SOME PRPERTIES OF ASPHALT CONCRETE IN ROAD CONSTRUCTION

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CERTIFICATION

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DEDICATION

This work is dedicated to God Almighty, whose for his continuous love, care and provision in all my time of need.

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ABSTRACT

Asphalt concrete roads are susceptible to deterioration over time due to factors such as wealthering, traffic loads, and environmental conditions. Premature cracking, rutting, and surface distress can lead to increased maintenance costs and reduced road service life. By conducting a thorough investigation into the key properties of asphalt concrete, this research aims to provide insights that will contribute to the development of optimized mix designs and construction practices, ultimately leading to more durable, safe and sustainable road infrastructure.

A series of test was carried out including the marshal test to check asphalt mix design, proportion aggregate and asphalt materials for pavement construction.Penetration test was also carried out to to measure of consistency, hardness or softness of bitumen been used.

From the test carried out, it is suggested that asphalts materials of high stability and stiffness should be used, as this reduces the shear deformation of roadswhich is a major failure of asphalt pavement. It was also noted that the asphalt concrete must be strong enough to withstand the stress transmitted to it.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND OF THE STUDY

A network of good roads is a need and not a luxury to any town,. These highways are needed to promote connection between the various villages, especially for economic and administrative needs. Thus, it can be suggested that a locality with many roads leading to it should be more advanced than that with fewer roads leading to it.

Asphalt Concrete has come widely into usage for surfacing roadways and constructing bases. This is manufactured by combining a bituminous binder with low penetration with well-graded aggregate at high temperatures (150°c - 200°c). In the continuous graded aggregate type of the mix, the aggregate is carefully graded from the maximum size down to the filler to create a mix with a controlled void content and the amount of bitumen added is connected to this void content and the climate conditions prevailing. The functions of the aggregate in an asphalt concrete mixture is to produce a mechanically stable frame, whilst the bitumen works as a lubricant during compaction and subsequently serve to water proof and contribute to the strength of the structure through the cohesion it gives as stated before. The function of the course aggregate in asphalt concrete is to produce stability by the interlocking of the aggregate particles and by their frictional resistance to displacement. Both the shape and surface roughness of the stone therefore contribute to the stability. The fine aggregate adds to the stability of the mix through the interlocking of the particles, at the same time it eliminates the spaces in the course aggregate. Proper balance between coarse and fine particles is crucial in order to give both the nonskid and bitumen carrying characteristics required. Normally the fine aggregate utilized is natural sand. The function of the filler in an asphalt concrete mix is to act as a final void filling material as well as a means of stiffening the bitumen film on the aggregate particle. The binder that is normally used for asphalt concrete is bitumen within the penetration range 40 - 200, the exact grade depending mainly on climate and traffic conditions. (Chen et al., 2002)

Asphalt concretes can be classified according to the following characteristics:

1. Type of binder. Asphalt cements are the primary type of binder used, but liquid asphalts (cutbacks and emulsions) are usually used in some certain applications.

2. When the aggregate is uniformly graded from the maximum size down to the filler to obtain a minimum void content and a high stability, mixtures are classified as dense-graded (well-graded), or if there is little or no fine material so that the void spaces in the compacted aggregate are relatively large, called open-graded.

3. Production methods. There are two mainly types of asphalt concrete: hot-mixed, hot-laid mixtures, which are mixed, placed, and compacted at various high temperatures determined by the viscosity-temperature relationship of the binder; and cold-mixed, cold-laid mixtures, which are mixed, placed, and compacted at, or slightly higher than the ambient temperatures, with liquid asphalt as the binder.(Qiang Yuan, 2021).

Asphalt concrete pavements are inherently non homogeneous in nature and exhibit instability (incompatibility) which can have serious consequences for mechanical properties of a roadway asphalt mix (Masad et al., 2009).

Property gradients are most severe across the thickness of the asphalt concrete layers. The main sources of non homogeneity (and instability) are;

(i) Aging

(ii) Varying temperature profile (Dave et al., 2010).

Asphalt concrete mix is, when well designed dense and impervious from the time of laying and does not undergo a material amount of subsequent compaction under traffic. Initial density necessitates a mixture containing at least 45 percent mortar comprising sand, filler and bitumen. This proportion of mortar moans that its properties are of the highest importance and that the mechanical stability of the material under the deforming action of traffic depends primarily on the stability of the mortar; and this is turn depends mainly on the viscosity of the bitumen binder. Survey in Britain shows that the average life of asphalt concrete roads before any treatment is required is about 20 years 117 In Nigeria some asphalt roads have lasted for three to five years and do not show any sign of failure yet. (Ouyang et al., (2005).

1.2 STATEMENT OF THE PROBLEM

This research study centers around the challenges and limitations associated with the qualities of asphalt concrete as a road material. These problems underline the necessity for a comprehensive examination to better the performance and sustainability of asphalt concrete in road construction and maintenance. Asphalt concrete roads are subject to deterioration over time due to factors such as weathering, traffic loads, and environmental conditions. Premature cracking, rutting, and surface distress can contribute to greater maintenance costs and lower road service life. Variability in asphalt concrete characteristics and performance among different mix designs, binder types, and aggregate sources leads in uneven road behavior. This can lead to uneven road conditions, poor safety, and compromised driving comfort. Temperature changes, moisture infiltration, and exposure to deicing agents can deteriorate asphalt concrete, compromising its durability and long-term performance Current asphalt concrete mix designs may not fully leverage the potential for better characteristics. Optimizing mix designs to promote durability, stability, rutting resistance, fatigue behavior, and moisture susceptibility is critical for sustainable road infrastructure.

The existing gaps in information regarding the characteristics of asphalt concrete demand a thorough investigation to overcome these difficulties. By performing a detailed analysis of the key features of asphalt concrete, this research intends to provide insights that will contribute to the development of improved mix designs and construction procedures, ultimately leading to more lasting, safe and sustainable road infrastructure.

1.3 AIM AND OBJECTIVES

The aim of this research project is to comprehensively investigate and analyze the key properties of asphalt concrete as a road material, with the goal of enhancing its performance and sustainability in road construction and maintenance.

Objectives:

1. To evaluate the stability and load-bearing capacity of asphalt concrete through laboratory testing, aiming to improve its ability to withstand traffic loads without significant deformation.

2. To determine the strength and load bearing capacity by subjecting them to varying environmental conditions and analyzing their resistance to deterioration overtime.

3. To access the workability of the asphalt concrete mix.

1.4 SCOPE OF WORK

i. The project will involve a combination of laboratory testing, data analysis, and practical recommendations.

ii. Design and plan a series of laboratory experiments to study the durability, stability, rutting resistance, fatigue behavior, and moisture susceptibility of different asphalt concrete mix designs.

iii. Select appropriate test methods and procedures for each property under investigation.

iv. Collect data from laboratory tests and measurements, ensuring accuracy and consistency.

v. Analyze the collected data using appropriate statistical and analytical techniques to derive meaningful insights.

vi. Interpret and analyze the results of each test to understand the behavior and performance of different asphalt concrete mix designs.

vii. Based on the findings, provide practical recommendations for optimizing asphalt concrete mix designs and construction practices to enhance road performance.

1.5 JUSTIFICATION OF STUDY

Road infrastructure has a significant role in economic development and societal well-being. Sustainable road constructing and maintaining procedures are crucial to reduce environmental consequences and provide long-lasting infrastructure. Asphalt concrete roads are prone to many forms of deterioration, such as cracking, rutting, and premature wear. Understanding the factors that are impacting these difficulties is vital to design solutions for their prevention and mitigation. Frequent maintenance and repairs of deteriorating roads put huge financial pressures on governments and communities. Roads with poor characteristics can undermine safety by increasing the chance of accidents and diminishing driver comfort. Sustainable road materials and designs have a lower environmental footprint. The findings of this study can provide useful insights to the road construction industry, enabling for the establishment of new standards, guidelines, and best practices. By studying and optimizing asphalt concrete mix designs, the research can lead to creative construction methods and materials, enabling breakthroughs in road engineering practices. Research outputs can guide policy decisions and laws linked to road building and maintenance, ensuring that infrastructure development fits with sustainable and long-term goals.

