USING IRON ORE TAILINGS AS PARTIAL REPLACEMENT OF FINE AGGREGATE IN ASPHALT CONCRETE PRODUCTION

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INTRODUCTION

Partial replacement has been in existence since time immemorial and it came to being as a means of sourcing alternative locally available materials to substitute the already available and exorbitant ones such as cement, lime and bitumen. Besides the cost effectiveness of using alternative materials in the production of asphalt concrete, it also brings about environment enhancement by taking care of some materials that would have been a threat to the environment. As the world is going green, there is every need for us to ensure that we promote this cause and this study is aimed at achieving this by introducing iron tailings as a partial replacement of fine aggregate in asphalt concrete.

With millions of tons of crushed aggregate used each year in Nigeria in road construction, significant environmental impact is caused. Annually, though we do not have an exact amount of iron ore tailings that is produced in the country, there are millions of tons of iron ore tailings that are lying in different places in the country, serving as environmental threat to communities. It is therefore necessary to evaluate the potential utilization of iron ore tailing in asphalt mixture which will greatly reduce the environmental impact of the waste material and produce more sustainable roads as well.

Road network in Nigeria stands at about 200,000km, showing that highways are conspicuous infrastructure that cannot be ignored and introducing an alternative material that would be able to improve the road and also solve environmental issues is an interesting venture.

Cost has to be considered when spending funds dedicated to road construction therefore quality paving products at reasonable price with maximized service life are very essential to any highway engineer. With limited funding and increased budget pressures in the country,

providing value engineered asphalt pavements is critical toward supporting the economy of Nigeria.

Tailings are the materials left over after the process of separating the valuable fraction from the worthless fraction of an ore. Therefore, iron tailings are fraction obtained from the processing of iron ore. The composition of tailings is directly dependent on the composition of the ore and the process of mineral extraction used on the ore.

The mineral processes that are involved in the eventual emanation of iron tailings include crushing, grinding, concentration, dewatering, leaching and heating.

STATEMENT OF PROBLEM

The manufacture of asphalt is very expensive and it contributes to the high cost of road construction in Nigeria. Introducing alternative materials that might reduce the cost of producing asphalt can bring about reduction in the total cost incurred in the building of roads.

Large volumes of tailings deposits and waste rock piles are usually dumped as mining wastes. They may cause air pollution, water pollution and land degradation problems. These wastes can affect the environment through some intrinsic ways which may include its chemical and mineralogical composition, its physical properties, its volume and the surface it occupies etc. (Sunil Kachhap, 2009).

Iron ore tailing is an industrial waste product of mining obtained from the extraction and processing of iron ores. Iron ores tailing cover a huge land as a result, it constitute an environmental hazard as it becomes difficult for it to be disposed.

Iron ore tailing as a kind of waste product after ore dressing is one of the major industrial solid waste which not only cover huge land and pollute environment but also give rise to security risk, therefore, there is need for proper disposal of iron ore tailings. The comprehensive utilization of iron ore tailings has been studied by many authors but there is also need for it to be studied systematically when it comes to introducing it into asphaltic mixture. Ugama (2013) in an on-going research shows that the iron ore tailing at Itakpe, though with less content of calcium oxide, has very similar oxide composition with ordinary Portland cement.

JUSTIFICATION OF THE STUDY

Technology in recent time has turn its search light in the direction of waste management as the environment is becoming more and more depleted and vulnerable due to the activities of man. The conventional mineral filler (cement) being used in the manufacture of asphalt contributes a lot in making asphalt very expensive. When the suitability of using iron tailings is confirmed and the optimal amount to be used as partial replacement of conventional filler is obtained, it will go a long way in reducing the cost of asphalt and will solve the issue of disposal of iron ore tailings to some extent.

AIM AND OBJECTIVES

The aim of this research is to evaluate the use of iron ore tailings aspartial replacement of filler in the production of asphalt concrete for highway construction.

