and for each face of specimen was compacted with 75 blows. The specimens were then left to cool at room temperature for 24 hours. Marshall stability and flow tests were performed for each specimen. The cylindrical specimen was placed in water path at 60ºC for 30 to 40 minutes then compressed on the lateral surface at constant rate of 50.8mm/min. until the maximum load (failure) was reached. Then the maximum load resistance and the corresponding flow values were recorded. Three specimens for each combination were prepared and the average results was reported. The bulk specific gravity, density, air voids in total mix and voids filled with bitumen percentages were determined for each specimen.

3.5.6. Optimum Binder Content

Marshall Test was used to determine the optimum binder content. Five percentages of bitumen were examined to determine the best percentage of bitumen for the aggregates used, which were (4, 4.5, 5, 5.5 and 6%) by weight of the total mix with three samples for each. The optimum binder content is calculated as the average of binder content values corresponding to the maximum stability, maximum density and median percent of air voids.

3.5.7. Optimum Natural Subbase Dust Content

A number of laboratory investigations were performed in order to determine the mix properties of natural subbase dust filler using Marshall test procedure. The best percentage of natural subbase dust that can be used as filler in the mixture was determined by investigating four percentages of screened and grinded NSD filler which were (2, 4, 6 & 8 %) by weight of the total aggregate with 3 samples for each percentage.

The **steps** followed to prepare the NSD filler samples are summarized as:

A) Purposive sampling technique was utilized to obtain Natural subbase material from the selected quarry site by screening, grinding and then sieving.

B) The NSD which passed on number 200 sieve was checked for PI test.

C) Four percentages of NSD (2% - 8% by weight of the total mixture with 2% incremental) were investigated with 3 samples for each percentage.

D) The NSD filler was mixed according to Marshall method designated in ASTM D1559-89 with other aggregates using the aforementioned percentages and then heated to a temperature of 135ºC before mixing with asphalt.

E) Prior mixing with aggregates, asphalt was heated up to 145ºC. Pre-heated asphalt was avoided and excess heated asphalt was disposed of to avoid variability in the asphalt properties.

F) The required amount of asphalt were then added to the heated aggregate and mixed thoroughly for at least three minutes until a homogenous mix was obtained.

G) Standard Marshall molds were heated in an oven up to 130ºC and then the hot mix was placed in the mold and each face of the specimen was compacted with 75 blows.

H) Specimens were prepared, compacted and tested according to Marshall method designated in ASTM D1559-89.

3.5.8. Mixture Characteristics and Behavior

Samples for paving mixture were prepared in the laboratory to analyze and determine their probable performance in a pavement structure. The analysis focused on four characteristics of the mixture and their influence on the behavior of the mixture. These are Mix Density, Air Void, Void in the mineral aggregate and Asphalt content.

A. 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/m^3). It is calculated by multiplying the bulk specific gravity of the mix with 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 standard procedure for determining the bulk specific gravity of compacted asphalt concrete involves weighing the specimen in air and in water. The following formula was used for calculating bulk specific gravity of a saturated surface-dry specimen:

$$\boldsymbol{Gmb} = \left(\frac{\boldsymbol{A}}{\boldsymbol{B-C}}\right) \text{...Eq. (1)}$$

Where;

G_{mb}= 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

B. 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% and 5% 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 proper air void content in HMA and other mix types are important for several reasons. If air void contents are too high, the pavement may be too permeable to air and water resulting significant moisture damage and rapid 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 to achieve an air void content of less than 8% and more than 3%. Air void content is calculated from the mixture bulk and theoretical maximum specific gravity:

$$\boldsymbol{Va = [100[1 - \left[\frac{Gmb}{Gmm}\right]]} \quad \text{...Eq. (2)}$$

Where;

V_a = Air void content, volume %

G_{mb} = Bulk specific gravity of compacted mixture

G_{mm} = Theoretical maximum specific gravity of loose mixture

C. Voids in 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 (all asphalt except the portion lost by absorption of 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. Economizing asphalt content by lowering VMA is actually counter-productive and detrimental to pavement quality hence, not advisable. Table (11) shows the nominal and minimum specification limit for VMA.

Table 11: Void in 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

$$\mathbf{VMA = (V_a - V_{be})} \qquad \text{Eq. (3)}$$

Where;

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

V_a = Air void content, % by total mixture volume

V_{be} = Effective binder content, % by total mixture volume

D. Binder Content

Binder content is one of the most important characteristics of asphalt pavement mix. The use of proper amount of binder is essential for good performance in asphalt concrete mixtures. Too little binder will result in a dry stiff mix difficulty 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 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:

$$Pb = 100\left[\frac{Mb}{Ms+Mb}\right] \quad \text{....Eq. (4)}$$

Where;

P_b = Total asphalt binder content, % by mix mass

M_b = Mass of binder in specimen

M_s = 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:

$$Vb = \left[Pb * \frac{Gmb}{Gb}\right] \quad \text{..Eq. (5)}$$

Where;

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

P_b = Total asphalt binder content, % by mix mass

G_{mb} = Bulk specific gravity of the mixture

G_b =Specific gravity of the asphalt binder

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

$$Vba = Gmb\left[\left(\frac{Pb}{Gb}\right) + \left(\frac{Ps}{Gsb}\right) - \left(\frac{100}{Gmm}\right)\right] \quad \text{..Eq. (6)}$$

Where;

V_{ba} = Absorbed asphalt content, % by total mixture volume

G_{mb}= Bulk specific gravity of the mixture

P_b= Total asphalt binder content, % by mix mass

G_b= Specific gravity of the asphalt binder

P_s = Total aggregate content, % by mix mass = 100 – P_b

G_{sb}= Average bulk specific gravity for the aggregate blend

G_{mm}= Maximum specific gravity of the mixture

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

$$\boldsymbol{Vbe = (Vb - Vba)} \quad \text{……..Eq. (7)}$$

Where;

V_{be}= Effective asphalt content, % by total mixture volume

V_b= Total asphalt binder content, % by mixture volume

V_{ba}, = Absorbed asphalt content, % by total mixture volume

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

$$\boldsymbol{Pba = Pb - Pbe} \quad \text{……..Eq. (8)}$$

$$\boldsymbol{Pbe = Pb\left[\frac{Vbe}{Vb}\right]} \quad \text{……..Eq. (9)}$$

Where;

P_{be} = Effective asphalt binder content, % by total mass

P_b = Asphalt binder content, % by total mass

V_{be} = Effective asphalt binder content, % by total mixture volume

V_b = Asphalt binder content, % by total mixture volume

P_{ba} = Absorbed asphalt binder, % by total mixture mass

E. Voids Filled with Asphalt

Voids filled with asphalt (VFA) are the percentage of inter-granular void space between the aggregate particles (VMA) that contained or filled with asphalt. VFA is used to ensure 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:

$$\boldsymbol{VFA = 100\left[VMA - \frac{Va}{VMA}\right]} \quad \text{……..Eq. (10)}$$

Where;

VFA = voids filled with asphalt, as a volume %age

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

V_a = Air void content, % by total mixture volume

3.6. Test Procedure

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

1. Bulk Specific gravity determination.
2. Stability and flow test.
3. Density and Void analysis.

A) 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 51mm at constant rate of vertical strain of 51mm 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. The figure (7) below shows experimenting on Marshall test Machine.

Fig. 7: Marshall Stability and Flow Test Machine

B) Water Bath

Water bath is at least 150mm deep and thermostatically controlled to 60^{o}C ± 1^{o}C. The tank should have a perforated false bottom or be equipped with a shelf suspending specimens at least 50mm.

Fig. 8: Samples in Water Bath

CHAPTER FOUR

RESULT AND DISCUSSIONS

4.1. General

In this study, forty four sets of bituminous mixtures using different types of mineral fillers were evaluated using the Marshal Mix design method. These mixtures were prepared using crushed stone aggregates and NSD fillers with varying contents of asphalt binder by the total mixture and their effect on Marshal properties were assessed thoroughly. Different researches have been conducted on the effect of fillers on bituminous mixtures as reviewed in Chapter 2 which revealed that the type and amount of fillers affect the performance of HMA. The test results obtained in this research are discussed under these subsequent sections.

4.2. Interpretation of Test Data

4.2.1. Aggregate Gradation of Mix Design

HMA are graded by percentage of different aggregate particle sizes they contain. Table (12) illustrated HMA gradations without natural subbase dust filler which is the normal gradation used as a control mix for the study. Certain terms used for referring the aggregate fractions and filler are: Course aggregate, G-1 ¾ inches, Intermediate Aggregate, G-2, 3/8 inch, Fine Aggregate, G-3 and Mineral Filler, G-4. Blending proportion for the mixture without NSD filler are G-1 = 32%, G-2 = 23% and G-3, = 45% by weight of the total mixture.