CHAPTER TWO

LITERATURE REVIEW

2.1 ASPHALT CONCRETE

Asphalt concrete is frequently termed asphalt, blacktop, or pavement in North America, and tarmac in Great Britain and Ireland. Asphalt concrete is known by many various names, examples are: (i) hot mix asphalt (HMA), (ii) warm mix asphalt (WMA), (iii) cold mix asphalt (CMA), (iv) plant mix, (v) bituminous mix, and (vi) bituminous concrete. When spilled into the environment, other names may be used. Asphalt concrete is a combination of two basic ingredients: (i) aggregate and (ii) asphalt cement. Typically, the aggregate constitutes 90–95% (w/w) of the entire mixture and the asphalt cement (asphalt binder) constitutes 5–10% (w/w) of the whole mixture to produce the asphalt concrete.

In the production process, the aggregate and binder are combined in an efficient manufacturing plant which produces the specified material. Plant equipment includes: (i) cold bins for storage of graded aggregate, (ii) a dryer for drying and heating aggregates to the required mixing temperature, (iii) tanks for storing the liquid asphalt, and (iv) a pug mill for combining the graded, heated aggregate and liquefied asphalt cement according to the specified mix formula.

Once produced, the asphalt concrete is transported by truck to the paving site where it is spread to a uniform thickness with a mechanical paving or finishing machine. Then the material is compacted to the required degree by heavy, self-propelled rollers, producing a smooth, well-compacted pavement course. The paving or finishing machine places the asphalt concrete at temperatures above 107°C (225°F). The material should be compacted before the temperature of the mix falls below 80°C (175°F) to achieve adequate density.(Speight, 2016)

2.1.1 Cold Mix Asphalt

Concrete Cold mix asphalt concrete (CMA, sometimes termed cold put mixture) is commonly a mixture created from emulsified asphalt or cutback asphalt. While in its emulsified, state the asphalt is less viscous and the mixture is easy to work and compact. The emulsion will dissolve once enough water evaporates and the cold mix will, ideally, take on the qualities of cold hot-mix asphalt concrete. Cold mix is widely used as a patching material and on lesser trafficked service roads. (James, 2016)

Slow-curing asphalt is commonly referred to as road-oil—this phrase originated in the early days of asphalt technology when asphaltic residual oil was utilized to give roadways a low-cost, all-weather surface. The degree of fluidity of each cutback asphalt relies on (i) the grade of asphalt cement, (ii) the volatility of the solvent, and (iii) the proportion of solvent to binder. The degree of fluidity results in many grades of cutback asphalt—some may be fluid at ordinary atmospheric temperatures while other cutback asphalts can be significantly more viscous and may require heating to melt them to be adequately suited for construction operations. Cutback asphalts can be utilized with cold aggregates, with a minimum of heat. Rapid-curing and medium-curing cutback asphalts are employed in a range of highway construction processes. Among the more essential uses are road mixing operations, stockpiling mixes, and spray applications such as prime. In the early days of the highway paving industry, cutback asphalts were utilized widely and successfully in numerous applications. Because the distillates are high-energy products that are wasted by evaporation into the atmosphere, environmental concerns and laws have led in emulsified asphalts supplanting reductions in most applications. The principal usage of cutback asphalts in the modern asphalt business is in the manufacture of asphalt cold-patching materials and as a prime coat spray application.(Speight, 1992).

2.1.2 Hot Mix Asphalt

Hot mix asphalt (HMA) concrete is a combination of about 95% (w/w) aggregate (stone, sand, or gravel) linked together with asphalt cement. In the creation of the mix, asphalt cement is heated aggregate, blended, and mixed with the aggregate at an HMA facility. The resulting HMA is put onto trucks for transfer to the paving site. The trucks deposit the HMA into hoppers placed at the front of paving machines. The asphalt is laid on the base of the roadway, and then compacted using a large roller, which is dragged over the asphalt. Traffic is normally permitted on the surface as soon as the pavement has cooled. Hot mix asphalt concrete (often abbreviated as HMAC) is formed by heating the asphalt binder to decrease its viscosity, and drying the aggregate to eliminate moisture from it prior to mixing. Mixing is done with the aggregate at roughly 150°C (300°F) for virgin asphalt and 165°C (330°F) for polymer-modified asphalt, and asphalt cement at 95°C (200°F). Paving and compaction must be completed while the asphalt is sufficiently heated. In many countries paving is restricted to summer months because in winter the compacted foundation will chill the asphalt too quickly before it is possible to be packed to the requisite density. HMAC is the form of asphalt concrete most typically used on high-traffic roadways such as those on major highways, racetracks, and airfields. It is also utilized as an environmental liner for landfills, reservoirs, and fish hatchery ponds. (Johnston et al., 2006)

2.1.3 Oxidized Asphalt

Oxidized asphalt (air-blown asphalt, air-refined asphalt) is asphalt that has been treated by blowing air through it at elevated temperatures to produce the physical properties required for industrial use of the final Oxidized asphalt is typically used in roofing operations, pipe coating, under sealing for Portland cement concrete pavements, and hydraulic applications. The penetration value and softening point usually classifies oxidized asphalt. (Button et al., 2007)

Mastic asphalt concrete or sheet asphalt is produced by heating hard grade blown asphalt in a green cooker (mixer) until it has become a viscous liquid after which the aggregate mix is then added. The asphalt– aggregate mixture is heated (matured) for approximately 6–8h and once it is ready the mastic asphalt mixer is transported to the work site where experienced layers empty the mixer and either machine or hand lay the mastic asphalt contents on to the road. Mastic asphalt concrete is generally used in footpath and road applications and for flooring or roof applications. In addition to the asphalt and aggregate, additives, such as polymers, and anti-stripping agents may be added to improve the properties of the final product. (Austerman et al., 2009)

Stone mastic asphalt is a unique form of asphalt for wearing courses and consists of a mineral mix with a greater asphalt and stone content—it also has a high content of the coarsest particles of each fraction. Typically, the asphalt utilized is a road construction type or, for roadways that encounter heavy traffic loads, polymer-modified asphalt with stabilizing additives is chosen. The mineral composition follows the principle of gap grading which results in a self-supporting chipping skeleton the cavities of which are mostly, filled with asphalt. Due to its particular composition, this mix is highly wear-resistant and less prone to deformation and fatigue cracking. (Bennert et al., 2010).

2.2 PROPERTIES OF ASPHALT CONCRETE

2.2.1 Stability

The stability of the asphalt–aggregate mix is critical for roadway performance and lifespan. However, stabilization is when chemical bonding procedures render a binder less hazardous and less detrimental to the environment. Examples of such stabilization include (i) ion exchange of heavy metals in an alumina silicate matrix of a cementitious agent or (ii) sorption of heavy metals on fly ash in an aqueous environment (D'Andrea et al., 2004).

Stability of an asphalt pavement is its ability to resist shoving and rutting under loads (traffic). A stable pavement retains its shape and smoothness under repeated pressure; an unstable pavement develops ruts (channels), ripples (wash boarding or corrugation) and other evidence of movement of the mixture. Because stability parameters for a pavement depend on the traffic predicted to use the pavement, the requirements can be defined only after a thorough traffic analysis. Stability criteria should be high enough to handle traffic properly, but not greater than traffic conditions need. overly high a stability value provides a pavement that is overly stiff and hence less durable than expected. The stability of a mixture depends on internal friction and cohesion. Internal friction among the aggregate particles (inter-particle friction) is related to aggregate features such as form and surface texture. Cohesion originates from the bonding ability of the binder (Suryakanta, 2016).