The objectives of this study are as follows

i. To determine the particle size gradation of the iron ore tailing treated bitumen for use in the asphalt mixture.

ii. To determine the stability of asphalt produced by partially replacing filler with iron ore tailing

iii. To determine the flow of asphalt produced by partially replacing filler with iron ore tailing.

iv. To determine the constituent of the material (iron tailing).

v. To determine the suitability of iron tailing as mineral filler in asphalt mixture as stipulated in AASHTO M17 and the Nigerian General specifications for Roads and Bridges, volume II- Federal Ministry of Housing.

vi. To subject the samples briquettes to Marshall testing and compare with standards.

LITERATURE REVIEW

The term *bituminous materials* are generally used to denote substances in which bitumen is present or from which it can be derived [Goetz and Wood, 1960]. *Bitumen* is defined as an amorphous, black or dark-colored, (solid, semi-solid, or viscous) cementitious substance, composed principally of high molecular weight hydrocarbons, and soluble in carbon disulfide. For civil engineering applications, bituminous materials include primarily *asphalts* and *tars*. Asphalts may occur in nature (natural asphalts) or may be obtained from petroleum processing (petroleum asphalts). Tars do not occur in nature and are obtained as condensates in the processing of coal, petroleum, oil-shale, wood or other organic materials. *Pitch* is formed when a tar is partially distilled so that the volatile constituents have evaporated off from it. *Bituminous mixtures (Asphalt concrete)*are generally used to denote the combinations of bituminous materials (as binders), aggregates and additives.

In recent years, the use of tars in highway construction has been very limited due to health and environmental concerns with the possible emission of hazardous flumes when tars are heated posing a threat to those handling the material and the environment.

The modern use of asphalt for road and street construction began in the late 1800s and grew rapidly with the emerging automobile industry. Since that time, asphalt technology has made giant strides so that today the equipment and techniques used to build asphalt pavement structures are highly sophisticated. One rule that has remained constant throughout asphalt's long history in construction is this: A pavement is only as good as the materials and workmanship that go into it. No amount of sophisticated equipment can make up for use of poor materials or poor construction practices.

Types of Bituminous Materials Used in Pavement Construction

Asphalt cement is asphalt which has been specially refined as to quality and consistency for direct use in the construction of asphalt pavements. An asphalt cement has to be heated to an appropriate high temperature in order to be fluid enough to be mixed and placed.

Cutback asphalt is liquid asphalt which is a blend of asphalt and petroleum solvents (such as gasoline and kerosene). A cutback asphalt can be mixed and placed with little or no application of heat. After a cutback asphalt is applied and exposed to the atmosphere, the solvent will gradually evaporate, leaving the asphalt cement to perform its function as a binder.

Emulsified asphalt(or *asphalt emulsion*) is an emulsion of asphalt cement and water that contains a small amount of emulsifying agent. In a normal emulsified asphalt, the asphalt cement is in the form of minute globules in suspension in water. An emulsified asphalt can be mixed and applied without any application of heat. After an asphalt emulsion is applied, sufficient time is required for the emulsion to break and the water to evaporate to leave the asphalt cement to perform its function as a binder. In inverted *emulsified asphalt*, minute globules of water are in suspension in liquid asphalt, which is usually cutback asphalt. Inverted asphalt emulsions are seldom used in pavement applications.

Asphalt composition

Aggregates

Recognition of aggregate properties and characteristics will assists in evaluating the different aggregates used in highway construction.

1) Related physical properties

2) Chemical properties

3) General field characteristics of these aggregates.

Aggregate particles have certain physical and chemical properties which make the aggregate acceptable or unacceptable for specific uses and conditions.

PHYSICAL PROPERTIES

The physical properties of aggregates are those that refer to the physical structure of the particles that make up the aggregate.

ABSORPTION, POROSITY, AND PERMEABILITY

The internal pore characteristics are very important properties of aggregates.

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 particle's ability to take in a liquid.

Porosity is a ratio of the volume of the pores to the total volume of the particle.

Permeability refers to the particle's ability to allow liquids to pass through. If the rock pores are not connected, a rock may have high porosity and low permeability.