Table 12: Aggregate Gradation and Blending without NSD Filler

Mass of Total Aggregate						
Before wash = 1356.1			After Wash = 1314.0			
AASHTO Sieve Size (mm)	G-1 (26.2-13.2)	G-2 (13.2-9.5)	G-3 (9.5-4.75)	Lower limit	Upper limit	Median
26.5	0.0	0.0	100.0	100	100	100
19.0	45.0	3.3	96.7	98.9	100	99.5
13.20	254.5	18.8	77.9	80.9	90.9	85.9
9.50	191.0	14.1	63.8	70.1	80.1	75.1
4.75	202.0	14.9	48.9	54.4	62.4	58.4
2.36	238.8	17.6	31.3	38.0	46	42
1.18	139.8	10.3	21.0	24.9	32.9	28.9
0.600	78.4	5.8	15.2	17.1	25.1	21.1
0.300	47.9	3.5	11.7	12.3	18.3	15.3
0.150	29.3	2.2	9.5	9.4	12.4	10.9
0.075	18.9	1.4	8.1	7.4	10	8.7
Passing 0.075	63.7	4.7	3.5			
Blending Proportion	32%	23%	45%			

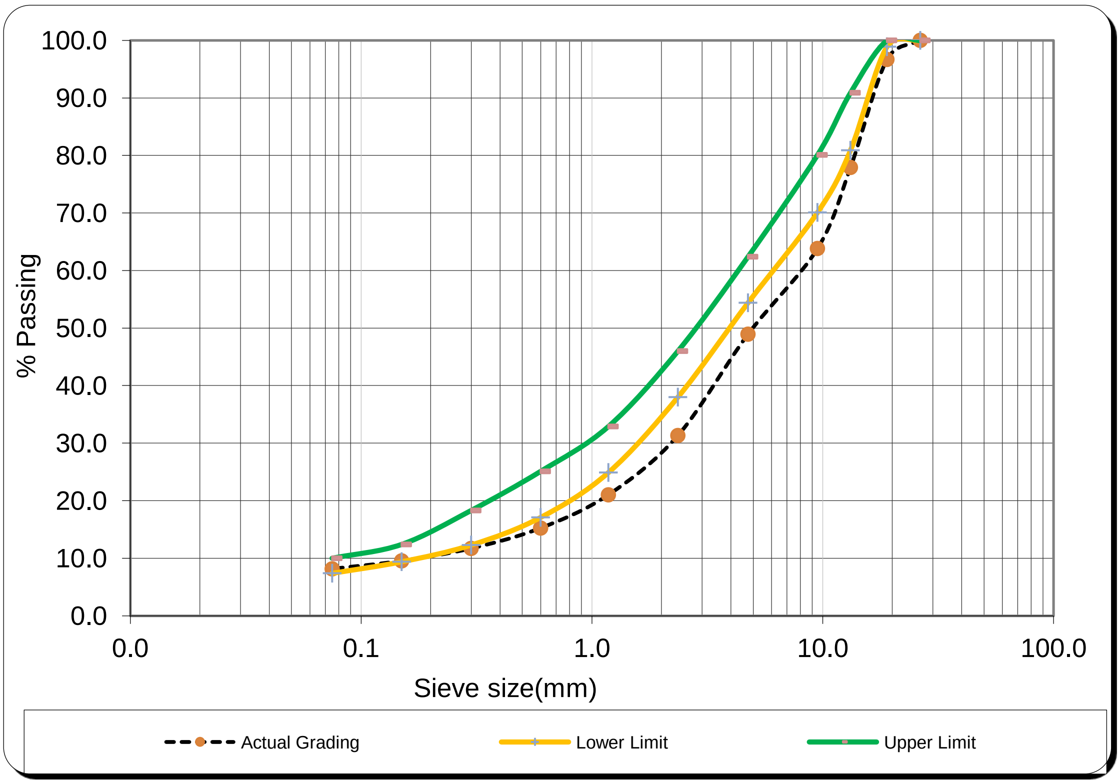


Fig. 9: Gradation of Aggregate without Filler Material

Figure (9) above shows the gradation of aggregates without NSD filler and from the graph it can be concluded that the mixture needs blending with NSD filler material to achieve the grading requirements as per the lower and upper specification limits.

Table 13: Aggregate Gradation and Blending with Natural Subbase Dust as Filler Material.

AASHTO Sieve Size mm	G-1 20/13.2mm	G-2 13.2/5.0mm	G-3 5.0/0.0mm	NS Dust	Blending Result	*Specification*		*Median*
						lower	*upper*	
26.5	100.0	100.0	100.0		100.0	100	100	100.0
19.0	92.121	100.0	100.0		98.0	85	100	92.5
13.2	16.131	100.0	100.0		78.2	71	84	77.5
9.50	2.585	80.6	100.0		70.6	62	76	69.0
4.75	0.663	15.3	99.9		56.4	42	60	51.0
2.36	0.206	2.4	74.6		41.1	30	48	39.0
1.18	0.069	1.2	46.4		27.0	22	38	30.0
0.600	0.027	0.9	31.1		19.4	16	28	22.0
0.300	0.011	0.7	22.0		14.9	12	20	16.0
0.150	0.004	0.6	16.4		12.2	8	15	11.5
0.075	0.002	0.5	12.9		10.4	4	10	7.0
Blending proportion	26	22	46.0	6.0	100			

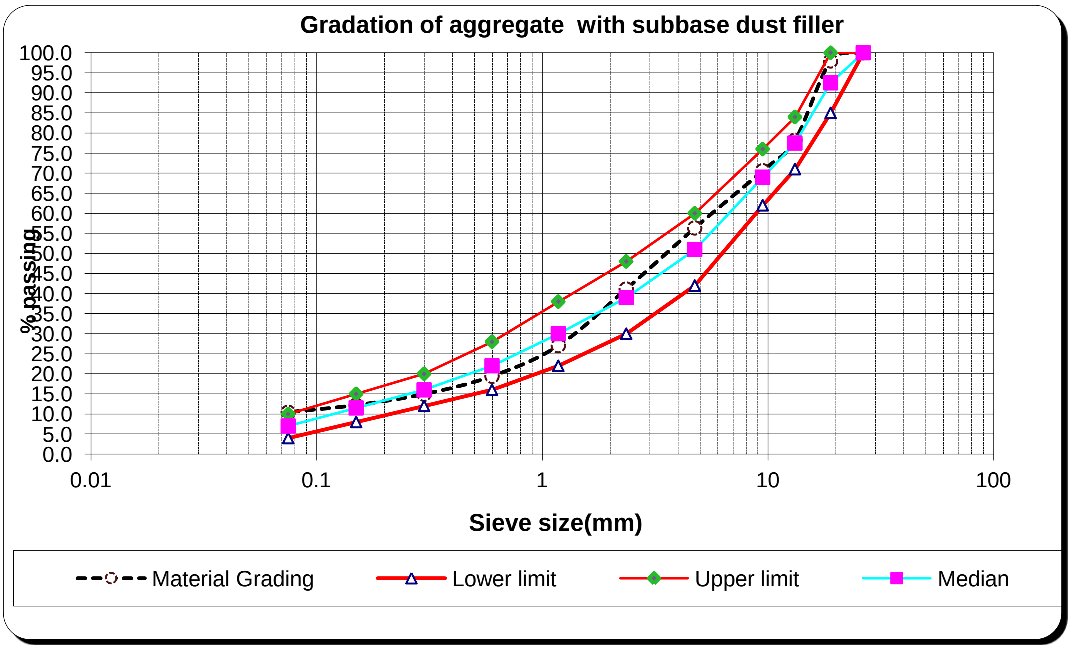


Fig. 10: Gradation of Aggregate with Natural subbase Dust Filler

To satisfy the grading requirements of the upper and lower limit, a job mix of G-4 = 6% of NSD was blended with the aggregates at a proportion of G-1 = 26%, G-2 = 22% and G-3 = 46% which resulted good blending for the Marshall mix design. The detail works for each aggregate gradation are shown in Appendix B.