2.2.2 Durability

The durability of an asphalt pavement is its ability to resist factors such as changes in the binder (polymerization and oxidation), disintegration of the aggregate, and stripping of the binder films from the aggregate. These factors can be the result of weather, traffic, or a combination of the two. Generally, durability of a mixture can be enhanced by three methods. They are; using maximum binder content, using a dense gradation of stripping-resistant aggregate, and designing and compacting the mixture for maximum impermeability.

Maximum binder content increases durability because thick binder films do not age and harden as rapidly as thin ones do. Consequently, the binder retains its original characteristics longer. Also, maximum binder content effectively seals off a greater percentage of interconnected air voids in the pavement, making it difficult for water and air to penetrate. Of course, a certain percentage of air voids must be left open in the pavement to allow for expansion of the binder in hot weather.

A dense gradation of sound, tough, stripping-resistant aggregate contributes to pavement durability in three ways. A dense gradation provides closer contact among aggregate particles. This enhances the impermeability of the mixture. A sound, tough aggregate resists disintegration under traffic loading; and stripping-resistant aggregate resists the action of water and traffic, which tend to strip the binder film off aggregate particles and lead to raveling of the pavement. Under some conditions, the resistance of a mixture to stripping can be increased by the use of anti-stripping additives, or mineral filler such as hydrated lime. Designing and compacting the mixture to give the pavement maximum impermeability minimizes the intrusion of air and water into the pavement. A lack of sufficient durability in a pavement can have several causes and effects (Suryakanta, 2016).

2.2.3 Workability

Workability describes the ease with which a paving mixture can be placed and compacted. Mixtures with good workability are easy to place and compact; those with poor workability are difficult to place and compact. Workability can be improved by changing mix design parameters, aggregate source, and/or gradation.

Harsh mixtures (mixtures containing a high percentage of coarse aggregate) have a tendency to segregate during handling and also may be difficult to compact. Through the use of trial mixes in the laboratory, additional fine aggregate and perhaps binder, can be added to a harsh mix to make it more workable. Care should be taken to ensure that the altered mix meets all other design criteria, such as void content and stability. Too high a filler content can also affect workability. It can cause the mix to become gummy, making it difficult to compact. Workability is especially important where quite a bit of hand placement and raking (luting) around manhole covers, sharp curves, and other obstacles is required. It is important that mixtures used in such areas are highly workable.

Mixtures that can be too readily worked or shoved are referred to be sensitive mixes. Tender mixes are too unstable to lay and compact appropriately. They are generally caused by a shortage of mineral filler, too much medium-sized sand, and smooth, rounded aggregate particles, and/or too much moisture in the mix. Although not generally a major contributor to workability concerns, the asphalt binder does have some effect on workability. Because the temperature of the mix impacts the viscosity of the binder, too low a temperature will make a mix unworkable, too high a temperature may make it delicate. Binder grade may also affect workability, as may the proportion of binder in the mix (Suryakanta, 2016).

2.2.4 Elasticity

The elastic properties of asphalt concrete refer to its ability to deform under stress and return to its original shape when the stress is removed. These properties are crucial for understanding how asphalt pavements respond to traffic loads, temperature changes, and other external forces. The main elastic properties of asphalt concrete include:

Elastic Modulus (Modulus of Elasticity): The elastic modulus, often denoted as E, is a measure of the material's stiffness or resistance to deformation under load. It quantifies the relationship between stress (force per unit area) and strain (deformation). In asphalt concrete, the elastic modulus varies with factors such as temperature, loading rate, and the type of aggregate and binder used. Higher elastic modulus values indicate a stiffer material that undergoes less deformation under a given load.

Poisson's Ratio: Poisson's ratio (ν) is a dimensionless value that represents the ratio of lateral strain to axial strain when a material is subjected to axial loading. It characterizes the lateral contraction that occurs when a material is stretched or compressed. Asphalt concrete typically exhibits a Poisson's ratio ranging from 0.2 to 0.35, indicating that it contracts laterally to some extent when subjected to axial deformation.

Shear Modulus: The shear modulus, often denoted as G or μ, is a measure of a material's resistance to shear deformation. It represents the ratio of shear stress to shear strain and is used to describe how a material responds to forces applied parallel to its surface.

2.2.5 Hardening

During mixing and service, the hardening shown by an asphalt under handling and service conditions was for a long time, taken as the best measure of its economic value. Resistance to deterioration is a term used to some extent, but it does not seem appropriate since durability under service conditions is frequently affected by changes that in the strictest sense cannot be called deterioration. Since asphalt is used primarily as an adhesive and binder, it is obvious that hardening and the changes in chemical, physical, colloidal, and rheological properties coincident thereto are of primary importance to the asphalt technologist .

2.2.6 Skid Resistance

Skid resistance is the ability of an asphalt surface to minimize skidding or slipping of vehicle tires, particularly when wet. For good skid resistance, tire tread must be able to maintain contact with the aggregate particles instead of riding on a film of water on the pavement surface (hydroplaning). Skid resistance is typically measured in the field at 40 mi/hr with a standard tread tire under controlled wetting of the pavement surface. A rough pavement surface with many little peaks and valleys will have greater skid resistance than a smooth surface. Best skid resistance is obtained with rough-textured aggregate in a relatively open-graded mixture with an aggregate of about 3/8 in.-1/2 in. (10-13 mm) maximum size. Besides having a rough surface, the aggregates must resist polishing (smoothing) under traffic. Calcareous aggregates polish more easily than siliceous aggregates. Unstable mixtures that tend to rut or bleed (flush asphalt to the surface) present serious skid resistance problems (Suryakanta, 2016).

2.3 BIODEGRADATION OF ASPHALT

The residuum or asphaltic fraction of petroleum is the fraction that is either (i) the residue remaining after completion of atmospheric distillation or (ii) the residue remaining after the completion of vacuum distillation. On the other hand, asphalt is the product produced from asphalt that is used for, among other uses, road and highway surfacing (Speight et.al 2014). The chemical composition of a residuum from an asphaltic crude oil is complex. Physical methods of fractionation usually indicate high proportions of asphalt constituents and resin constituents, even in amounts up to 50% (or higher) of the residuum. In addition, the presence of ash forming metallic constituents, including such organo-metallic compounds as those of vanadium and nickel, is also a distinguishing feature of asphalt. Furthermore, the deeper the cut into the crude oil to produce the residuum from which asphalt is manufactured, the greater is the concentration of sulfur and metals in the residuum and the greater the deterioration in physical properties (Speight, 2014). On the other hand, asphalt is manufactured from petroleum and is a black or brown material that has a consistency varying from a viscous liquid to a glassy solid. To a point, asphalt can resemble bitumen, hence the tendency to refer to bitumen (incorrectly) as native asphalt. It is recommended that there be differentiation between asphalt (manufactured) and bitumen (naturally occurring) other than by use of the qualifying terms petroleum and native since the origins of the materials may be reflected in the resulting physio-chemical properties of the two types of materials. It is also necessary to distinguish between the asphalt which originates from petroleum by refining and the product in which the source of the asphalt is a material other than petroleum. When the asphalt is produced simply by distillation of an asphaltic crude oil, the product can be referred to as residual asphalt or straight run asphalt. If the asphalt is prepared by solvent extraction of residua or by light hydrocarbon (propane) precipitation, or if blown or otherwise treated, the term should be modified accordingly to qualify the product (e.g., propane asphalt, blown asphalt). Asphalt softens when heated and is elastic under certain conditions. The mechanical properties of asphalt are of particular significance when it is used as a binder or adhesive. The principal application of asphalt is in road surfacing, which may be done in a variety of ways. Light oil dust layer treatments may be built up by repetition to form a hard surface, a granular aggregate may be added to an asphalt coat, or earth materials from the road surface itself may be mixed with the asphalt.

