Influence of Periwinkle Shells Ash as Filler in Hot Mix Asphalt

C. Nwaobakata[1], J.CAgwunwamba[2]

[1]Department of Civil Engineering,, University of Port Harcourt, Nigeria

[2]Department of Civil Engineering, University of Nigeria, Nsuka, Nigeria

Abstract: ***Nigeria has been experiencing tremendous development in the national infrastructure road network over the last decade. Nigeria economic growth in rural areas has been triggered by good and safe roads and a good highways network system. Studies have shown that climate, traffic conditions, characteristics of the asphalt binder and the aggregate are the main factors that can contribute to premature pavement failures. The ability of periwinkle shell ash as filler to improve the fatigue and rutting resistance of Hot Mix Asphalt (HMA) as well as moisture sensitivity was investigated. In this study, the mechanistic properties of asphalt concrete mixes modified with PSA as a replacement for limestone dust mineral filler were evaluated. Five replacement rates were used; 1, 2, 3, 4 and 5 percent by weight. Asphalt concrete mixes were prepared at their optimum asphalt content and then tested to evaluate their engineering properties which include moisture damage, permanent deformation and fatigue characteristics. These properties have been evaluated using marshal Stability text and indirect tensile strength. The experimental results, in general, showed that the mixes modified with PSA were found to have improved fatigue and permanent deformation characteristics, also showing lower moisture susceptibility. The use of 3 percent of PSA filler has shown a significant improvement in asphalt concrete behavior and has added to the local knowledge the possibility of producing more durable mixtures with higher resistance to distress.***

Keywords: Marshall Stability, fatigue cracking, indirect tensile and moisture susceptibility test.

1. Introduction

With the rapid economy growth and continuously increased consumption, a large amount of waste materials is generated [2]. The vast quantities of waste (such as scrap tires, glass, blast furnace slag, and steel slag, plastics, and construction and demolition wastes, agro waste) accumulating in stockpiles and landfills throughout the world are causing disposal problems that are both financially and environmentally expensive. Dealing with the growing problem of disposal of these materials is an issue that requires coordination and commitment by all parties involved. One solution to a portion of the waste disposal problem is to recycle and use these materials in the construction of highways [2] The use of waste materials (recycling) in the construction of pavements has benefits in not only reducing the amount of waste materials requiring disposal but can provide construction materials with significant savings over new materials. The use of these materials can actually provide value to what was once a costly disposal problem [3]

The overall relevance of asphalt concrete in virtually all highway engineering practice and civil construction works cannot be overemphasized. The growing concern of resource depletion and global pollution has challenged many researchers and engineers to seek and develop new materials relying on renewable resources. These include the use of by-products and waste materials in construction. Many of these by-products are used as fillers for the production of acceptable mix design. With the global economic recession coupled with the market inflationary trends, the constituent materials used for these mix design had led to a very high cost of construction. Hence, researchers in material science and engineering are committed to having local materials to partially or fully replace these costly conventional materials. Numerous achievements have been made in these regards and the subject is attracting attention due to its functional benefit of waste reusability and sustainable development. Reduction in construction costs and the ability to produce adequate mix are added advantages. In continuing quest for more cost - efficient and environmentally acceptable materials, recently, there has been a growing interest in the use of agricultural wastes as pozzolans. Some of the pozzolans of agricultural origin include sawdust ash]14,16,], rice husk ash [17], corn cob ash [6,7,8,and 15]and periwinkle shell ash [9,11,13] Other similar efforts in the direction of waste management strategies include structural performance of concrete using oil palm shell (OPS) as lightweight aggregate. In addition, other materials explored in partial replacement for concrete aggregates include cow bone ash, palm kernel shells, fly-ash, rice husk, and rice straw as pozzolanic materials. The use of coconut husk ash, corn cob ash and peanut shell ash as cement replacement has also been investigated [5]. Cost of construction in the Niger Delta areas especially the south-south zone is highest.