4.2.2. Aggregate Physical Properties

To investigate the physical properties of the aggregates and their suitability in road construction, various tests were conducted and the results are indicated in Table (14). The specific surface area for each aggregate size distribution was determined by multiplying surface area factors by the percentage passing the various sieve sizes and adding together. As it can be seen from the results, as the filler content increases, the specific surface area also increases. The detail works for physical properties of aggregate are shown in Appendix B.

Table 14: Aggregate Physical Properties

No	Test Description	Test Method			Result	Specification (ERA Manual 2002)
		ASTM	AASHTO	BS		
1	Los Angeles Abrasion, %	AASHTO T 96			14.25	< 30
2	Aggregate Crushing Value, ACV, %	BS 812 part 104			16.7	<25
3	Durability and Soundness, %	ASTM C 128			5.5	<12
4	Coarse Aggregate Specific Gravity (Bulk)(kg/m^3)	AASHTO T 85			2.72	N/A
5	Fine Aggregate Specific Gravity (Bulk)(kg/m^3)	AASHTO T 84			2.59	N/A
6	Coarse Aggregate Specific Gravity (Apparent)(kg/m^3)	AASHTO T 85			2.86	N/A
7	Fine Aggregate Specific Gravity (Apparent)(kg/m^3)	AASHTO T 84			2.87	N/A
8	Water Absorption, %	ASTM C 127			1.71	<2

9	Particle shape, Flakiness, %	BS 812, Part 110	24.9	<45

4.2.3. Asphalt Binder Test Results

A series of tests including penetration, specific gravity, softening point, flash point, ductility and solubility were conducted for basic characterization properties of penetration grade asphalt. The test results are shown below in Table (15) which complies with the requirement of ERA specifications.

Table 15; Physical Properties of Used Bitumen

No	Test Description	Unit	Test Method	Test Result	Specification Limit
1	Penetration @25°C	1/10mm	ASTM D5-06	90	85 –100
2	Specific gravity @25°C	kg/cm^3	ASTM D70	1023	1020
3	Ductility @25 °C	cm	ASTM D113-86	100+	100+
4	Solubility	%	ASTM D2042	99.6	Min 99
5	Softening Point	^0C	ASTM D36	46.4	42 –52
6	Fire Point	^0C	ASTM D92-90	23	Max 100
7	Flash Point	^0C	ASTM D92-90	562	Min 232

Table 16: Filler Materials Used for Control Mix and Reference

No.	Filler Materials	Test Method	Specific Gravity
1	Hydrated Lime	ASTM D854	2.15
2	OPC Cement	ASTM D854	3.5
3	Marble Dust	ASTM D854	2.69

The table (16) above shows the specific gravity values of different filler materials used for control mix and for reference of the experiment works.

4.2.4. Natural Subbase Dust Filler

The filler used in the current study namely screened and grinded natural subbase material was obtained from natural quarry site. The physical properties affecting the bituminous mixture property such as gradation parameters and plasticity index were determined as shown in Table (17).

Table 17: Laboratory Test Result for NSD Filler

No	Test Description	Test Method		Result	Specification (ERA Manual 2002)
		ASTM	AASHTO		
1	Specific gravity (kg/m^3)	D 854 or C88	T 100 or 104	2.683	N/A
2	PI, (Plastic Index)	D 423 or 424	T 89 or T 90	NP	Max 4

NP= Non Plastic, N/A =Not Available

4.3. Determination of Optimum Bitumen Content

Marshall test was used to examine the asphalt mixture specimens with different percentages of bitumen content that were (4.0, 4.5, 5.0, 5.5 and 6.0%) and 5.1% optimum bitumen content was obtained.

4.4. Marshall Test Results

Marshall test results of the mixtures with different binder content are presented in Table (19). The relationships between binder content and the mixture properties such as Stability, Flow, VFB, VMA, VA and Bulk Density are presented in Figures (15 – 20). A sets of 44 samples each weighing 1200 gram were prepared using five different bitumen contents (4.0, 4.5, 5.0, 5.5 and 6.0%) by total weight to determine the optimum bitumen content. Further details are presented in Appendix (B).

The process of measuring the stability values from the standard 63.5mm thickness were converted to an equivalent 63.5mm value by means of conversion factor. The applied correlation ratio to convert the measured stability values are set in Table (18). The conversion was made on the basis of either measured thickness or measured volume.

Table 18: Correlation Ration for Adjusting the Stability Values

Volume of Specimen cm^3	Approximate Thickness of Specimen, mm	Correlation Ratio
380 to 392	47.6	1.67
393 to 405	49.2	1.56
406 to 420	50.8	1.47
421 to 431	52.4	1.39
432 to 443	54	1.32
444 to 456	55.6	1.25
457 to 470	57.2	1.19
471 to 482	58.7	1.14
483 to 495	60.3	1.09
496 to 508	61.9	1.04
509 to 522	63.5	1
523 to 535	64	0.96
536 to 546	65.1	0.93
547 to 559	66.7	0.89
560 to 573	68.3	0.86
574 to 585	71.4	0.83
586 to 598	73	0.81
599 to 610	74.6	0.78
611 to 625	76.2	0.76

Source: *Hot Asphalt Mix Manual, 2nd edition*

As shown in table (18) above, the values that need corrections were adjusted by multiplying each measured stability values by an appropriate correlation factors.

Table 19: Marshall Test Result for Mixes with 0% Filler Content

MARSHALL PROPERTIES OF BITUMINOUS MIXTURES					
	Aggregate Size				
	G1, 3/4mm	G2, 3/8mm	G3, Fine	G4, Filler	
Blending proportion, %	26	23	51	0	**100**
Bulk Specific Gravity of each	2.590	2.620	2.79	0.00	
Bulk Specific Gravity of Total Aggregate, Gsb					**2.696**
Ring Factor =12.67N/Div					

% AC	Trial	Specimen Mass, gm			Bulk Vol, cc	Bulk S.G	Th. Max. S.G. (Loose Mix)	Unit Wt, Mg/m³	% Air Void	% VMA	% VFB	Stability			Flow, mm
		In Air	In Water	SSD In Air								Measured, div	Factor	Adjusted,kN	
4.0	A	1165.0	665.3	1170.5	505.2	2.306	2.571	2.306	10.3	17.89	42.4	1080.0	0.93	12.32	4.40
4.0	B	1166.5	661.0	1167.0	506.0	2.305	2.571	2.305	10.3	17.92	42.5	1150.0	0.93	13.12	4.70
4.0	C	1155.5	657.0	1156.5	499.5	2.313	2.571	2.313	10.0	17.64	43.3	1003.0	0.93	11.45	3.40
Average						**2.308**	**2.571**	**2.308**	**10.2**	**17.82**	**42.7**			**12.30**	**4.17**
4.5	A	1198.5	687.5	1200.0	512.5	2.339	2.525	2.339	7.4	17.15	56.8	1050.0	1.04	13.40	3.50
4.5	B	1174.0	680.0	1178.5	498.5	2.355	2.525	2.355	6.7	16.58	59.6	859.0	1.04	10.96	3.40
4.5	C	1168.0	665.0	1168.5	503.5	2.320	2.525	2.320	8.1	17.82	54.5	1021.0	1.04	13.03	4.00
Average						**2.338**	**2.525**	**2.338**	**7.4**	**17.18**	**56.9**			**12.46**	**3.63**
5.0	A	1148.0	658.0	1150.5	492.5	2.331	2.502	2.331	6.8	17.86	61.9	890.0	1.04	11.36	3.95
5.0	B	1179.5	685.4	1182.0	496.6	2.375	2.502	2.375	5.1	16.31	68.7	860.0	1.04	10.97	3.60
5.0	C	1188.5	689.0	1190.0	501.0	2.372	2.502	2.372	5.2	16.42	68.3	859.0	1.04	10.96	3.50
Average						**2.359**	**2.502**	**2.359**	**5.7**	**16.86**	**66.2**			**11.10**	**3.68**
5.5	A	1153.0	666.0	1154.0	488.0	2.363	2.470	2.363	4.3	17.17	75.0	652.0	1.09	8.72	3.52
5.5	B	1177.5	689.5	1180.0	490.5	2.401	2.470	2.401	2.8	15.84	82.3	738.0	1.09	9.87	4.30
5.5	C	1191.5	700.5	1192.0	491.5	2.424	2.470	2.424	1.9	15.03	87.4	654.0	1.09	8.75	4.00
Average						**2.396**	**2.470**	**2.396**	**3.0**	**16.02**	**81.3**			**9.11**	**3.94**
6.0	A	1188.0	691.0	1189.0	498.0	2.386	2.464	2.386	3.2	16.81	81.0	804.0	1.04	10.26	5.20
6.0	B	1179.5	687.0	1180.0	493.0	2.392	2.464	2.392	2.9	16.60	82.5	945.0	1.04	12.06	5.90
6.0	C	1191.0	692.1	1196.0	503.9	2.364	2.464	2.364	4.1	17.58	76.7	1070.0	1.04	13.65	4.00
Average						**2.381**	**2.464**	**2.381**	**3.4**	**16.99**	**80.0**			**11.99**	**5.03**

Where; *Gmb= Bulk specific gravity, Gmm= Theoretical maximum specific gravity, Va= Air Void in the total mix, VMA= Voids in the Mineral Aggregate, & VFA% = % Voids Filled with Asphalt*

The table (19) above shows the laboratory test results of mixtures without filler material and the corresponding values of Marshall properties with different bitumen contents.