2.4 PROPERTIES OF AGGREGATES FOR ASPHALT

The suitability of the aggregate material also depends upon the chemical and physical properties as well as the mineral type, particle size, particle shape, and interrelationship of the mineral particles. The performance of the asphalt mix (binder plus aggregate) also relies upon specifications, which, in turn, depend upon the relative proportions of the components as well as the physical properties of each of the components. Thus, the strength and quality of the asphalt roadway depend upon (i) the physical properties of the mix, (ii) the design of the pavement structure, and not forgetting (iii) the quality of the construction.

General properties just as the properties of the binder influence the properties of an asphalt, the properties of the aggregate also play a role in determining the performance and the life of the roadway. The properties of the aggregate influence the amount of binder required for satisfactory performance and the properties of interest include: (i) surface texture and shape, (ii) gradation, (iii) absorption, (iv) clay content, and (v) durability. These properties are particularly noteworthy for the specification relating to the performance grading of asphaltic roadways.

2.4.1 Surface Texture and Shape

The surface texture of the aggregate is an extremely important factor that makes a contribution to frictional resistance. The surface texture also has a strong influence on the resistance of asphalt mix to rutting—the rougher the texture of the aggregate, the better the resistance of the mix to rutting. However, during construction, a mix containing a rough-textured aggregate requires greater compaction energy to achieve the required density than hot mix asphalt containing a smooth-textured aggregate.

The shape of the aggregate particles also influences the rutting resistance of an asphalt mix—angular aggregate produces a greater resistance than more rounded aggregate particles. The improved resistance of angular aggregates is a result of the increased surface roughness produced during the crushing operation as well as the ability of the aggregate particles to interlock with each other. However, as with surface texture, the more angular the aggregate, the greater the compaction energy required to produce a mix with a specified degree of density. The coarse aggregate angularity test is a method of determining the angularity of coarse aggregate. The fine aggregate angularity test is an indirect method of assessing the angularity of fine aggregate. Fine aggregate angularity is important because an excess of rounded fine aggregate (often in the form of natural sand) can lead to rutting. Generally, the acceptance criteria used for these parameters are higher as the amount of traffic increases and as the mix is placed closer to the pavement surface. (Speight et al., 2002)

2.4.2 Particle Size Distribution

One of the important properties of aggregates for use in pavements is the distribution of particle sizes (gradation) which is generally controlled by specifications that define the distribution of particle sizes. Typically, the larger the maximum size of aggregate in a given mix types in relation to the layer thickness and the greater the amount of large aggregate in the mix, the more compaction energy that is required. Furthermore, if the nominal maximum aggregate size exceeds one-third of the compacted thickness of the pavement layer, the surface texture of the mix can be affected, and the degree of density of the mix obtained by compaction may be reduced. (Hsu et al., 2006)

2.4.3 Absorption

The amount of asphalt cement that is absorbed by the aggregate can significantly affect the properties of the asphalt mixture. If the aggregate particles have high asphalt absorption, the asphalt content in the mix must be increased to compensate for binder material that is drawn into the pores of the aggregate and is unavailable as part of the film thickness around those particles. If that asphalt content adjustment is not made, the mix can be dry and stiff, the amount of compaction energy needed to achieve density in the mix will need to be increased, and the mix will have a tendency to deform in service. If absorptive aggregates that have high water content are used, extra time will be required in the production of hot mix asphalt to ensure that the moisture in the pores can evaporate or the asphalt may not be properly absorbed, leading to difficulties during the compaction process.

2.4.4 Porosity

The internal pore characteristics are very important properties of aggregates since the size, the number, and the continuity of the pores through an aggregate particle may affect the strength of the aggregate, abrasion resistance, surface texture, specific gravity, bonding capabilities, and resistance to freezing and thawing action. Absorption relates to the ability of a particle to take in a liquid. Thus, porosity is a ratio of the volume of the pores to the total volume of the particle. The related property permeability refers to the ability of the particle to allow liquids to pass through. If the pores taken together are not connected, the result will be high porosity and low permeability. The porosity of an aggregate is generally indicated by the amount of water absorbed when the aggregate is soaked in water. A certain degree of porosity is desirable, as it permits aggregates to absorb binder, which then forms a mechanical linkage between the binder film and the stone particle. Related to this the affinity of the aggregate for the binder is the stripping (separation) of the binder film from the aggregate through the action of water (AASHTO T283) may make an aggregate material unsuitable for asphalt concrete mixtures. Many of these materials may be used with the addition of a heat-stable additive that reduces the stripping action. Aggregates, which exhibit a high degree of resistance to stripping in the presence of water, are usually most suitable in asphalt concrete mixes. Such aggregates are referred to as hydrophobic (water hating).

2.4.5 Soundness

The soundness (AASHTO T104) refers to the durability of an aggregate in terms of the resistance to the action of weather and is an indication of the resistance to weathering of fine and coarse aggregates. Items for consideration under weathering action are freezing, thawing, variation in moisture content, and temperature changes. In addition, the particle shape of the aggregate moisture has an effect on the workability of the mix as well as the compaction energy necessary to obtain the required density. Particle shape also has an effect on the strength of the asphalt concrete mix. Irregular or angular particles tend to interlock when compacted and resist displacement. In addition, like particle shape, the surface texture also influences the workability and strength of asphalt concrete mixtures. Surface texture has often been considered more important than shape of the aggregate particles since a rough, sandpaper-like surface texture, as opposed to a smooth surface, tends to increase the strength of the mix. Compacted aggregates without the addition of a cementing material may be used as a base or sub-base for hot mix asphalt and Portland cement concrete pavements. Portland cement concrete pavements are rigid pavements. For these types of pavements, the purpose of the base may be to improve drainage, to prevent pumping, or to cover a material that is highly susceptible to frost. Consequently, gradation and soundness are the primary considerations in selecting or evaluating aggregates for bases under rigid pavements. The load-carrying capacity is a primary factor in the selection of aggregates for hot mix asphalt pavements. A hot mix asphalt pavement does not carry the load; help from the underlying base courses is required. In addition to grading requirements, the aggregates are required to posses the strength to carry and transmit the applied loads. (Gary et al., 2007)

2.4.6 Moisture susceptibility

Moisture susceptibility is a critical factor influencing the durability and performance of asphalt pavements. The interaction between moisture and asphalt mixtures can lead to distress, such as cracking and stripping, which significantly reduces the lifespan of the pavement. This review aims to provide an in-depth analysis of the key factors contributing to moisture susceptibility, strategies for mitigation, and testing methods used to evaluate moisture-related distress.

The moisture susceptibility of asphalt mixtures is influenced by several factors, including adhesion and cohesion between asphalt binder and aggregates, binder properties, aggregate characteristics, environmental conditions, and construction practices. The proper adhesion between binder and aggregates is crucial for preventing moisture-induced damage, the type of binder used and its compatibility with aggregates play a significant role in the moisture resistance of the pavement.

2.5 THE FATIGUE BEHAVIOR OF ASPHALT CONCRETE

The fatigue process is characterized by the repetitive application of loads, such as those from vehicles passing over the pavement. Each loading cycle induces stress within the asphalt concrete, causing micro cracks to initiate and propagate. Over time, these cracks accumulate and link, eventually leading to the formation of visible fatigue cracks on the pavement surface. The loading cycles cause stress redistribution within the pavement layers. Initially, the stress is concentrated near the surface, but as fatigue progresses, the stresses redistribute to deeper layers. This phenomenon can accelerate the growth of cracks and contribute to pavement deterioration. The properties of both the asphalt binder and the aggregate significantly influence the fatigue behavior. The stiffness and fatigue resistance of the binder affect how well it can withstand the repeated stresses, while the aggregate properties, such as particle shape and size distribution, affect the overall structural integrity of the mixture. Temperature variations play a crucial role in asphalt concrete fatigue. The stiffness of the asphalt binder changes with temperature, affecting its ability to absorb and distribute stresses. Thermal cycles can also induce stress due to differential expansion and contraction between the pavement layers. The range of load magnitudes and frequencies experienced by the pavement, known as the load spectrum, is a critical factor in fatigue behavior. Different traffic patterns and vehicle types can subject the pavement to varying load cycles, influencing the rate of fatigue damage accumulation.