SURFACE TEXTURE

Surface texture is the pattern and the relative roughness or smoothness of the aggregate particle. Surface texture plays a big role in developing the bond between an aggregate particle and a cementing material. A rough surface texture gives the cementing material something to grip, producing a stronger bond, and thus creating a stronger hot mix asphalt or Portland cement concrete.

Surface texture also affects the workability of hot mix asphalt, the asphalt requirements of hot mix asphalt, and the water requirements of Portland cement concrete.

Some aggregates may initially have good surface texture, but may polish smooth later under traffic. These aggregates are unacceptable for final wearing surfaces. Limestone usually falls into this category. Dolomite does not, in general, when the magnesium content exceeds a minimum quantity of the material.

STRENGTH AND ELASTICITY

Strength is a measure of the ability of an aggregate particle to stand up to pulling or crushing forces. Elasticity measures the "stretch" in a particle. High strength and elasticity are desirable in aggregate base and surface courses. These qualities minimize the rate of disintegration and maximize the stability of the compacted material. The best results for Portland cement concrete may be obtained by compromising between high and low strength, and elasticity. This permits volumetric changes to take place more uniformly throughout the concrete.

DENSITY AND SPECIFIC GRAVITY

Density is the weight per unit of volume of a substance. Specific gravity is the ratio of the density of the substance to the density of water.

The following chart illustrates these relationships for some common substances.

Table showing typical values of specific gravity and density of some materials.

Typical Values		
Substance	**Specific Gravity**	**Density (lb/ft3)**
Water	1.0 (73.4°F)	62.4 lb/ft3 (73.4 °F)
Limestone	2.6	165 to 170 lb/ft3
lead	11.0	680 to 690 lb/ft3

The density and the specific gravity of an aggregate particle is dependent upon the density and specific gravity of the minerals making up the particle and upon the porosity of the particle. These may be defined as follows:

1) All of the pore space (bulk density or specific gravity)

2) Some of the pore space (effective density or specific gravity)

3) None of the pore space (apparent density or specific gravity)

Determining the porosity of aggregate is often necessary; however, measuring the volume of pore space is difficult. Correlations may be made between porosity and the bulk, apparent and effective specific gravities of the aggregate.

As an example, specific gravity information about a particular aggregate helps in determining the amount of asphalt needed in the hot mix asphalt. If an aggregate is highly absorptive, the aggregate continues to absorb asphalt, after initial mixing at the plant, until the mix cools down completely. This process leaves less asphalt for bonding purposes; therefore, a more porous aggregate requires more asphalt than a less porous aggregate. The porosity of the aggregate may be taken into consideration in determining the amount of asphalt required by applying the three types of specific gravity measurements.

AGGREGATE VOIDS

There are aggregate particle voids, and there are voids between aggregate particles. As solid as aggregate may be to the naked eye, most aggregate particles have voids, which are natural pores that are filled with air or water. These voids or pores influence the specific gravity and absorption of the aggregate materials.

The voids within an aggregate particle should not be confused with the void system which makes up the space between particles in an aggregate mass. The voids between the particles influence the design of hot mix asphalt or Portland cement concrete.

HARDNESS

The hardness of the minerals that make up the aggregate particles and the firmness with which the individual grains are cemented or interlocked control the resistance of the aggregate to abrasion and degradation. Soft aggregate particles are composed of minerals with a low degree of hardness. Weak particles have poor cementation. Neither type is acceptable. The Mohs

Hardness Scale is frequently used for determination of mineral hardness. Although there is no recognizable specification or requirement which pertains to Mohs Hardness Scale, the interpretation, concept, and use of this scale is useful for the field identification of potentially inferior aggregates.

PARTICLE SHAPE

The shape of the aggregate particles affects such things as:

1) The asphalt demands of hot mix asphalt

2) The workability and the strength of both Portland cement concrete and asphalt pavements

The best aggregates to use for strength are crushed stone or crushed gravel.

Crushed aggregate have irregular, angular particles that tend to interlock when compacted or consolidated.