Table 20: Marshall Test Result for Mixes with 6% NSD Filler

MARSHALL PROPERTIES OF BITUMINOUS MIXTURES					
	Aggregate Size				
	G1, 3/4mm	G2, 3/8mm	G3, Fine	G4, Filler	
Blending proportion, %	26	22	46	6	**100**
Bulk Specific Gravity of each	2.590	2.620	2.79	2.683	
Bulk Specific Gravity of Total Aggregate, Gsb					**2.691**

% AC	Trial	Specimen Mass, gm			Bulk Vol, cc	Bulk S.G of Speci. (Gmb)	Th. Max. S.G. (Gmm)	Unit Wt, Mg/m3	% Air Void	% VMA	% VFB	Stability			Flow, mm
		In Air	In Water	SSD In Air								Measured, div	Factor	Adjusted,KN	
4.0	A	1181.5	663.0	1184.0	521.0	2.268	2.569	2.268	11.7	19.09	38.7	1252.0	1.04	16.50	3.40
4.0	B	1176.0	663.5	1177.5	514.0	2.288	2.569	2.288	10.9	18.38	40.7	1417.0	1.04	18.67	4.00
4.0	C	1154.5	655.0	1157.0	502.0	2.300	2.569	2.300	10.5	17.95	41.5	1361.0	1.04	17.93	3.30
Average						**2.285**	**2.569**	**2.285**	**11.0**	**18.47**	**40.5**			**17.70**	**3.57**
4.5	A	1184.5	668.5	1186.0	517.5	2.289	2.562	2.289	10.6	18.77	43.5	1220.0	1	15.46	3.60
4.5	B	1180.5	667.0	1182.5	515.5	2.290	2.562	2.290	10.6	18.73	43.4	890.0	1	11.28	3.85
4.5	C	1188.5	669.5	1190.0	520.5	2.283	2.562	2.283	10.9	18.98	42.6	890.0	1	11.28	4.00
Average						**2.287**	**2.562**	**2.287**	**10.7**	**18.83**	**43.2**			**12.67**	**3.82**
5.0	A	1178.5	668.0	1181.0	513.0	2.297	2.498	2.297	8.0	18.91	57.7	813.0	1	10.30	4.00
5.0	B	1174.5	669.0	1179.0	510.0	2.303	2.498	2.303	7.8	18.70	58.3	1029.0	1	13.04	4.00
5.0	C	1195.0	682.0	1198.0	516.0	2.316	2.498	2.316	7.3	18.24	60.0	1149.0	1	14.56	4.50
Average						**2.305**	**2.498**	**2.305**	**7.7**	**18.62**	**58.6**			**12.63**	**4.17**
5.5	A	1189.0	682.0	1190.5	508.5	2.338	2.479	2.338	5.7	17.90	68.1	881.0	1.04	11.61	4.00
5.5	B	1188.0	682.5	1198.0	515.5	2.305	2.479	2.305	7.0	19.06	63.3	783.0	1.04	10.32	3.52
5.5	C	1196.5	695.0	1197.0	502.0	2.383	2.479	2.383	3.9	16.32	76.1	1060.0	1.04	13.97	4.00
Average						**2.342**	**2.479**	**2.342**	**5.5**	**17.76**	**69.0**			**11.96**	**3.84**
6.0	A	1183.0	673.5	1183.5	510.0	2.320	2.448	2.320	5.2	18.96	72.6	806.0	1.04	10.62	4.80
6.0	B	1192.5	687.0	1193.5	506.5	2.354	2.448	2.354	3.8	17.77	78.6	795.0	1.04	10.48	4.00
6.0	C	1203.0	696.0	1204.0	508.0	2.368	2.448	2.368	3.2	17.28	81.5	610.0	1.04	8.04	5.00
Average						**2.347**	**2.448**	**2.347**	**4.1**	**18.00**	**77.2**			**9.71**	**4.60**

Compaction = **75 Blows,** AC Grade = **85/100,** Specific Gravity of AC = **1.010,**
Ring Factor=12.67N/Div

The table (20) above shows the laboratory test results of mixtures with filler material and the corresponding values of Marshall properties with different bitumen contents. And the summary of the Marshall test results without and with filler materials are presented on the table (21) below.

Table 21: Summary of Marshall Test Results for Table 19 and 20

AC content (%)	Unit Wt (Mg/m^3)		Air Void, (%)		VMA (%)		VFB (%)		Corrected Stability (KN)		Flow (mm)	
	A	B	A	B	A	B	A	B	A	B	A	B
4	2.308	2.285	10.2	11.0	17.82	18.47	42.7	40.5	12.30	17.7	4.17	3.57
4.5	2.338	2.287	7.4	10.7	17.18	18.83	56.9	43.2	12.46	12.67	3.63	3.82
5	2.359	2.305	5.7	7.7	16.86	18.62	66.2	58.6	11.10	12.63	3.68	4.17
5.5	2.396	2.342	3.0	5.5	16.02	17.76	81.3	69.0	9.11	11.96	3.94	3.84
6	2.381	2.347	3.4	4.1	16.99	18.0	80.0	77.2	11.99	9.71	5.03	4.60

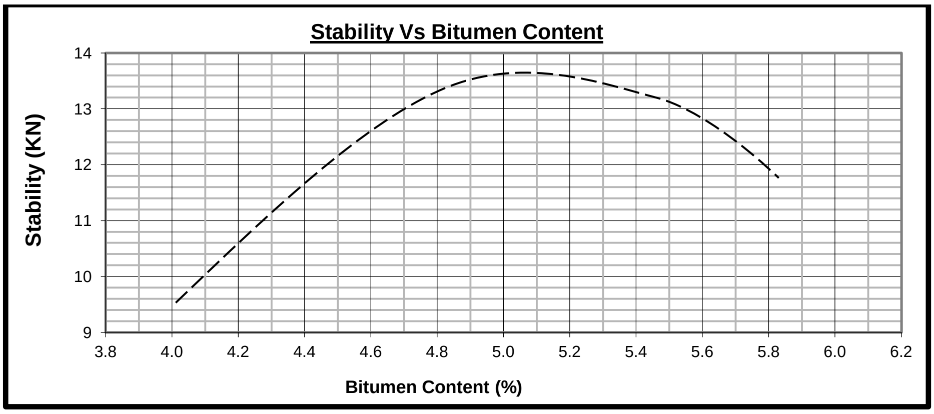
Where A: - Mixture Blended without Filler

B: - Mixture Blended with NSD Filler

4.4.1. Marshall Stability

Stability is generally a measure of the mass viscosity of the aggregate-asphalt cement mixture and is affected significantly by the angle of internal friction of the aggregate and the viscosity of the asphalt cement. The stability of the specimen is the maximum load required to produce failure of the specimen when load is applied at constant rate 50mm / min. From figure (11) below it is noticed that the maximum stability of asphalt mixed with 6% NSD filler is 13KN at 5.1% bitumen content.

The addition of NSD filler in the asphalt mix reduced the deformation due to high temperatures. Furthermore, the mixture with NSD filler is less sensitive to moisture effects by improving the aggregate asphalt bond. The use of filler in the hot asphalt mix has resulted high stability by avoiding rutting, flushing and bleeding effects. Figure (11) shows the stability result for different bitumen contents due to the combination of 6% NSD filler and 5.1% asphalt cement in the mix acting as more viscous binder. That means a mixture with NSD filler had good resistance of deformation than that of bended without filler.