2.6 RHEOLOGICAL PROPERTIES

Dynamic Shear Modulus The Strategic Highway Research Program (SHRP) originally conceived the idea of characterizing bitumen using geological properties, in response to a perception from within the highway industry that quality of paving-grade bitumen had in many instances deteriorated to an unacceptable level. Because of this perception, the primary objective of the bitumen related section of SHRP was to develop performance-based specifications for bitumen and bituminous mixtures (Mihai et al., 2000).

In particular, the complex modulus (G*) is a major indicator of the mechanical behavior and performance. In the case of viscoelastic materials such as, bitumen, a tensile stress, σ applied at a loading time t = 0, causes a strain, εt which increases not proportionally with loading time. The stiffness modulus, St is defined as the ratio of the applied stress to the resulting strain. Therefore, dynamic (oscillatory) shear rheometer was developed, which is considered the best technique to explain the uniqueness of the behavior of bitumen.

2.6.1 Stiffness Modulus

The stiffness modulus of bituminous mixtures is fundamental to the analysis of the stress–strain response of pavement under traffic loading. It can be measured using various methods such as the resilient modulus test, indirect tensile test and uniaxial direct tensile test.

The stiffness modulus of bituminous mixtures containing coarse RCA in relation to that of reference NA bituminous mixtures is given in Figure 12.12. The results at low RCA content (less than 40%) are inconsistent, showing that the stiffness modulus could be higher or lower than that of the reference NA bituminous mixtures. However, the use of coarse RCA is not likely to result in an increase in stiffness modulus, given that the adhered cement paste is weak and has low elastic modulus. Notwithstanding this, it becomes clear that the stiffness modulus of bituminous mixtures decreases as the coarse RCA content increases. On average, every 10% increase in coarse RCA can lead to about 3% reduction in stiffness modulus of bituminous mixtures, giving a total of 30% reduction when NA is fully replaced by coarse RCA. For mixed-size and fine RCA, the trend of the results is not definite, but in general, they should also result in a reduction in stiffness modulus due to the presence of adhered cement paste (Ravindra, et.al, 2019)

2.7 RUT FORMATION IN ASPHALT PAVEMENTS

Rutting results from the accumulation of permanent deformations which may be due to compaction or to plastic strain. For mixtures compacted well during construction, rutting due to additional compaction under traffic is normally small. The concern is then for the measurement of the ability of a mixture to resist plastic movement. The view that rutting in asphalt materials occurs mainly by horizontal deformation or shear displacement is borne out by the laboratory rutting tests of Hofstra and Klomp (10) which distinctly show a ridge of displaced material on either side of rut. Indirect evidence that asphalt materials are nearly incompressible has been provided by palmer and Thomas (17) who found that although asphalts do density under traffic, this densification only reduces air voids by 2% to 3%. Assuming that a 3% reduction of air voids takes place vertically, a vertical displacement of only 3 mm per 100 mm ("per 4") of mixture depth would be produced. It can then be seen that the reduction of thickness as a result of densification in asphalt materials laid on the road can be neglected. It then follows that the total surface rut depth will be made up of components;

i. Primarily due to horizontal or shear displacement in asphalt layers.

ii. Due to vertical compression displacement and to (a lesser extent) shear displacement in the underlying unbound layer.

It is thus clear that the primary factors controlling the susceptibility of pavement materials to permanent deformation is resistance to shear distortion in asphalt layers.

2.8 RESISTANCE OF ASPHALT CONCRETE LAYERS TO SHEAR DISTORTIONS

A recurring observation is that asphalt concrete materials become more prone to rutting in hot seasons and all established that at high temperatures asphalt materials show more distortion. Also several authors have stressed the importance of shear strength as a means of reducing rut susceptibility. (Knitht et al., 2003).

Investigations by Nijboer and Gregg, Dehlem and Rigdeu indicate that while the angle of shearing resistance is relatively independent of temperature T, and loading rate E, the cohesion intercept, C is highly sensitive to both the loading rate and temperature, reducing rapidly as the temperature increases or the loading rate reduces. While it is actually resistance to shear distortion that is required to limit rutting susceptibility, it is generally true that a particular strain modulus of a multiphase granular-base material increases as its corresponding stress resistance increases. It therefore appears that any measure that will increase the angle of sheering resistance, or inter-particle friction within an asphalt material will decrease its susceptibility to permanent deformation. (Hofmen Et Al 2018).

2.9 FAILURES IN ASPHALT CONCRETE

2.9.1 Permanent Deformation

Permanent deformation results from the accumulation of small amount of unrecoverable strain as a result of repeated loads applied to the pavement. Rutting can occur as a result of problematic subgrade, unbound base course, or hot mix asphalt. Brown et al., (2001) reported that consolidation and or lateral movement of the HMA under traffic cause permanent deformation in HMA.

Shear failure (lateral movement) of the HMA courses generally occurs in the top 100 mm of the pavement surface. However, it can run deeper if proper materials are not used. Eisenmann and Hilmer (1987) also found that rutting is caused mainly by deformation flow rather than volume change. Sousa (1994) claimed that after the initial densification, the permanent deformation of the bituminous mixture occurs due to shear loads which occur close to the surface of the pavement, in the area that confines the contact area between the tire and the pavement. These efforts increase without the occurrence of volume variations in the bituminous mixture and they are the main mechanisms of rutting development during the design life period of the pavement. Investigations have been carried out on incorporating polymer modified bitumen to improve the performance of bituminous composites (Zoorob et al., 2000). This included bitumen modification using SBS or EVA or SBR (natural and ground tire rubber) in various concentrations. Most of the results obtained from laboratory and full-scale trials demonstrate varying improvement in the performance of these modified bituminous mixes in terms of increased resistance to permanent deformation. An experimental program consisting of resilient modulus and creep-rebound testing was conducted to determine the effects of maximum aggregate size on the stiffness and resistance to permanent deformation of bituminous concrete mixtures (Newtson and Turner, 1993).

2.9.2 Fatigue Cracking

Fatigue cracking of flexible pavements is thought to be caused by the horizontal tensile strain at the bottom of the HMA layer. The failure criterion relates the allowable number of load repetitions and the tensile strain. The cracking initiates at the bottom of the HMA where the tensile strain is highest under the wheel load. The cracks propagate initially as one or more longitudinal parallel cracks. After repeated heavy traffic loading, the cracks become interconnected in a manner that resembles the skin of an alligator. Laboratory fatigue tests are performed on small HMA beam specimens. Due to the difference in geometry and loading conditions; especially rest period between the laboratory and the field, the allowable number of repetitions for actual pavements is greater than that obtained from laboratory tests. Therefore, the failure criterion may require incorporating a shift factor to account for the difference. Fatigue cracking is generally considered to be more of a structural problem than just a material problem. A number of pavement factors that have to occur simultaneously usually cause it. Obviously, repeated heavy loads must be present. Poor subgrade drainage, resulting in a soft, high deflection pavement, is the principal cause of fatigue cracking. Improperly designed and or poorly constructed pavement layers also contribute to fatigue cracking. It has been reported that fatigue cracks initiate from the bottom and migrate toward the surface. These cracks occur because of the high tensile strain at the bottom of the HMA. However, Brown et al., (2001) observed fatigue cracks to start at the surface and migrate downwards. The surface cracking starts due to tensile strains in the surface of 21 the HMA. Generally, it is believed that for thin pavements the fatigue cracking typically starts at the bottom of the HMA while, for thick pavements it starts at the HMA surface. Typically, fatigue cracking is not caused by the lack of control of HMA properties; however, these properties would certainly have a secondary effect (Brown et al., 2001)

CHAPTER THREE

METHODOLOGY

3.1 EXPERIMENTAL DETAILS

The work carried out includes;

i. Blending the aggregate to achieve desired grading

ii. Performing penetration test on the bitumen being used.

iii. Making asphalt mixes with each of the aggregate grading obtained, using binder contents ranging from 4.0% - 7.5% and then carrying out Marshal test on the laboratory specimens.