Periwinkles (*Nodilittorina radiata*) are small greenish blue marine snails with spiral conical shell and round aperture. The average winkle lives three years and grows to a shell height of 20 mm, but the largest recorded winkle grew to 52 mm. They are common in the riverine areas and coastal regions of Nigeria where they are used for food. The hard shells, which are regarded as wastes ordinarily posed environmental nuisance in terms of its unpleasant odours and unsightly appearance in open-dump sites located at strategic places, are now being considered as coarse aggregates in full or partial replacement for expensive, unaffordable or unavailable crushed stones or local washed gravels. This is a usual practice among the average residents of these areas especially where they are found. Previous research works on the use of PSA in concrete production [12, 13 10] have been centered on the effect of the ash on the concrete compressive strength up to 28-days hydration period. The use of PSA as partial replacement of cement in concrete by [18, 16] only investigated the effect of varying percentages of the ash on the compressive strength of the concrete produced.

This paper therefore studies the physical properties of periwinkle shell ash as filler with respect to the requirements for hot mix asphalt concrete. The marshal stability test made with varying percentages of periwinkle shell ash (PKA) and indirect tensile strength were also investigated.

2. Materials and Methods

The materials used in this research include 40/50 penetration grade bitumen, river sand free from deleterious materials and crushed granite was purchased from a quarry site at mile 3 area of Port Harcourt and periwinkle shells were obtained in sufficient quantities from mile 3 market where they were dumped after the removal of the edible portion. Impurities such as soils and other dirt were removed and the shells were sun dried and oven dry at a temperature of 400c and crushed. And sieved with sieve No 200. Table 1 gives a summary of the result of some of the test performed on the bitumen. Also Table 2 gives some properties of coarse and fine aggregates.

2.1 Testing program

2.1.1 Marshall Stability

Marshall Stability and flow test were carried out on compacted specimens at various binder contents according to ASTM D1559. The Marshall test is an empirical test in which cylindrical compacted specimens, 100mm diameter by approximately 63.5mm high are immersed in water at 60^0C for 30-40 min and then loaded to failure using curve steel loading plates along a diameter at a constant rate of compression of 51mm/min. The Marshall Stability value in (KN) is the maximum force recorded during compression whilst the flow in (mm) is the deformation recorded at maximum force. The binder content at maximum bulk specific gravity, maximum stability, 4% air void in total mixture, and 80% void in the aggregate mass filled with binder are used in order to determine the optimum binder content.

2.1.2 Indirect tensile strength test (ITS)

The indirect tensile strength test (ITS) is performed at loading rate of 51mm/min by using the Marshall apparatus. The (ITS) test involves loading a cylindrical specimen with compressive loads that act parallel and loading diametrical plane. The ITS test is carried out to define the tensile characteristics of asphalt concrete which can be further related to cracking properties of the pavement. To compute the ITS, according to the maximum load carried by a specimen at failure, the following equation is used:

$$ITS=\frac{2P}{\pi hd}$$

Where P_{max} is the maximum applied load (KN), h is thickness of specimen (mm), d is diameter of specimen (mm).

Table 1: Physical properties of the bitumen

properties	standard	Bitumen
Specific gravity (g/cm3) at 25^0C	ASTM D70	1.05
Penetration (0.1mm), 100g, 5s	ASTM D5	43
Softening point (^{0}C)	ASTM D36	51

Table 2: Properties of mineral aggregate

Properties	standard	coarse	fine
Abrasion loss (%) (Los angeles)	ASTM DC 131	30	
Specific gravity (g/cm^3)	ASTM C127	2.63	
Specific gravity (g/cm^3)	ASTM C128		2.64

Table 3: Chemical Content of Periwinkle

Elemental oxidation	%
SiO2	33.84
Al2O3	10.2
Fe2O3	6.02
CaO	40.84
MgO	0.48
SO3	0.26
K2O	0.14
Na2O	0.24
Mn2O3	0
P2O5	0.01
TiO2	0.03
LOI	7.6