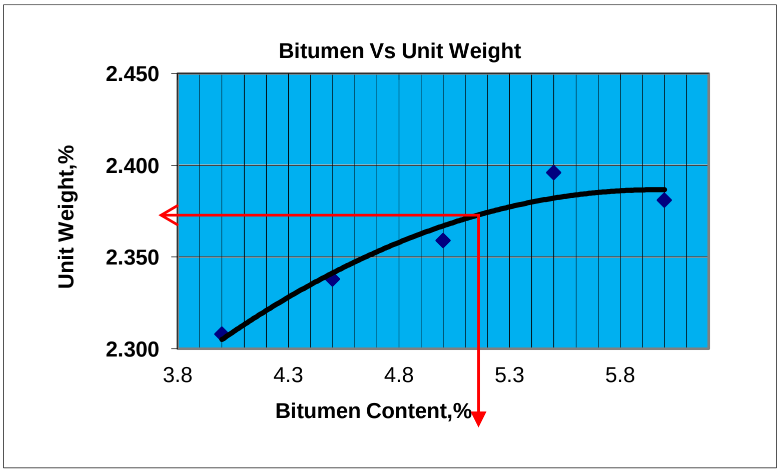


Bitumen Content = 5.1%
Stability (KN) = 13.9

Fig. 11: Stability Vs Bitumen Content

4.4.2. Unit Weight (Density)

The density of the compacted mix is the unit weight of the mixture. 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. The combination of 6% NSD filler and 5% OBC acted as more viscous binder filling the voids and increasing the unit weight too. However, at higher content the mix became stiffer that needs greater compaction effort then consequently lower dense mixture obtained. From Figure (12) below it is noticed that the maximum unit weight was 2.375% at 5.1 % bitumen content.



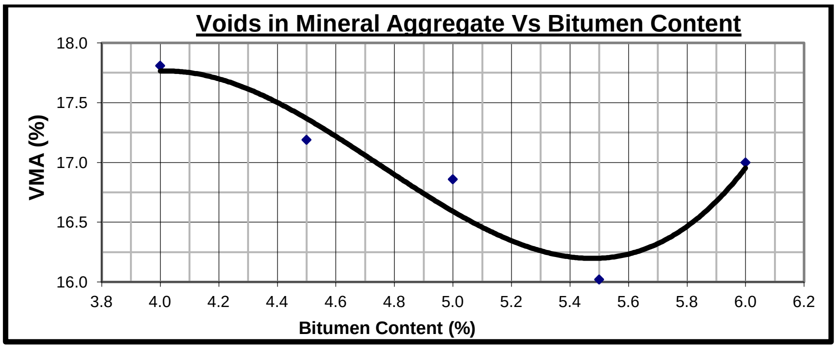
Bitumen Content = 5.1%
Unit Wt (%) = 2.375

Fig. 12: Unit Weight Vs Bitumen Content

4.4.3. Voids in Mineral Aggregate (VMA)

The voids in the mineral aggregate (VMA) are defined as the intergranular void space between the aggregate particles in a compacted paving mixture that includes the air voids and the effective bitumen content, expressed as a percentage of the total volume. From the figure (13) below it is noticed that the VMA decreased gradually as bitumen content increased.

It is common that as filler content in the mix increases, the voids in mineral aggregate decreases up to minimum value then increases at higher filler content. As it can be seen from the figure below, mixtures blended with 6% NSD filler exhibited the same manner. Figure (13) shows the result of VMA with different bitumen contents.



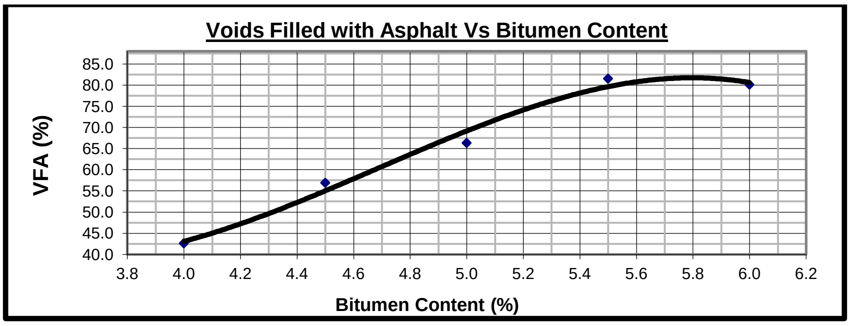
Bitumen Content = 5.1%
VMA = 16.5%

Fig. 13: VMA Vs Bitumen Content

4.4.4. Voids Filled with Asphalt (VFA)

The voids filled with asphalt (VFA) are the percentage of the intergranular void space between the aggregate particles. From figure (14) it is noticed that the VFB% increases gradually as bitumen content increases and due to the increase of voids percentage filled with bitumen in the asphalt mix.

VFA represents the volume of effective bitumen content in the mixture. It is inversely related to air voids hence, as air voids decrease, the VFA increases. But from the result it can be concluded that the addition of NSD filler on the bituminous mixture has changed the trend from inverse to reveres resulting the decrease of both air void and asphalt content. Figure (14) shows the results of VFB at different bitumen contents.

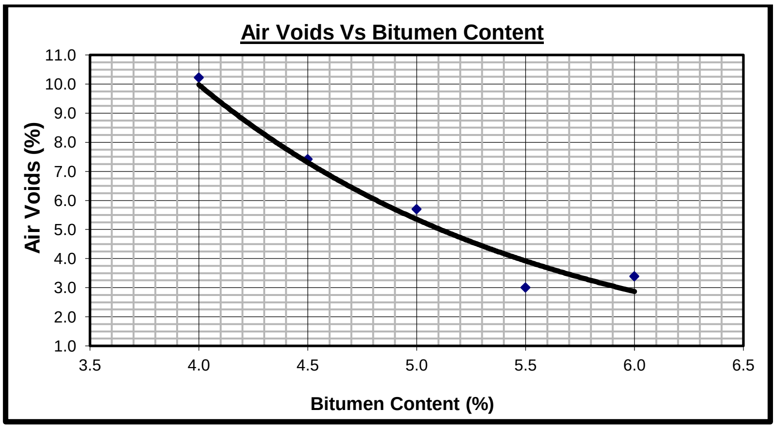


Bitumen Content = 5.1%
VFA = 70.5%

Fig. 14: VFA Vs Bitumen Content

4.4.5. Air Voids Content (Va)

The air voids (Va) is the total volume of the small pockets of air between the coated aggregate particles throughout a compacted paving mixture. It is expressed as a percentage of the bulk volume of the compacted paving mixture. From figure (15) below it is noticed that the air voids content gradually decreases with increasing the bitumen content and that is due to the increase of voids percentage filled with bitumen in the asphalt mix. Figure (15) shows results of air voids content with different bitumen contents.



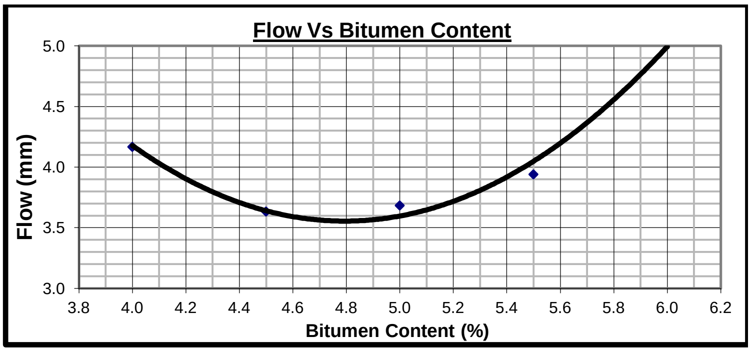
Bitumen Content = 5.1%
Ai r Void = 5.0%

Fig. 15: Air Void Vs Bitumen Content

4.4.6. Flow

Flow is the total amount of deformation which occurs at maximum load. From figure (16) below it is noticed that the maximum flow of the asphalt mix was at 6% bitumen content.

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 may experience premature cracking due to mixture brittleness during the life of the pavement. Figure (16) shows bitumen flow results with different bitumen contents. The flow value has a consistent increase with increasing asphalt content were within the range of (2 – 4mm).



Bitumen Content = 5.1%
Flow (mm) = 3.7mm

Fig. 16: Flow Vs Bitumen Content

4.4.7. Optimum Asphalt Content Determination

It is expected that the effective asphalt content determines the performance of the mixtures. This is expressed as the effective asphalt content which makes the asphalt film around the aggregate particles. 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 get increased and resulting bleeding on the surface of paved road.