In all, three aggregate mixes were investigated and in addition S.125 and 70/80 pen. Bitumen were used with mix 1. These mixes are;

Mix 1 Well graded to limits of specifications.

Mix 2 The above mix with less filler.

Mix 3 A mix with less fines.

The aggregate grading and blending was performed in the University laboratory, while all asphalt mixes and Marshal tests on the laboratory specimens were performed in the materials laboratory of the state's Ministry of Works and Transport, Benin City.

3.1 Sources of Material

The materials for the project were obtained from various sources. The aggregates used were crushed granite, and the sizes 12mm to 16mm were obtained from state commission for Works, while the smaller aggregates were obtained from Dumez, upper Sakponba, Benin city.

The binder used in of two types; 5.123 Bitumen which was obtained fromstate commission for Works and 70/80 pen bitumen which was obtained from Dumez Asphalt plant. The filler used is Portland cement.

3.2 Mix Design

Mechanical analysis was performed on the aggregates obtained, The aggregates were then blended to meet the specification.

Specific Gravity of Mixed Aggregate (S.G.M.A)

The specific gravity of the mixed aggregate in the blend was found by determining separately the specific gravity of each aggregate in the blond and combing them according to the formula:-

$$\text{S.G.M.A} = \frac{100}{\left(\frac{W_A}{G_A}+\frac{W_B}{G_B}+\frac{W_C}{G_C}+\frac{W_D}{G_D}+\frac{W_E}{G_E}+\frac{W_F}{G_F}\right)} \qquad (3.1)$$

Where W is the percentage weight of the aggregate in the blend

G is the specific gravity of the aggregates

Compacted Density of Mixed Approrate (C.D.M.A.)

The compacted density of the mixed aggregates was obtained by compacting the dry mixed aggregate in a Marshal mould, in three layers, each layer being given 25 blow with the Marshal hummer.

The C.D.M.A was obtained from the formula:-

$$\text{C.D.M.A.} = \frac{weight\ of\ compacted\ mixed\ aggregate}{volume\ of\ container} \quad (3.2)$$

3.3 Penetration Test

The Penetration Test, also known as the Penetration Test for Bitumen, is a common laboratory test used to measure the consistency or hardness of asphaltic concrete or bituminous materials. This test provides valuable information about the asphalt's viscosity or stiffness at a specific temperature, which can be important for assessing its suitability for various applications.

Apparatus

Penetrometer: A device that consists of a needle or cone that penetrates the asphalt surface under a specified load.

Sample: A cylindrical or prismatic specimen of the asphaltic concrete.

Test Temperature: The test is often conducted at a specific temperature, typically 25°C (77°F) or 15.5°C (60°F).

Procedure

A sample of the asphaltic concrete is obtained. This sample is heated to a specified temperature to make it more workable and ensure uniformity.

The penetrating needle or cone is placed vertically on the surface of the sample. The needle is a standard size, and its weight is standardized as well.

A specified weight (100 grams) is applied to the penetrating needle or cone. This weight is allowed to rest on the asphalt surface for a specific period (5 seconds).

After the loading period, the needle or cone is allowed to penetrate the asphalt surface for a specific duration (5 seconds). The depth of penetration is measured in tenths of a millimeter or hundredths of an inch.

The penetration depth is recorded as the penetration value. The test may be repeated multiple times to ensure accuracy, and the average penetration value is then recorded.

The penetration value obtained through the test is an indication of the asphalt's consistency or hardness at the specified temperature. Lower penetration values indicate harder or more viscous asphalt, while higher values indicate softer or less viscous asphalt.

The test results can be used to classify asphaltic concrete or bituminous materials into different penetration grade categories, such as penetration-graded asphalt binders like PG 64-22 or PG 76-22. These grades are commonly used in road construction to ensure that the asphalt binder's properties are suitable for the expected environmental and traffic conditions.

3.4 The Marshal Test

The Marshall Stability Test is a common test method used to evaluate the quality and performance of asphaltic concrete or asphalt mixtures. It helps assess the suitability of an asphalt mix for use in road construction and other applications.In outline, the procedure consists of making asphalt mixes with bitumen contents ranging from 4.0% to 7.5% and measuring the stability and flow with the Marshal apparatus.

Test Specimens

i. Two specimens for each combination of aggregate and bitumen content were prepared.

ii. For each test specimen, the proportion of each aggregate type required to produce a batch that will result in compacted specimen or 24" in height into (approximately 1200 g) was weighed a steel pan.

iii. The pan was then placed in an oven and heated to a temperature of about 170°C for about two hours before taking it out.

iv. The required amount of bitumen was added into the mix and the mixing was done manually but quickly, until the aggregate was thoroughly conted by the bitumen.

v. The mixture was then placed in the Marshal mould (4" in diameter and 3" in height) and compacted on the compaction pedestal by applying 50 blows with the marshal harner (10 lb with a free fall of 18 in).

vi. The mould was then reversed and the same number of compaction blows was applied to the reverse side of the specimen.

vii. The specimen was then extracted and allowed to stand overnight at room temperature on a flat surface before weighing and testing. Testing Procedure

viii. The test specimen, approximately 2" in height was immersed in hot water bath at a temperature of 60°C for about 40 minutes.

ix. The apocinon was then loaded into the breaking head of the testing machine (Marshal Apparatus) and the assembly placed in position on the testing machine.

x. Load was then applied by means of a constant movement of the testing machine head of 2" per minute until the maximum is reached and the load decreases as indicated by the dial guage attached to the proving ring.

xi. The reading of the dial gunge attached to the proving ring was then taken and also the reading of the flow motor was noted. The stability in the maximum load developed during the test expression in pounds or kilograms. The Flow is the deformation of the sample up to tho moment when the maximum load occurs, i.e. the movement of the upper hand relative to the lower head.

The procedure for the above tost was followed in testing asphalt mixon for the four casos considered with bitumen content ranging from 4% to 7.5%

The Four Cases Considered Are:-

Mix 1 with 70/80 pen bitumen

Mix 1 with S.12 5 bitumen

Mix 2 with 70/80 pen bitumen

Mix 3 with 70/80 pen bitumen.

The stability was corrected using the correcting factors as the specimens were not exactly 2" in height.