The crushed stone or crushed gravel aggregate make the asphalt or concrete mix somewhat difficult to place. To improve the workability, many mixes contain both angular and round particles. The coarse aggregate particles are usually crushed stone or crushed gravel, and the fine aggregate particles are usually natural sand. The Standard Specifications detail the requirements for crushed materials for various uses.

COATINGS

Coating is a layer of substance covering a part or the entire surface of an aggregate particle. The coating may be of natural origin, such as mineral deposits formed in sand and gravel by ground water, or may be artificial, such as dust formed by crushing and handling.

Generally when the aggregates are used in hot mix asphalt or Portland cement concrete mixes, the aggregates are required to be washed to remove the coating (contaminant) left on the particles. The coating may prevent a good bond from forming between the aggregate surfaces and the cementing agent. The coating could even increase the quantity of bonding agent required in the mixture. If the quantity of the coating varies from batch to batch, undesirable fluctuations in the consistency of the mix may result. Deposits containing aggregates which display a history of coating problems require decantation.

UNDESIRABLE PHYSICAL COMPONENTS

Particles with undesirable physical characteristics include but are not limited to the following:

1) Non-durable soft or structurally weak particles

2) Clay lumps or clay balls

3) Flat or elongated particles

4) Organic matter contaminants

4) Lightweight chert

COMPOSITION

The chemical composition of aggregate is significant in determining the difference between limestone and dolomite. Limestone is a rock consisting mainly or wholly of calcium carbonate and has a tendency to polish smooth under traffic. Therefore, limestone is limited to use in low traffic-volume HMA surface courses. Dolostone under traffic maintains a

higher-friction, skid-resistant surface and is used on higher traffic volume locations. Dolostone is a carbonate rock which consists largely of calcium magnesium carbonate.

The word dolomite is the mineral calcium magnesium carbonate Ca Mg (Co3)2.

An elemental magnesium (Mg) content test can be used to determine if a rock source is dolomitic. Elemental magnesium content of 10.3 percent or above is required for dolomite aggregates.

Some aggregates have minerals that are subject to oxidation, hydration, and carbonation. These properties are not particularly harmful, except when the aggregates are used in Portland cement concrete. As might be expected, iron sulfides, ferric and ferrous oxides, free lime, and free magnesia in industrial products and wastes are some of the common substances. Any of these substances may cause distress in the Portland cement concrete and give the concrete an unsightly appearance.

REACTIONS WITH ASPHALT AND CEMENT

There are several types of substances found in mineral aggregates which may have a negative effect on the cementing and overall performance qualities of asphalt and cement. Most are rarely significant but various organic substances may retard hardening, reduce strength development or cause excessive air entrainment in Portland cement concrete. These organic substances include, but are not limited to, mica, iron oxide, lightweight chert, shale, coal, and lignite.

SURFACE CHARGE

Aggregate particle surfaces possess either positive or negative electrical charges. Limestone and dolostone generally have a high affection for liquid asphalt.

GENERAL CHARACTERISTICS

Aggregates have three primary uses in highway construction:

1) As compacted aggregates in bases, sub- bases and shoulders

2) As ingredients in hot mix asphalt

3) As ingredients in Portland cement concrete

Aggregates may also be used as special backfill material, riprap, mineral filler, and other less significant uses.

COMPACTED AGGREGATES

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 gradation requirements, the aggregates are required to also possess the strength to carry and transmit the applied loads.

Aggregates are sometimes used to make up the entire pavement structure. In this type of pavement, aggregates are placed on the natural soil to serve as a base course and surface course. Again, the primary requirement is the gradation.

In many instances, compacted aggregates are also used to construct roadway shoulders and berms. In these applications, gradation and stability are very important.