The figure (18) below is plotted for determination of the effective asphalt content for mixes blended with 6% NSD filler. As the effective asphalt content decreases, the filler content increases in the mix. This is because more voids are filled with mineral fillers as the filler content in the mix increases resulting lower total asphalt content and hence, lowering the effective asphalt content. Besides, as the filler content increases, more asphalt is absorbed by fine aggregates due to higher proportion of fines in the mixture. The properties of the mix design at this design binder content with recommended Marshall criteria were shown in Table (19 and 20).

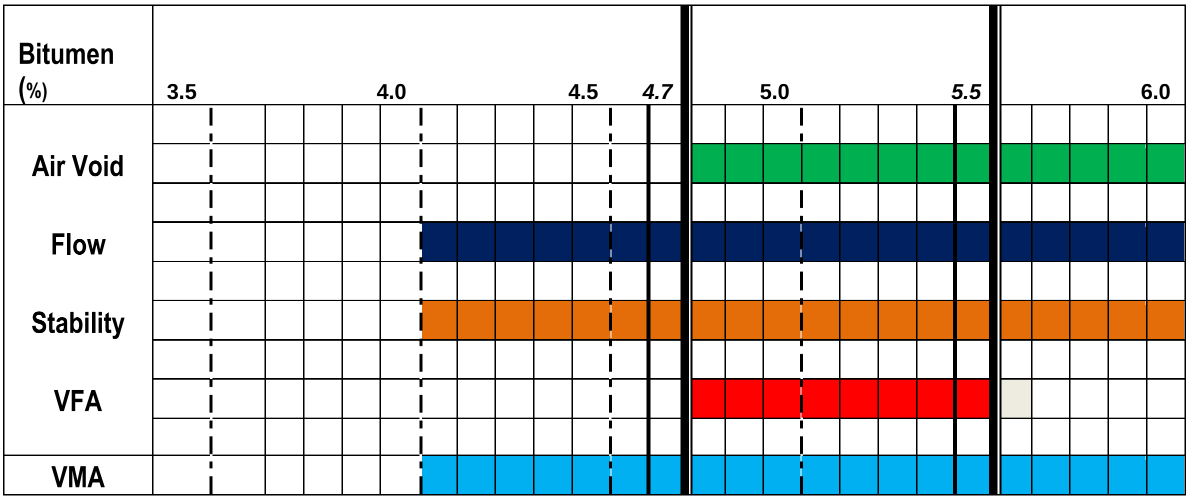


Fig. 17: Determination of Asphalt Content

Table 22: Mechanical Properties of Asphalt Mixes with NSD @5.1% Bitumen Content

NSD Filler Content (%)	Sample No	Corrected Stability (KN)	Flow (mm)	Density (g/cm^3)	Air Void, Va (%)	VMA (%)	VFB (%)
0% (See Table 19)		**10.2**	**2.80**	**2.317**	**7.8**	**17.1**	**54.3**
2%	1	11.00	3.02	2.364	5.70	15.40	6.20
	2	10.00	3.50	2.338	6.70	16.30	59.00
	3	11.00	3.20	2.334	6.90	16.50	58.40
Average		**10.70**	**3.24**	**2.345**	**6.40**	**16.10**	**60.20**
4%	1	10.40	2.97	2.382	5.60	14.80	62.50
	2	10.70	3.13	2.374	5.90	15.10	61.50
	3	11.50	3.40	2.387	5.40	14.60	63.40
Average		**10.90**	**3.17**	**2.381**	**5.60**	**14.80**	**62.30**
6%	1	13.10	3.60	2.378	5.10	15.00	65.90
	2	15.10	4.00	2.394	4.50	14.40	69.00
	3	13.40	3.40	2.405	4.00	14.00	71.20
Average		**13.90**	**3.66**	**2.392**	**4.50**	**14.50**	**68.70**
8%	1	11.00	3.02	2.443	3.70	12.60	70.40
	2	10.00	3.50	2.44	3.90	12.80	69.70
	3	11.00	4.30	2.446	3.60	12.50	71.10
Average		**10.70**	**3.61**	**2.443**	**3.70**	**12.60**	**70.40**

Table (22) above shows the asphalt mixtures laboratory test results with different filler content and the corresponding values of Marshall properties at 5.1% bitumen contents. And the optimum filler content that satisfies all parameters was found to be at 6%.

Table 23: Summary of Marshall Test Result of the Study

Marshall Mix Property	Stability (KN)	Flow (mm)	VFB (%)	VMA (%)	Va (%)	Density (g/cm^3)	OBC (%)
Mix Criteria As per ERA Spec.	Min 8	2-4	65 to 75	10 to 16	3 to 6	-	4 to 10
Mix without Filler	10.2	3.7	70.5	16.5	5.0	2.317	5.1
Mix with 6% NSD Filler	13.9	3.66	68.7	14.5	4.5	2.392	5.1

The table (23) above shows the summery of the Marshall mix results with and without filler material corresponding to the standard specification criteria.

Table 24: Marshall Test Results for Types of Fillers to OBC at Various Filler Content

Filler Type	% Filler	OBC (%)	Air Void (%)	VMA (%)	VFB (%)	Corrected Stability (KN)	Flow (mm)
HL	2	5.10	6.40	15.90	58.70	10.80	3.01
OPC	2	5.10	5.90	15.80	62.5	11.50	3.20
Marble Dust	4	5.10	4.80	16.50	70.50	10.20	3.70
Natural subbase dust	0	5.10	7.80	17.10	54.30	10.20	2.80
	2	5.10	6.40	16.10	60.20	10.70	3.24
	4	5.10	5.60	14.80	62.30	10.90	3.17
	6	**5.10**	**4.50**	**14.50**	**68.70**	**13.90**	**3.66**
	8	5.10	3.70	12.60	70.40	10.70	3.61

Table (24): Illustrates the Marshall properties of the mixes corresponding to filler content for control mix as well as mix modified with NSD filler. The OBC of control mix was 5.1%. The Marshall stability (MS) values of mixes containing 2, 4, 6 and 8% of NSD filler were 10.7, 10.9, 13.9 and 10.7KN respectively in which all the results are within the specification. The flow values of all the mixes respective to OBC stayed in the specified range of 2−4mm. The sources of all materials and aggregate gradation were the same for all the mixes and the changes in all properties obtained were attributed to the type of filler and their contents only.

4.5. The relationship of Marshall Properties with NSD Filler Material

4.5.1. Marshall Stability – NSD Filler Content Relationship

From Figure (18) below it is noticed that all values of stability with different filler content has achieved the specification requirements. As shown below the stability of mixes with NSD has increased as the filler content increases till it reaches the maximum stability that was 13.9KN at 6% filler content then it started to decline.

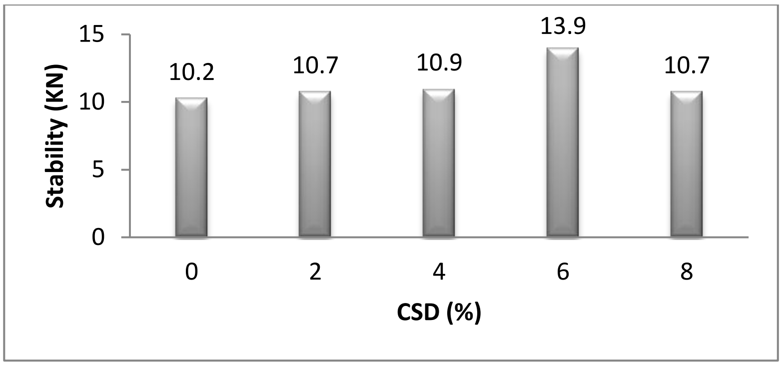


Fig. 18: Asphalt Mix Stability – Filler Content Relationship

4.5.2. Flow – NSD Filler Content Relationship

The flow of mixes with 6% NSD filler has the value of 3.66mm and it is within the range of the specifications. Figure (19) shows flow value results of HMA at different filler content.