2.1.3 Resistance to moisture Damage

Moisture susceptibility of asphalt mixture is defined as vulnerability of the mixture to be damaged by water. As moisture is collected within the asphalt mixture, it can damage the bond between the asphalt binder and the aggregates resulting in stripping. The moisture susceptibility of asphalt mixture was evaluated using AASHTO T283 test. The specimens sorted into two subsets were approximately equal. One subset was conditioned by soaking with distilled water for 2days. After soaking they were placed in water bath at 60^0C for an hour. Also at the same time the unconditioned specimen were placed water bath at 60^0C. After an hour of temperature stabilization, the indirect tensile strength was determined on all specimens. The ratio of the condition indirect tensile strength to unconditioned indirect tensile strength was calculated from the following equation:

$$ITSR=\frac{ITSwet}{ITSdry}$$

Where ITSR is indirect tensile ratio, ITS wet is average indirect tensile strength of wet subset (KPa); ITS dry is average indirect tensile strength of dry subset (KPa).

Mixture with tensile strength ratio less than 0.7 or 0.75 i.e (70-75%) are moisture susceptible and moistures with ratios greater than 0.7are relatively resistant to moisture damage

3. Results and Discussions

3.1 Marshall Stability

In the Marshall test, the heights of the samples were measured and specimens were immersed in a water bath at 60°C for 35±5 minutes. Specimens were removed from the water bath and quickly placed in the Marshall loading head. The Marshall apparatus deformed the specimen at a constant rate of 50.8 mm per minute. Stability was identified as the maximum load sustained by the sample. Flow was the deformation at maximum load. The stability values were then adjusted with respect to sample height.

Figure 1 shows an initial increase in stability values once the filler content increased in the mixture, but it also decreases with higher filler contents. To increase stability, it seems that there is optimum percentage of filler content. A large amount of filler in the mixture produces lower contact points between aggregates, hence resulting in lower stability.

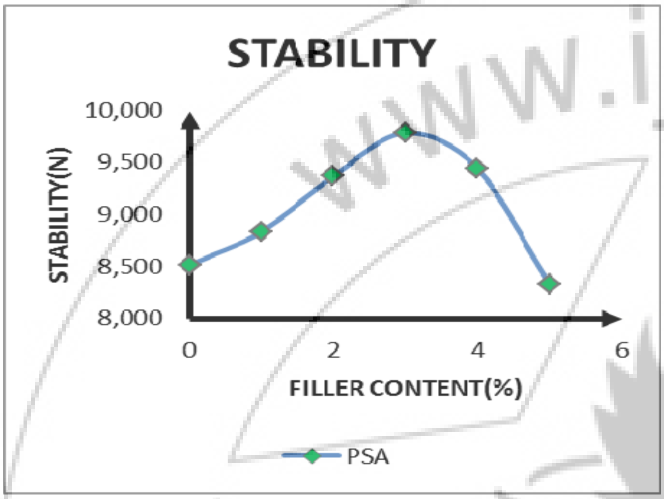

Figure1: Graph of stability vs. filler content

3.2 Flow Values

Figure 2 shows that an increase in filler content decreases the flow value and as such, when the filler content is higher than 3% (*i.e.* 4% and 5%), the flow values start to increase.

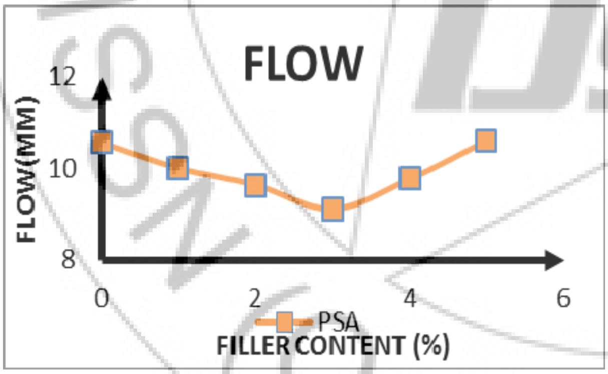

Figure 2: Graph of Flow vs. filler content

3.3 Density

Figure 3 shows an initial increase in density values once the filler content increased in the mixture, but it also decreases with higher filler contents. To increase density, it seems that there is optimum percentage of filler content. A large amount of filler in the mixture produces lower density.