AGGREGATE FOR HOT MIX ASPHALT

The use of aggregate in hot mix asphalt is in a number of different ways. In all cases the aggregates used should meet five requirements:

1) Strong, tough and durable

2) The ability to be crushed into bulky particles, without many flaky particles, slivers or pieces that are thin and elongated

3) Low porosity

4) Low permeability

5) Correct particle size and gradation for the type of pavement

AGGREGATES FOR PORTLAND CEMENT CONCRETE

There are many uses of Portland cement concrete in highway construction. Some of the major uses of aggregates are in rigid-pavement slabs, bridges, concrete barriers, sidewalks, curbs, slope walls, and other structures. Aggregates in Portland cement concrete are required to always be physically and chemically stable. Other factors to be considered include:

1) The size, distribution, and interconnection of voids within individual particles

2) The surface character and texture of the particles

3) The gradation of the coarse and fine aggregates

4) The mineral composition of the particles

5) The particle shape

6) Soundness abrasion resistance

7) Water absorption

OTHER AGGREGATES

There are other uses for aggregates in highway construction. The requirements are somewhat different from the ones already discussed; however, in most cases, gradation as a controlling factor is common to all applications.

Mineral Filler

The earliest study of mineral filler dates back to 1931, when the Detroit Edison Company compared the physical properties of fly ash with those of limestone dust. Mineral fillers are finely divided substances, which are insoluble in bitumen but can be admixtures by modifying its consistency and mechanical properties. They are usually mineral materials. Organic fillers such as wood flour or cork dust are rarely used as filler bitumen. Typical mineral filler are limestone dust, cement hydrated lime, slate dust, pulverised fuel ash, talc, silica and asbestos. Non-fibrous fillers usually have a particle size of less than 75μm.

According to Zimmer and Frank (1970), the general effect of adding filler to bitumen is to make it harder and stiffer and the extent of this hardening or stiffening effect depends on the amount of filler added and on its particle shape, size and grading. Normal fillers such as limes or slate dust produce the least effect. Fillers with plate-like particles such as are intermediate and fibrous like asbestos show the greatest effect for a given concentration of filler.

Hydrated lime is much more effective than limestone. The volume percentage of filler in bitumen must be calculated from the weight and density of the mineral and not estimated from the volume of filler added. For normal fillers, the effect of the filler concentration for concentrations up to about 40% volume of the mixture. For fibrous fillers, the upper limit for proportional behaviour is much lower.

Mineral fillers are often used in asphalt concrete mixtures to supply the fines, as they are very important in producing dense-graded strong asphalt concrete (Atkins, 1997).

A laboratory study conducted by Chan, (1996) and Calvin Fong proved that fly ash as a mineral filler is highly beneficial in terms of strength and stripping resistance. The improvement on stripping resistance increase significantly with the increase of fly ash content (Chan, 1996). In addition, Sankaran and Rao (1973) conducted research based on 2% fly ash filler content, and found out that mixes with 2% fly ash and 5% asphalt obtained the highest stability, and retained strength after immersion.

Petersen (1987) concluded that hydrated lime is a superior anti-stripping agent in Hot mix asphalt. It reacts with the aggregates in the system to strengthen the aggregate-asphalt bonding. At the same time, lime reacts with the highly polar molecules (water-soluble soaps) at the asphalt binder that promotes stripping. When lime reacts with these molecules, they have a tendency to form insoluble salt that is not favourable to water attraction.

The physical-chemical mechanism of stripping are not fully understood. Detachment, pore water pressure, and asphalt-aggregate properties have been proposed to define the cause of water susceptibility problems. More detailed study is needed to fully understand the basic mechanism of this problem. However, traditional lime material is a proven anti-stripping agent (Little, 2001).

TYPES OF MINERAL FILLERS

Mineral filler is produced at the production stage by crushing and screening of the material passing the number 200 sieve (less than 75µm). Mineral filler that is finer than the thickness of asphalt film will make the asphalt binder more mastic. Many researchers have proven that sufficient amount of mineral filler replacement will enhance pavement performance by stiffening the asphalt binder. Laboratory studies have shown that mineral filler in asphalt mixtures could achieve similar properties of hot mix asphalt with hydrated lime. It is believed that the gradation, particle shape, size and texture of the mineral filler have influences on hot mix performances.