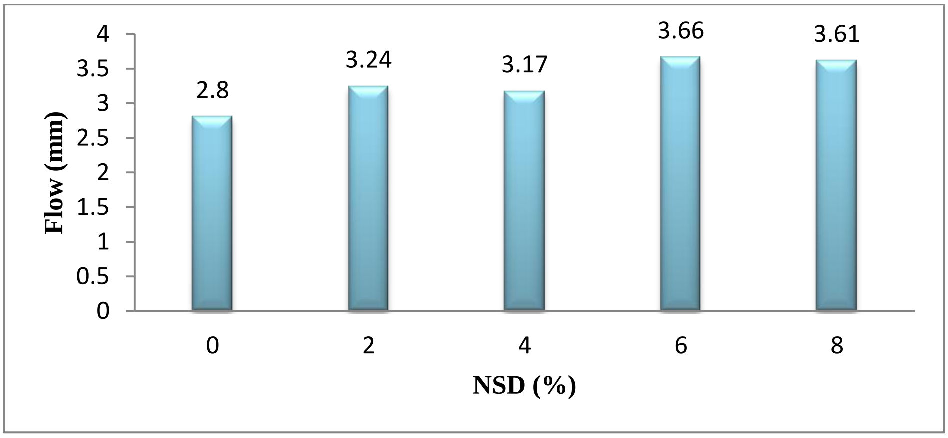


Fig. 19: Asphalt Mix Flow – Filler Content Relationship

4.5.3. Bulk Density – NSD Filler Content Relationship

The bulk density of HMA mixes with different percentages of NSD filler content achieves the specification requirements. The value of bulk density at 6% NSD filler was 2.392g/cm^3. The general trend shows that the bulk density increases as the filler content increases. Figure (20) represents asphalt mix bulk density at different filler content.

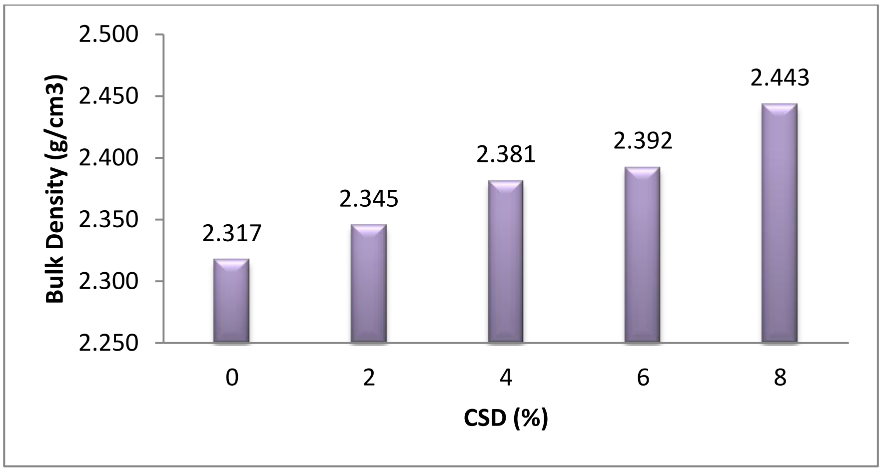


Fig. 20: Asphalt Mix Bulk Density – Filler Content Relationship

4.5.4. Air Voids (Va) – NSD Filler Content Relationship

The air voids value of the mixes decreased gradually as the NSD filler content increases. It can be noticed from the figure that at 6% filler content the air voids percentage was 4.5% which is the median value of the specification. Figure (21) represents the air voids values of asphalt mixes at different filler content.

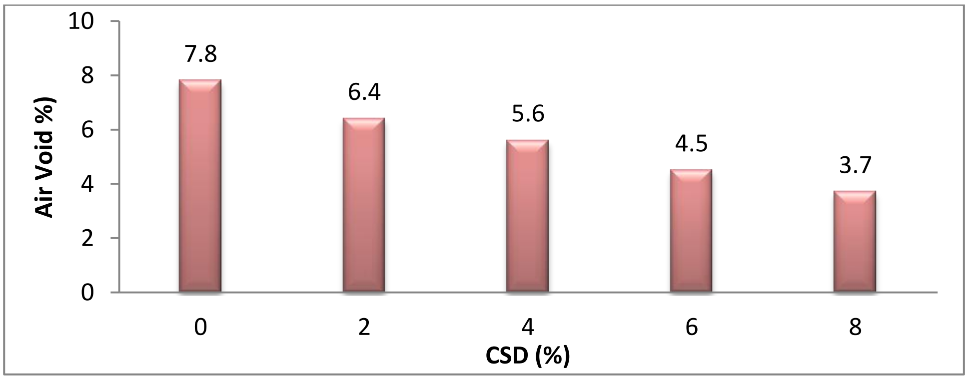


Fig. 21: Asphalt Mix Air Voids – Filler Content Relationship

4.6. Summary of HMA Properties

The table (25) indicated below summarizes the properties of HMA with different filler content.

Table 25: Properties of Mixtures with Different Filler Content

Property	Filler Content (%)				
	0	**2**	**4**	**6**	**8**
Stability (KN)	10.20	10.70	10.90	**13.90**	10.70
Flow (mm)	2.80	3.24	3.17	**3.66**	3.61
Bulk Density (gm/cm^3)	2.317	2.345	2.381	**2.392**	2.443
% of Voids in Tot. Mix (Va)	7.80	6.40	5.60	**4.50**	3.70
% of Voids in Mineral Agg. (V.M.A %)	17.10	16.10	14.80	**14.50**	12.60
% of Voids Filled with Binder (V.F.B %)	54.30	60.20	62.30	**68.70**	70.40

4.7. Optimum Filler Content

From figure (19) it is noticed that all values of Marshall stability for different filler content satisfies the specifications which is 8KN minimum and the maximum stability corresponding to 6% NSD filler content is 13.9KN. Figure (22) represents the air voids percentage at different filler content and at 6% filler content the corresponding air voids value was 4.5% which is very close to the median air voids in the specifications. From Figure (21) it is noticed that all values of bulk density at different filler content were very close to each other and all of them are consistent with the specifications requirements.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The objective of this study was to evaluate the potential use of screened and grinded natural subbase (NSD) as alternative filler material in the characteristics of hot mix asphalt. Based on the findings we can draw the conclusion as follow:

The study revealed the property of NSD filler material has the potential to be used as alternative filler in HMA projects. Besides, the investigation of 6% NSD filler has resulted good effects on the Marshall properties of the asphalt mixture.

The comparison of NSD with the conventional fillers and the standard specifications satisfies all the requirements to be used in HMA mixtures.

Furthermore, the outcome of Marshall parameters like Stability, Air voids and bulk density values were consistent with the standard specifications at 6% NSD content. Therefore, NSD filler can potentially be used in HMA concrete with optimum replacement of 6% by total weight of the total mixture.

5.2. Recommendations

Based on the findings of this research;

- **Road Agencies** are recommended to exercise the use of NSD filler in HMA.
- **Consultants** are suggested to encourage the use of NSD filler for HMA projects in order to ensure the quality of works.
- **Contractors** are advised to use NSD filler for HMA they are engaged in order to save transportation cost and time spend to import other filler materials from far away.

- Other **researchers** are also recommended to conduct further investigations on these abundantly available natural resources.

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APPENDICES

Appendix (A) Physical properties and sieve analysis of aggregates

AGGRGATE CRUSHING VALUE TEST	BS 812 Part 110 : 1990	
SAMPLE NO.	1	2
Size of aggregates ,mm	10 - 14	10 - 14
Maximum load applied ,KN	400	400
Duration of testing ,mm	10	10
Weight of sample tested ,gm	2656.3	2633.8
Wt. of sample ret.On 2.36 sieve ,gm	2201.2	2204.1
Aggregate crushing Value ,%	17.1	16.3
Average agg.crushing value,%	**16.7**	

DETERMINATION OF FLAKINESS INDEX	BS 812 Part 105: 1

Sieves Nominal Apperture Size ,mm	Mass of test portion (gm)	Mass of agg. passing on the flakiness gauge (gm)	Flakiness Index (%)	% in the total aggregate	Weighted average for flakiness index
63.0 - 50.0					
50.0 - 37.5					
37.5 - 25.0					
25.0 - 19.0					
19.0 - 13.2					
13.2 - 9.5	1679.1	500.2	19.4	65.2	
9.5 - 6.3	897.1	135.2	5.2	34.8	
Total weight	2576.2	635.4	24.7	100.0	
FLAKINESS INDEX (%)	**24.7**				

LOSS IN ABRASION AND IMPACT BY LOS ANGELES ABRASION MACHINE
(AASHTO T-96)

Sieve Size		Weight of indicated sizes,g			
Passing	Retained	A	B	C	D
37.5 mm	25.0 mm	1250±25	……….	………..	………..
25.0 mm	19.0 mm	1250±25	……….	………..	………..
19.0 mm	12.5 mm	1250±10	2500±10	………..	………..
12.5 mm	9.5 mm	1250±10	2500±10	……….	………..
9.5 mm	6.3 mm	……….	……….	2500±10	………..
6.3 mm	4.75 mm	………	……..	2500±10	………..
4.75 mm	2.36 mm	………	……….	………..	5000±10
Total		5000±10	5000±10	5000±10	5000±10
No. of spheres		12	11	8	6
Mass of Charge, gm		5000±25			