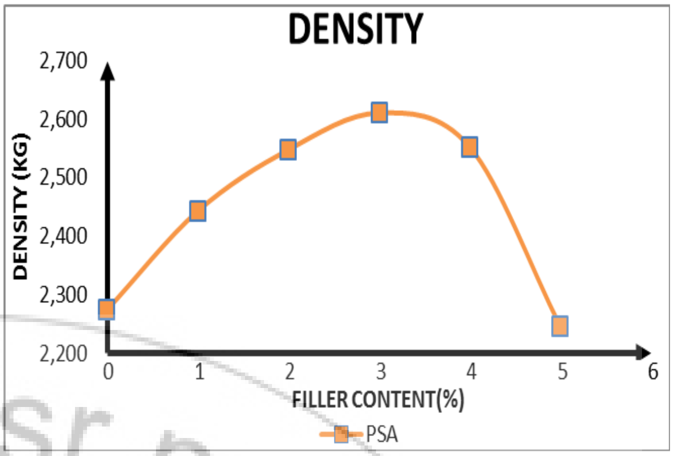

Figure 3: Graph of Density vs. filler content

3.4 Voids in Mineral Aggregate (VMA)

Figure 5 shows consistent results concerning the effect of filler content on the VMA. Accordingly, an increase in filler content in the mixture followed a decrease in the VMA.

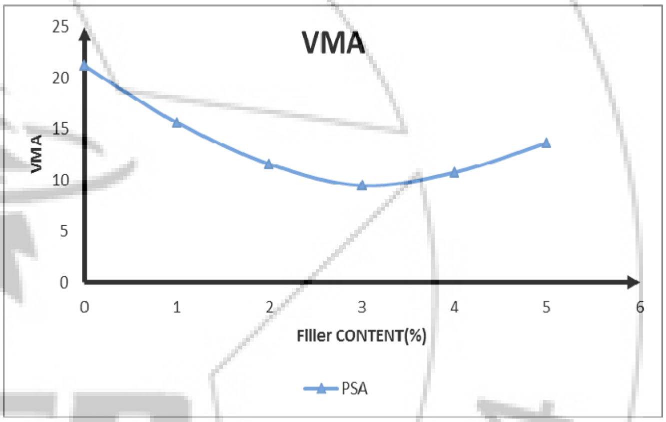

Figure 4: Graph of VMA vs. filler content

3.5 Air Void

Figure 4 shows that an increase in filler content decreases the air void value linearly.

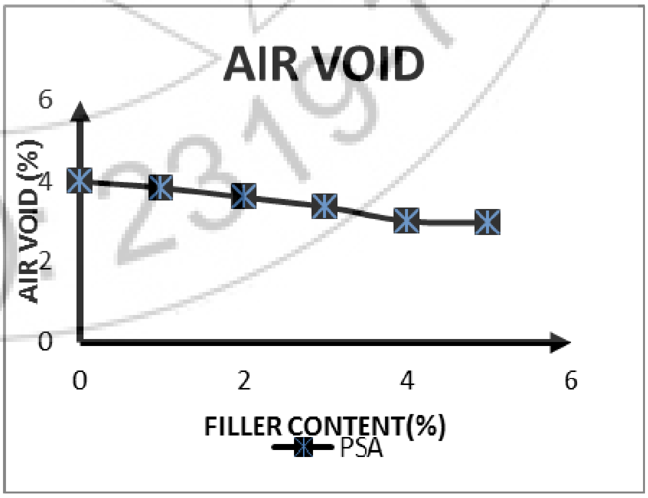

Figure 5: Graph of Air void vs. filler content

Figure 6 shows consistent results concerning the effect of filler content on the ITSR. Accordingly, an increase in filler content in the mixture followed an increase in the ITSR. Therefore, it can be said that the PSA as filler improved the moisture susceptibility of the mix.