Hydrated lime

Hydrated lime is a traditional and popular material used in the asphalt industries with many associated benefits. Many studies have been conducted to evaluate the performance of the asphalt binder with the use of hydrated lime. It is important to understand why hydrated lime is so effective in hot mix asphalt. Highway material researchers have been investigating the use of by-product materials as filler in asphaltic concrete mixtures to replace the traditional asphalt mixes with hydrated lime in order to reduce production costs.

Petersen's (1987) reported that the chemical reaction between the calcium oxide (CaO) found in hydrated lime and the polar molecules in the asphalt mix reduce the oxidation and aging of the asphalt binder. When the calcium hydroxide reacts with the polar molecules, the asphalt binder is inactive with the environment. The pavement structure remains flexible for longer service life than without lime. The flexibility given by hydrated lime reduces the chance of fatigue and low temperature.

Low temperature cracking

As reported by Johannson (1998), the addition of 20% hydrated lime (by weight of asphalt) would significant increase the creep stiffness. However, the physical hardening of the binder did not increase. This is considered as a positive effect at low temperatures since it reduces fracture potentials (Little, 2001).

Lime fillers do not impact the binder's relaxation rate at low temperatures while increasing its low temperature stiffness and fracture toughness (Lesueur et al, 1998).

The age-hardening effect associated with hydrated lime is found more at high temperature than at low temperature conditions.

Moisture susceptibility

Laboratory and field tests have been conducted, and proved that the use of hydrated lime in hot mixes has significant reduction in moisture susceptibility, improved asphalt-aggregate bonding, and improved water-induced damage resistance (Little, 2001).

Field study

A field study was conducted by Jones (1997) that concluded that while the viscosity of the asphalt binder was reduced compared to a 'No Additive' mix, the hardening effect stabilized with hydrated lime after eight years of aging time, as illustrated in Figure 10. Similar research was carried out at Western Research Institute and found that the hardening effect of the asphalt could be reduced by hydrated lime (Petersen et al., 1987). A minimum of one percent hydrated lime is needed to achieve reduction of age hardening.

Fly ash

Fly ash was found to have positive effects on hot mix asphalt as mineral filler. Fly ash is a glassy, amorphous structured material created after the combustion process of coal at a power plant. It is commonly used in asphalt mixes as an anti-stripping additive, as well as an asphalt extender due to its particles' fineness (Suheibani, 1986). The performance properties of fly ash in asphaltic concrete mixtures vary by the amount lf lime present. Fly ashes with low calcium content may not have significant improvements in its physical performance of the asphalt specimens. However, fly ashes with high calcium content shows significant improvements in retain strength and asphalt stripping under laboratory conditions.

Fly ash in asphalt mixtures

Fly ash has been used as mineral filler in hot mix asphalt mixtures. Mixtures with 5% (by weight of aggregate) fly ash has compatible mix design properties with mixtures containing hydrated lime and lime stone dust (Huang, 2006). It has been shown to have comparable physical properties to lime stone dust with good void filling and water resistance characteristics, which make it an excellent anti-stripping agent (Zimmer, 1970).

A study on fly ash as mineral filler was conducted at the North Dakota State University, and the results were compared with mixes containing hydrated lime and crusher dust. Mixes with fly ash has retained stability and provided excellent ant-stripping characteristics (Carpenter, 1952).

Further confirmation of the anti-stripping properties of fly ash was reported by Rosener(1982), where two types of fly ash (Class C and Class F) were utilized on hot mix

asphalt mixtures. All mixes with fly ash showed significant improvement in retained stability and immersion Marshall Stability results. Galloway (1980) observed that the use of fly ashes as mineral filler retards the rate of hardening in asphalt binder. At the same time, it was found that fly ash with high lime content indicated excellent anti-stripping results with polish-susceptible aggregates. Low calcium content fly ash may not have a significant influence on pavement performance. Fly ash with high calcium content is believed to be influential in pavement performance, especially to prevent asphalt stripping.

Workability of hot mix with fly ash

Galloway (1980) prove that the predominantly spherical shape and particle size of fly ash particles lead to significant improvement on compaction of hot mix asphalt. Mixes with fly ash had a greater workability index compared to conventional hot mix. Galloway (1980) suggested that mixes with fly ash required less energy at the mixing and compaction stages, by allowing temperatures reductions to as low as 110^{o}c and 85^{o}c respectively without affecting the pavement performance and properties.