Sieve Size		Weight of Sample before test ,gm	Weight of Retained on SieveNo.12 ,gm	Weight of passing SieveNo.12 ,gm	% Loss %
Passing	Retained				
37.5 mm	25.0 mm				
25.0 mm	19.0 mm				
19.0 mm	12.5 mm	2500.45			
12.5 mm	9.5 mm	2500.45			
9.5 mm	6.3 mm				
6.3 mm	4.75 mm				
4.75 mm	2.36 mm				
Total		**5000.9**	**4262.3**	**738.6**	**14.8%**

LOSS IN ABRASION AND IMPACT BY LOS ANGELES ABRASION MACHINE
(AASHTO T-96)

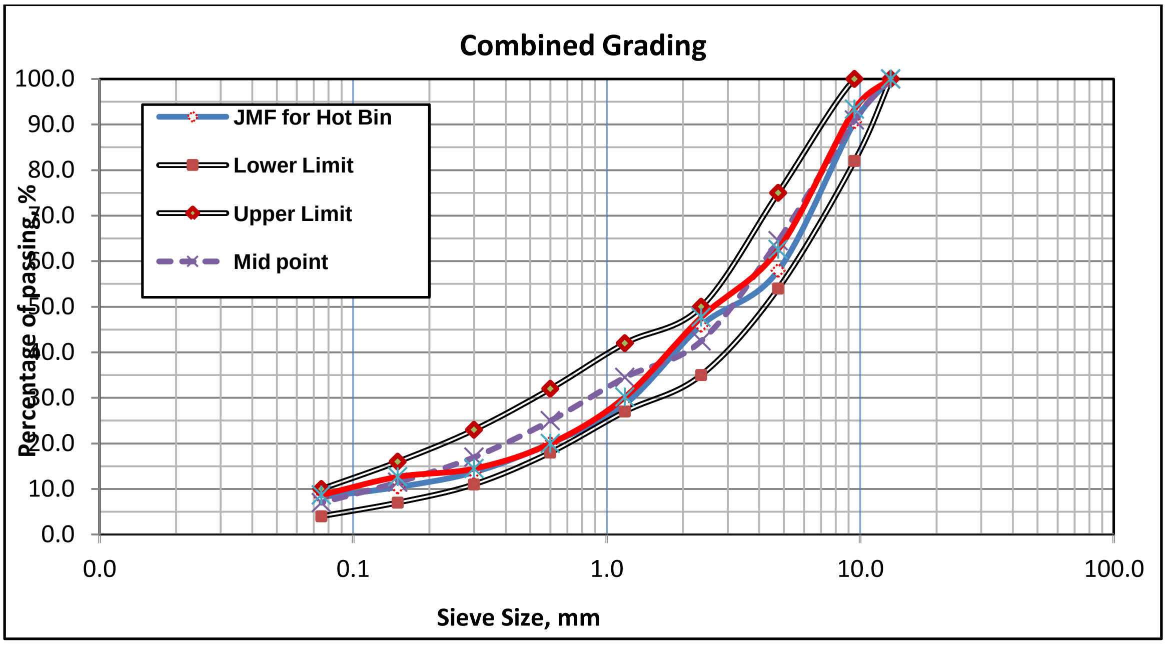
Sieve Size		**Weight of indicated sizes,g**			
Passing	**Retained**	**A**	**B**	**C**	D
37.5 mm	**25.0 mm**	**1250±25**	**……….**	**………..**	**………..**
25.0 mm	**19.0 mm**	**1250±25**	**……….**	**………..**	**………..**
19.0 mm	**12.5 mm**	**1250±10**	**2500±10**	**………..**	**………..**

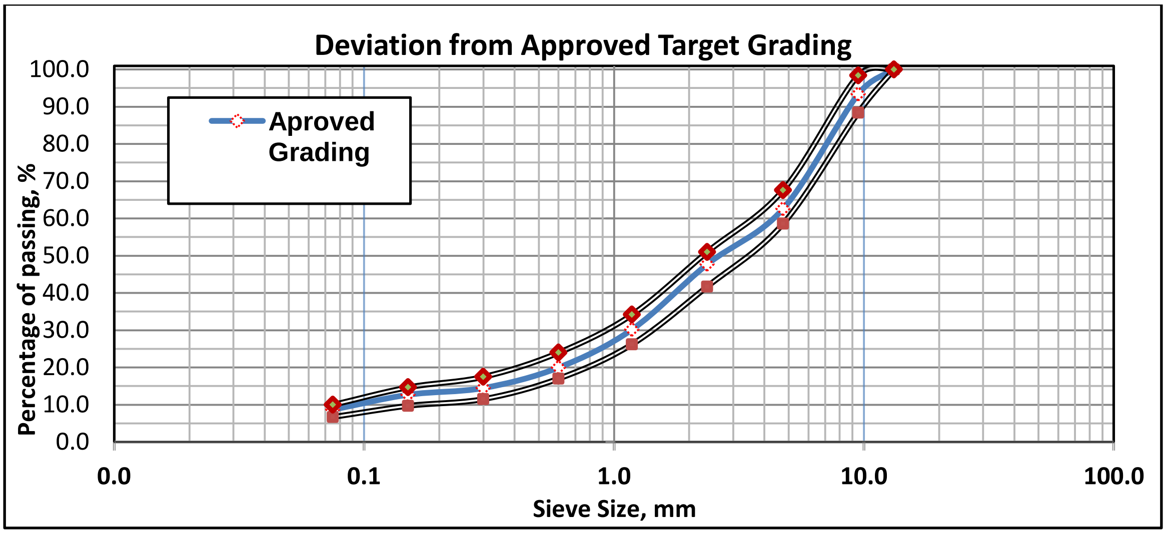
12.5 mm	9.5 mm	1250±10	2500±10	………	……….
9.5 mm	6.3 mm	………	………	2500±10	……….
6.3 mm	4.75 mm	………	……..	2500±10	……….
4.75 mm	2.36 mm	………	………	……….	5000±10
Total		5000±10	5000±10	5000±10	5000±10
No. of spheres		12	11	8	6
Mass of Charge,gm		5000±25			

Sieve Size		Weigth of Sample before test ,gm	Weigth of Retained on SieveNo.12 ,gm	Weigth of passing SieveNo.12 ,gm	% Loss %
Passing	Retained				
37.5 mm	25.0 mm				
25.0 mm	19.0 mm				
19.0 mm	12.5 mm	2500			
12.5 mm	9.5 mm	2500.7			
9.5 mm	6.3 mm				
6.3 mm	4.75 mm				
4.75 mm	2.36 mm				
Total		5000.7	4345.2	655.5	13.1%

Sieve size (mm)	JMF for Hot Bin		Mid point of spec.	Lower limit spec.	Upper limit spec.
	G3 (13.2-6mm)	G2 (6-3mm)	G1 (3-0mm)	Aproved Average Mix Grading (10km)	
13.2	100.0	100.0	100.0	100.0	100.0
9.5	79.1	100.0	100.0	93.4	90.6
4.75	6.9	98.8	100.0	62.6	58.0
2.36	5.4	11.5	96.0	47.7	45.9
1.18	1.6	2.6	62.7	30.2	28.6
0.600	1.3	1.7	43.7	20.0	20.0
0.300	1.2	1.4	29.5	14.5	13.7
0.150	1.0	1.3	22.4	12.7	10.4
0.075	0.6	1.0	17.8	8.7	8.2

% Comp.	45	11	44		





% Bitumen (By wt. of mix)	Maximum Theoretical Density
4.00	2.571
4.50	2.525
5.00	2.502
5.50	2.470
6.00	2.464

Appendix (B) Binder Course Job Mix

% Bitumen (By total wt.)	Absorbed Asphalt - By Agg. Wt.(%)	Effective Asphalt - By Wt. of mix (%)
4.00	0.36	3.65
4.50	0.36	4.15
5.00	0.36	4.66
5.50	0.36	5.16
6.00	0.36	5.66

1. JOB MIX FORMULA & SPECIFIC GRAVITY OF SEPARATE FRACTIONS

Hot Bin Compartment→	3/4mm	3/8mm	Fine	Filler	Remarks
Composition (%)	26	22	48	4	
Bulk Sp. Gr.	2.590	2.620	2.790	2.638	
Apparent Sp. Gr.	2.600	2.710	2.970	0.000	
Water Absorption (%)	0.62	0.98	1.17	0.00	

Appendix (C) Photos