CHAPTER FOUR

DISCUSSION OF RESULTS

4.1 ANALYSIS OF RESULTS

The results obtained from the Marshal test are stability and Flow. Having obtained the specific gravity of the mixed aggregates (S.G.M.A.) the following were then obtained:

Volume of each specimen (V)

Compacted density of the Mix (C. D. M)

Compacted density of Mixed Aggregates (C. D. M. A)

Specific gravity of Mix (S. G. M)

Voids Filled with bitumen (V. F. B)

The calculations necessary to obtain these are

$$\text{V} = \text{weight in air} - \text{weight in water ml} \quad (4.1)$$

$$\text{C.D.M} = \frac{\text{weight in air}}{(\text{weight in air} - \text{weight in water})} \quad (4.2)$$

The mean C.D.M. of the two specimens was taken as the C.D.. of the mix and was used in the subsequent calculations.

$$\text{C.D.M.A} = \frac{C.D.M}{\frac{1+B}{100}} \ \text{(g/ml)} \quad (4.3)$$

where B = bitumen content (p.h.a)

S.G.M.A.= $\frac{100+B}{\frac{100}{S.G.M.A}+\frac{B}{S.G\ of\ bitumen}}$ (g/ml)

(4.4)

V.I.M = $\frac{S.G.M-C.D.M}{S.G.M}\times 100\%$ (4.5)

C. M.A =$\frac{S.G.M.A-C.D.M.A}{S.G.M.A}\times 100\%$ (4.6)

D. F.B = $\frac{V.M.A-V.I.M}{V.M.A}\times 100\%$ (4.7)

The stiffness of a mix is defined as;

$\frac{Stability}{Flow}$

This was also calculated for all the cases considered. Graphs of stability, Flow, C.D.M., V.I.M., V.F.B. and stiffness against bitumen content (p.h.a.) were then plotted for all the cases considered.

Penetration Test

The penetration test carried out gave the results 78, 76, 80. Thus the mean value is

T2 $=\frac{(78+76+80)}{3}=78$

Therefore the bitumen tested is of penetration grade 70/80

TABLE 4.1: GRADING OF AGGREGATES USED

	AGGREGATES					
SIEVE(mm)	A	B	C	D	E	F(filler)
25						
19	100					
13.2	31.3	100				
9.5	12.4	31.3	100			
4.75			64.9	100	100	
2.36			22.4	96	84	
1.18			12.2	85	68	
36			4.1	44	43	
72					24	100
100					15	94.19
200					5	54.13

TABLE 4.2: RESULTS OF AGGREGATES BLENDING FOR MIX 1

AGGREGATE		A	B	C	D	E	F	TOTAL		GRAD	
PERCENTAGE		23	5	20	26	16	10		CUM	REQ	SAMPLE
Pass sieve	Rt on sieve										
25	19	11						11	100	100	100
19	13.2	10						11	89	88	87
13.2	9.5	2	3	7				12	78	80	77
9.5	4.75		1	8	1	2		12	66	65	61
4.75	2.36			2	3	3		8	54	53	49
2.36	1.18			2	11	4		17	46	43	43
1.18	36			1	7	3		11	29	28	29
36	72				3	1	1	5	18	18	18
72	100				1	2	4	7	13	15	14
100	200					2	5	6	6	10	10
200											

NOTE: The column for sample mix is the average of 3 different mixes.

TABLE 4.3: AGGREGATE GRADING OF THE MIXES

PERCENTAGE		MIX 1	MIX 2	MIX 3
Pass sieve	Rt on sieve			
25	19			
19	13.2	100	100	100
13.2	9.5	85	87	89
9.5	4.75	77	76	78
4.75	2.36	61	61	61
2.36	1.18	50	51	46
1.18	36	52	46	47
36	72	29	28	31
72	100	18	16	20
100	200	14	10	18
200		10	14	6

TABLE 4.4: RESULTS FROM MXI 1 WITH 70/80 PEN BITUMEN

% BITUMEN	STABILITY	FLOW	STIFFNESS	CDM	VIM	VFM
4.06	1969	9.1	216.4	2.18	13	38
4.5	2200	10.2	215.7	2.27	9	50
5	2300	12.2	133.5	2.34	6	63
5.5	2376	14.2	167.3	2.35	4	75
6	2244	14.6	153.7	2.35	4	76
6.5	2024	18.9	107.1	2.33	4	78
7	1793	20.1	89.2	2.34	3	83
7.5	1562	26.8	58.3	2.33	3	83

TABLE 4.4: RESULT FROM MIX 1 WITH S .125

% BITUMEN	STABILITY	FLOW	STIFFNESS	CDM	VIM	VFM
4.0	902	14.0	64.4	2.30	9	47
4.5	1078	16.2	66.5	2.33	6	63
5	1056	16.5	65.0	2.33	6	65
5.5	979	17.3	56.6	2.31	6	67
6	660	22.1	29.9	2.31	5	72
6.5	528	22.5	23.5	2.30	5	74
7	418	26.8	15.6	2.29	5	75
7.5						

TABLE 4.5: RESULTS FROM MIX 2 WITH 70/80 PEN BITUMEN

% BITUMEN	STABILITY	FLOW	STIFFNESS	CDM	VIM	VFM
4.0	1452	7.5	144	2.12	15	35
4.5	1793	7.7	223.3	2.20	11	45
5	1936	7.9	245	2.21	10	50
5.5	1892	9.5	144.2	22.7	7	63
6	2068	9.1	227.3	22.9	6	67
6.5	2112	11.4	105.3	2.29	5	74
7	2046	12.2	167.7	2.28	5	74
7.5	1859	14.6	127	2.26	5	75

TABLE 4.6: RESULTS FROM MIX 3 WITH 70/80 PEN BITUMEN

% BITUMEN	STABILITY	FLOW	STIFFNESS	CDM	VIM	VFM
4.0	2090	9.9	211	2.14	15	35
4.5	2200	11.4	193	2.24	10	50
5	2222	13.0	170	2.28	8	56
5.5	2208	14.6	156	2.30	7	61
6	2310	16.4	136	2.32	5	71
6.5	2200	19.3	113	2.3	5	74
7	1980	24.4	81	2.28	5	75
7.5						

4.2 VARIATIONS OF PROPERTIES OF ASPHALT CONCRETE WITH BITUMEN CONTENT

When this graph of stability, density, flow, stiffness, void in mix, and voids filled with bitumen were plotted for the first mix with 70/80 per bitumen, it was found that

1. The stability value of the mixture increases with increasing binder content to a maximum value of 2388 1b at optimum bitumen content of 5.5% (p.h.a.) and thereafter decreases rapidly.

2. The density also increases to a maximum value of 2.55 g/l at a bitumen content of 5.8% (p.h.a.) and thereafter decreases.

3. The Flow value increases an the bitumen content increases, also at the rate of increase is higher with higher bitumen content. This is to be expected in roadway, surfacing with low Flow and high stability will not deform easily but are likely to be brittle, while those with low stabilities and high Flow deform easily under traffic.

4. The stiffness of the mix also reduces with increase in bitumen content.

5. The voids in the mix decreases with increasing bitumen content until a value is reached when it begins to level off.

6. The voids filled with bitumen increases with increase in the binder content. Again the rate of increase is higher at lower bitumen content.

It is important that the voids in the mineral aggregate franc- work must be as nearly filled with bitumen as is possible. To select an optimun bitumen content for the mix, the above six graphs should be taken into account.

4.3 Effects of Hardness of Bitumen on Asphalt Mixes

The graphs obtained for Mix I with 70/80 pen Bitumen and 5.125 Bitumen were compared. S.125 gave an asphalt mix of lower stability, (In fact about half that given by 70/80 pen bitumen), higher flow and lower stiffness than the asphalt made with 70/80 pen bitumen.

4.4 Effects of Filler Content

Results obtained by testing specimens made with Mix 1 and Mix 2 but with the same bitumen (70/80 pen) were compared. Mix 1 gave higher stability, higher flow but lower stiffness. Also the highest stability for mix 2 was reached at a higher bitumen content than MIX 1. One might say that since MIX 2 takes more bitumen, from the stand point of stiffness it is better than Mix 1.

4.5 Effects of Using less Fines

Results obtained by testing specimens made with Mix 1 and Mix 3 but with the same bitumen (70/80 pen bitumen) were compared. The two mixes gave about the same stability, but Mix 3 gave higher flow and lower stiffness. Also the highest stability for mix 3 was reached at a higher bitumen content than for mix I.