Iron ore: organized mining began in 1903 when the Mineral Survey of the Northern Protectorates was created by the British colonial government. A year later, the Mineral Survey of the Southern Protectorates was founded. By the 1940's, Nigeria was a major producers of tin, columbite and coal. Presently, there is significant deposit of iron ore at Itakpe hills in Kogi state, North central Nigeria with the mining company having the capacity to produce 5.5 million tonnes per year. Proven iron ore reserve are at least 200 million tonnes in the region. Other major sedimentary iron deposit is found in Nupe basin, Sokoto basin and Enugu. In Nigeria, 50 thousand metric tons of iron ore was produced in 2009.

Blast Furnace Slag filler

Granulated Blast Furnace Slag (GBFS) is an active material commonly used as a supplementary cementitious material in concrete applications. It is a glassy material with a particle shape, size and texture dependent on the chemical composition and purification process. Variability during the purification process can directly lead to low consistency in its physical properties, and hot mix asphalt containing Blast Furnace Slag. The un-combusted particles in the Blast furnace Slag may lead to future stripping problems during the pavement life.

Portland cement

Portland cement (PC) is a combination of hydraulic calcium silicates that is widely used in asphalt mixes. The performance and properties of the PC are controlled during the manufacturing stage with appropriate proportions of calcium, silica, alumina, and iron components (Portland Cement Association, 2002). Studies have proven that PC greatly contributes to anti-stripping of pavement. Asphalt mixes with PC filler significantly improves the Marshall properties, including stabilities and flow (Aljassar, 2004). Ramzi and Amer (2002) reported that all mix design properties (air void, Marshall stability, flow, Voids Mineral Aggregate, and Voids Filled with Asphalt) meets the minimum specifications for both surface and base course. Also, Ramzi and Amer (2002) suggested that the optimum percentage of PC should not exceed 5% by weight of the aggregate. Any percentage higher would produce an uneconomical mix with higher asphalt content.

Mineral filler mixes Vs. conventional mixes

Reusing mineral filler in asphalt mixes is a worldwide trend. Mineral fillers were originally added to reduce air voids in HMA mixtures. However, fillers were else found to extend the asphalt binder, stiffen the asphalt binder, or both (NCHRP). The binder modification occurs by adding the filler to the asphalt concrete matrix.

Asphalt mixes with additional mineral filler generally have greater performance, especially in Indirect Tensile Strength (ITS) value and improvements on the bonding of aggregate-asphalt binder in the pavement matrix. Kandhal and Parker (1999) concluded the influence of HMA properties with filler were as follows:

1. Depending on the particle size of the filler, it can act as an extender of the asphalt binder. All asphalt extender usually causes flushing and rutting in many cases. Reduction of asphalt cement is a common practice to prevent pavement bleeding.
2. Certain fillers make HMA mixtures susceptible to moisture damage. The stripping of HMA mixes is closely related to the properties of the filler-asphalt combination.
3. Certain fillers have significant effect on the asphalt binder. The stiffening effect of the asphalt binder caused in association with the filler can seriously affect pavement performance.

Advantages of filler in asphalt mixes

Mineral filler plays an important role in the performance of hot asphalt mixes. In general, an asphalt mix with mineral filler has the following advantages:

1. A substantial amount of limestone dust could be replaced by mineral filler to make it an economically feasible alternative (Khatri, 1993).