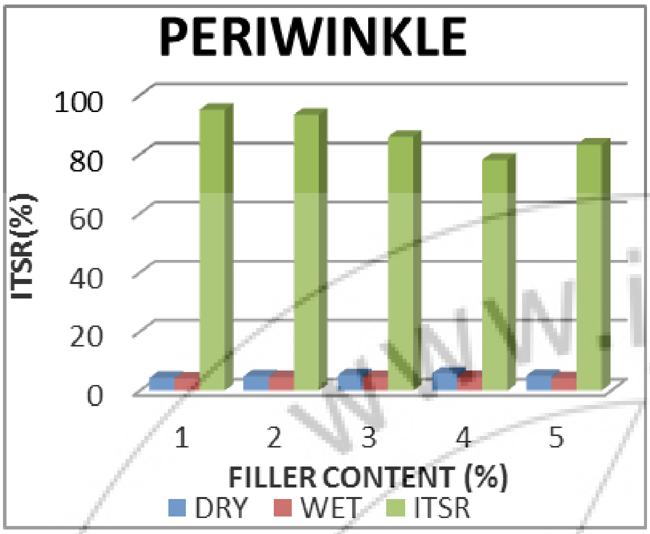

Figure 6: Graph of ITSR vs. filler content

3.6 Correlation between Fatigue Life with the stiffness and Deformation Properties of PSA

Figures 7 showed that the correlation factor between the fatigue life and tensile strain was R2 = 0.98. The fatigue life of the specimens showed an inverse correlation with the horizontal strain. In simple words the increase in horizontal strain properties of the specimens is followed by a decrease in fatigue life of the specimens and this is expected and understood.

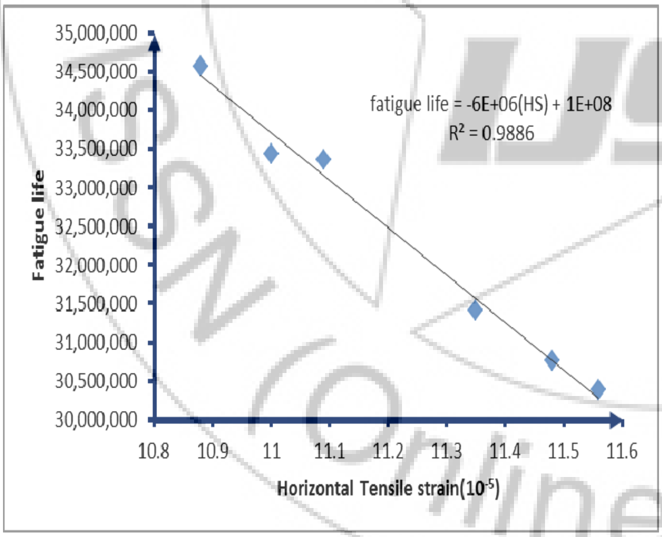

Figure 7: Graph of Fatigue vs horizontal tensile strain

4. Conclusion

The use of periwinkle shell ash as filler revealed consistency of results in the present study. It was observed that the addition of filler positively affects the properties of bituminous mixtures by increasing its stability and voids and decreasing the flow value. As such, it can be said that filler has the potential to improve structural resistance to distress occurring in road pavement due to traffic loads. Further, addition of filler improves fatigue life and permanent deformation of bituminous mixtures by improving mix stiffness. Compared to the control mixture, the filler content of 3% by weight of total mix resulted in highest performance in terms of stiffness, resistance to permanent deformation and fatigue; however, some mechanical properties of the same mix may be compromised when the filler content exceeds 3% level. To achieve these improvements, proper attention must be paid to ensure that the fillers are uniformly dispersed in the mixture. Periwinkle shell ash filler mixtures show significant increases in fatigue life, and moisture resistance, indicating good correlation between fatigue life and permanent deformation. This increase in stiffness is directly related to the addition of filler, and its contents and properties.

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