4.6 Effects of the Various Parameters on the Performance of Asphalt Concrete Pavements

Asphalt concrete used as pavements is exposed to loading conditions which are different from that at which the laboratory specimens were tested. In the field, the traffic loading is intermittent, the climate conditions are far from that at which the laboratory specimens were tested, the size and shape of the specimens are quite different from that of road pavements, also in the service condition, the unbound soil beneath the pavement plays major roles on the way the asphalt pavement deforms. From all the above, it follows that, here in the tropics the major requirement for any pavement would be high stability to withstand applied traffic load and high stiffness to be able to distribute the load to the unbound soil effectively. From the stand point of fatigue type failure and durability, a mix with high bitumen content is better than that with low bitumen content, all other things being the same. From this angle, mix 2 may be selected in preference to mix 1. Since on roads, failure by cracking in fatigue is not a major failure criterion (20, 26), stability should be of major concern. Mix 1 and Mix 3 have almost the same stability (2365 lbs at bitumen content of 5.5% for mix 1 and 2310 lbs at bitumen content of 65% for mix 3) also mix 3 has a higher voids content and a higher flow. It might be said then that Mix 3 would give a better asphalt mix for road pavement than mix 1.

CHAPTER FIVE

CONCLUSION AND RECOMENDATIONS

5.1 CONCLUSION

From the tests carried out, it is concluded that: The viscosity of the bitumen used affects the stability, Flow value and stiffness of the specimens as depicted in figures 4 to 5 It is soon that the soften the bitumen, the lover the values of stability and stiffness of the mix and also the higher the flow value.

There is an optimum bitumen content corresponding to any particular mix as can be soon from figures 4 to 5. Reduction in filler content lowers the stability and stiffness of the mixes and increases the voids content of the specimens. Mix 3 which is a gap graded mix would be preferred to other mixes, if all the desirable qualities of good pavement is taken into consideration.

5.2 RECOMENDATIONS

After fully considering the results obtained from the tests and what has been discussed under literature review, it is suggested that Hard bitumen should be used in Nigeria for the following reasons.

(a) It has a higher softening point and hence will not soften under the high temperatures in Nigeria.

(b) It gives high stability mixtures. Brittleness will not constitute a problem here because at 20°c which in about the lowest temperature here, the bitumon is still vinooun enough not to exhibit brittleness

Asphalt materials of high stability and stiffness should be used, this reduces the shear deformation which in a major failure criteria of asphalt pavement here in Nigeria, this is manifested by rut formation.

3. In Southern part of Nigeria where there in heavy rainfall, asphalt material should be preferred, because of its impermeability, entry of rainwater is prevented and hence the base and other underlying soils are not weakened by rainwater.

4. Since asphalt concrete is flexible, the natural soil and other unbound as materials underneath it must be strong enough to withstand the stress transmitted to it, because any failure of the soils will be reflected at the surfacing asphalt.

5. The use of gap graded nix should be tried on our roads (even if on an experimental basis) instead of the conventional dense graded mix.

6. Laboratory study of asphalt materials coupled with extensive field study of the behaviour of asphalt pavement in Nigeria should be started no an to determine a mixture that is is most suitable for Nigerian roads. This important because the climate and the traffic conditions in Nigeria are quite different from those in Europe or in Canada, because of this it would not

be expected that a mixture designed to suite the conditions in Europe or Canada would suite the conditions that prevail in Nigeria.

REFERENCES

AASHTO - American Association of State Highway and Transportation Officials, 2000, T304 “Uncompacted Void Content of Fine Aggregate.”

AASHTO - American Association of State Highway and Transportation Officials, 2002, T315 “Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR).”

AASHTO - American Association of State Highway and Transportation Officials, 2003, T322 “Determining the Creep Compliance and Strength of Hot-Mix Asphalt (HMA) Using the Indirect Tensile Test Device.”

AASHTO - American Association of State Highway and Transportation Officials, 2003, TP62 “Determining Dynamic Modulus of Hot-Mix Asphalt Concrete Mixtures.”

ASTM - American Society for Testing and Materials, 2006, D1073 “Standard Specification for Fine Aggregate for Bituminous Paving Mixtures.”

ASTM - American Society for Testing and Materials, 2004, D242 “Standard Specification for Mineral Filler for Bituminous Paving Mixtures.”

ASTM - American Society for Testing and Materials, 2000, D692 “Standard Specification for Coarse Aggregate for Bituminous Paving Mixtures.”

ASTM - American Society for Testing and Materials, 2001, D5821 “Standard Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate.”

Anderson, D. A, Christensen, D. W., Bahia, H. U., Dongre, R., Sharma, M. G., Antle , C. E., & Button, J. (1994). Binder Characterization and Evaluation - Volume 3: 127 Physical Characterization. Report SHRP-A-369, Strategic Highway Research Program, National Research Council, Washington, D.C. 10.

Bari, J., & Witczak, M. W. (2005). Evaluation of the Effect of Lime Modification on the Dynamic Modulus Stiffness of Hot-Mix Asphalt. In Transportation Research Record, TRB, 1929, 10-19. National Research Council, Washington, D.C. 11.

Baumgarten, K., 2007, Personal Contact, Department of Geosciences - UNL. 12. Beason, J., 2006, Personal Contact, NDOR aggregates lab.

Bettenhausen, R., 2006, Personal Contact, IT Business Systems Analyst - NDOR Project Scheduling & Program Management.

Brown, E. R., Mallick, R. B., Haddock, J. E., & Bukowski, J. (1997) Performance of Stone matrix Asphalt (SMA) Mixtures in the United States. Report 97-1, National Center for Asphalt Technology (NCAT), Auburn.

Brown, E. R., Kandhal, P. S., & Zhang, J. (2001) Performance Testing for Hot Mix Asphalt (Executive Summary). Report 01-05A, National Center for Asphalt Technology (NCAT), Auburn.

Buchanan, M. S. (2000) Evaluation of the Effect of Flat and Elongated Particles on the Performance of Hot Mix Asphalt Mixtures. Report 00-03, National Center for Asphalt Technology (NCAT), Auburn.

Castelo Branco, V. T. F. (2004). Caracterização de Misturas Asfálticas Com o Uso de Escória de Aciaria como Agregado. (Characterization of Hot Asphalt Mixes using Steel Slag as Aggregate). Master Thesis approved by the Universidade Federal do Rio de Janeiro (Federal University of Rio de Janeiro). Rio de Janeiro, Brazil. 128

Chehab, G.R., & Kim, Y. R. (2007) Inter-Relationships among Asphalt Concrete Stiffnesses. In-Press, Chapter 9, ASCE Book, Modeling of Asphalt Concrete, McGraw Hill.

Choubane, B., Page, G. C., & Musselman, J. A. (2000) Suitability of Asphalt Pavement Analyzer for Predicting Pavement Rutting. In Transportation Research Record, TRB, 1723, 107-115, National Research Council, Washington, D.C.

Chowdhury, A. T., Grau, J. D. C., Button, J. W., & Little, D. N. (2001) Effect of Gradation on Permanent Deformation of Superpave Hot-Mix Asphalt.

Munday, M.; Reynolds, L.; Roberts, A. Re-Appraising ‘in-Process’ Benefits of Strategic Infrastructure Improvements: Capturing the Unexpected Socio-Economic Impacts for Lagging Regions. Transp. Policy 2023, 134, 119–127.

Mohmand, Y.T.; Mehmood, F.; Mughal, K.S.; Aslam, F. Investigating the Causal Relationship between Transport Infrastructure, Economic Growth and Transport Emissions in Pakistan. Res. Transp. Econ. 2021, 88, 1009

Pradhan, R.P.; Arvin, M.B.; Nair, M. Urbanization, Transportation Infrastructure, ICT, and Economic Growth: A Temporal Causal Analysis. Cities 2021, 115, 103213.