2. Mineral filler mixes provide essentially equal or better performance compared to conventional hot mix asphalt concrete (Khatri, 1993).
3. The same equipment that is used for mixing, placing and compacting with a conventional hot mix is applicable to an asphalt mix with mineral filler.
4. Mineral filler with high lime (CaO) content has significant improvements on indirect tensile strength and tensile strength ratio.
5. A successful mix with mineral filler will enhance asphalt and aggregate bonding which provides high stripping resistance.
6. Certain mineral fillers act as asphalt extenders that reduce the amount content necessary for optimum asphalt content, thereby generating an economical mix.
7. Mixes with mineral fillers containing hydrated lime tend to have higher retained strength and Marshall stability when compared to normal conventional mixes (Ahmad, 2004).
8. Mineral filler replacement mixes can be produced with available materials and Superpave equipment.
9. Mixtures with 5% filler replacement meet all Marshall Design properties, including stability, flow, VMA, and VFA.
10. With all filler types containing high lime (CaO) content, the asphalt penetration generally decreased as filler content increased (Ramzi, 2001).
11. With all filler types containing high lime (CaO) content, the ductility decreased as the filler content increased (Ramzi, 2001).
12. No environmental hazards are expected as a result of using mineral filler as fine replacement. (Khatri, 1993).
13. Filler stiffens the asphalt binder to prevent rutting and fatigue cracking (Little, 2001).

14. Mineral filler improves short and long-term aging by altering oxidation kinetics (Little, 2001). Increasing the filler content in the asphalt binder does not change the shear susceptibility of binder samples regarding long-term aging hardening by oxidation and heat (Huang and Zeng, 2006).

Features to be considered for mineral replacement mixes include:

1. Substitution of 5% filler replacement is the optimum value used in asphalt mixes. Mixes with more than 5% filler would require more asphalt binder in the mixture, which generates an uneconomical mixes (Ramzi, 2001).
2. A mastic mix may be presented when filler replacement is greater than 5%.
3. Mixes with mineral filler are usually tender and difficult to compact under hot weather conditions.
4. Mineral filler materials are typically dusty materials, which generate more dust during the production stage.
5. Mixes with mineral filler, such as slag, might cause rougher surfaces in a full depth pavement system (Khatri, 1993).
6. Optimum asphalt content and volumetric properties vary due to the percentage of different types of mineral filler.
7. Mineral fillers with rough particle textures increase the stiffening of the mixture and become more mastic.

INTERNAL STRUCTURE OF ASPHALT CONCRETE MIXTURES AND OTHER COMPOSITES

The internal structure of an asphalt concrete mixture refers to the content and special distribution of asphalt, aggregates and air-voids. The internal structure of the mixture is dictated by the proportions and properties of its constituent materials and method of

compaction. It is well recognized that the internal structure of an asphalt mixture plays a significant role in influencing the mechanical properties and the resistance of the mixture to major distresses including rutting, fatigue cracking, thermal cracking and low temperature cracking. Most mixture design methods recognize the importance of internal microstructure by imposing requirements for aggregate size, gradation, shape, density during compaction, and volumetrics.

METHODOLOGY

For asphalt mixture, major materials needed include bitumen, aggregates and filler (fines). The aggregate comprises of fine and coarse aggregates. Each of this particular material has specific role it plays in the properties of the asphalt that would be produced at the end of the mix.

Materials that would be used in the study includes bitumen, coarse aggregate, fine aggregate, quarry dust and iron ore tailings. The bitumen would be obtained from KRPC Kaduna, and the laboratory test to be conducted on it include penetration test (BS 2000 - 49), ductility test (ASTM D113) and specific gravity test. The coarse aggregate would be sourced from PW quarry site and laboratory test to be conducted on the coarse aggregate include sieve analysis (BS 1377, [1.2]), aggregate crushing value test (BS 812), aggregate impact value test (BS 812) and specific gravity test. Fine aggregate would be sourced from same quarry site and also, test to be conducted on it include the following: sieve analysis and specific gravity test.

The iron tailing to be used for the soil modification will be collected from Itakpe National Mining Ore Company in Ajaokuta local government area of Kogi State, geographically located in the north central Nigeria. It supplies the steel works of Ajaokuta, Kogi State and Aladja, Delta State.

The percentages of the fine aggregate would be reduced in the design mix and replace with iron ore tailings from 0% no replacement to 100% full replacement of fine aggregate by iron ore tailings and the optimal percentage value of the iron ore tailing would be noted. The replacement would take the order of 10% increment in ascending order and Marshall tests would be conducted on the asphalt mix briquettes.

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