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Effect of Almond Ash as Partial Replacement of Cement Filler on the Performance of HMA

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***Abstract*—*Several of the newly constructed highway pavements in Nigeria have shown early failures with far-reaching negative impacts on both roadway safety and economy. Major types of these failures are permanent deformation (rutting) and cracking. Fillers were not used as a result of high cost and scarcity of conventional fillers. The objective of this study is to evaluate the influence of new different fillers extracted from different local sources on the performance of asphalt mixtures. The effect of partial replacement of conventional and content on the failures potential of asphalt concrete as well as other mix properties was investigated. A detailed laboratory study is carried out by preparing asphalt mixtures specimens using aggregate from akanpa quarry, (40-50) grade asphalt from construction company and almond leave ash source local and Portland cement were tested in the laboratory. Marshal Mix design was made using all of fillers and different ratios to evaluate the performance of filler in the asphalt mixture. The mechanical properties of mixes were studied using marshal tests. Results of this study indicate that replacement of Portland cement by 1% of almond leave ash (i.e. 0.2 ratio) met the criteria for marshal test for light and medium traffic. Furthermore, coal fly ash cannot be used as mineral filler in hot mix asphalt paving applications*.

***Keywords*—** *Almond leave ash, filler, marshal stability.*

I. INTRODUCTION

Asphalt pavement is a composite material consisting of mineral aggregates, asphalt binder and air voids. The load-carrying behavior and resulting failure of such material depends on many mechanisms that are strongly related to the local load transfer between aggregate particles [1]. The increase in traffic loading repetitions in combination with an insufficient degree of maintenance and difficulties in supplying high quality materials has caused an accelerated and continuous deterioration of the road network. To alleviate this process, several ways may be effective, e.g., securing funds for maintenance, improved roadway design, better control of materials quality and the use of more effective construction methods [2]. Asphalt pavement performance is affected by several factors, e.g., the properties of the components (binder, aggregate and additive) and the proportion of these components in the mix. The performance of asphalt mixtures can be improved with the utilization of various types of fillers, these fillers include: rock dust, slag dust, hydrated lime, hydraulic lime, fly ash or other suitable mineral matter [3]. It's proven that the addition of certain additive to asphalt mix can improve the performance of road pavement. Filler acts as one of the major constituents in asphalt mixture. Filler not only fill voids in the coarse and fine aggregates but also affect the ageing characteristics of the mix [4]. Road usually show excessive failures at an early stage of the pavement life. A major step in the improvement of the existing performance of roads starts with modification of mix design. The filler plays a major role in the properties and behavior of bituminous paving mixtures [5] The mechanical properties of bituminous road pavement depend decisively upon the properties of its filler-bitumen [6]. For modification of asphalt paving materials, the high quality additives are quite expensive for the mass production of bituminous mixtures, a solution to this problem can be obtained by considering the influence of natural mixture ingredients, such as filler [7], [8]. Filler used in the asphalt mixture are identified to affect the mix design, specially the optimum asphalt content. The term (filler) is often used loosely to term a material with a particle size distribution smaller than #200 sieve. The filler theory assumes that "the filler serves to fill voids in the mineral aggregate and thereby create dense mix", [9]. The addition of filler to the mixture can improve adhesion, cohesion substantially and the reduction of hardening by age and improve the property of flow at low temperature. The function of mineral filler is essentially to stiffen the binder. According to various studies, the properties of mineral filler especially the material passing 0.075mm (No. 200) sieve (generally called P200 material) have a significant effect on the performance of asphalt paving mixtures in terms of permanent deformation, fatigue cracking, and moisture susceptibility[10]

1.1 Objective of the Study

To determine the suitability of almond leave ash filler on the mechanical properties of asphalt concrete paving mixture.

To study the effect of new material of filler on the properties of asphalt mixtures and comparing it with traditional filler (Portland cement)

II. MATERIAL AND METHOD

2.1 Materials

The Materials used in this study are locally available and selected from the currently used materials in road construction in Port Harcourt, Rivers of Nigeria.

2.1.1 Asphalt Cement

Asphalt cement with penetration graded of (40/50) was used in this study; it is obtained from MCC Construction Company. The physical properties of this type of asphalt cement are shown in Table 1.

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TABLE 1. Physical properties of asphalt cement

Test	Unit	Results
Specific Gravity (g)	(g)	1.02
Penetration (mm)	mm	46
Viscosity (sec)	(Sec)	54
Softening Point(ball and ring)	^oC	52

2.1.2 Aggregate

One source of crushed aggregate was used in this study, which was brought from MCC Construction Company. The source of this type of aggregate is from Akanpa quarry. The physical properties of the aggregates are shown in Table 2.

TABLE 2. Physical properties coarse and fine aggregate

Properties	Coarse Aggregate	Fine Aggregate
Bulk specific gravity(g)	2.86	2.65
Apparent specific gravity (g)	2.87	2.68

2.1.3 Mineral filler

It has been long recognized that the filler plays a major role in the performance of the asphalt mixtures. The importance of fillers in asphalt mixtures has been studied comprehensively. In this study Almond leave ash has been used, which is obtained from the local sources. The physical properties of the filler is shown in Table 3.

TABLE 3. Physical/Chemical properties of almond leave ash

Properties	Percentage (%)
pH	8.40
Calcium oxide (CaO)	5.8
Aluminum oxide (Al_2O_3)	9.02
Specific gravity (g)	0.375
% passing sieve No. 200	90

2.1.3.1 Portland cement

Portland cement is basically a calcium silicate cement, which is produced by firing to partial fusion, at a temperature of approximately 1500^0C

2.2 Preparation of Mix Design

In this study filler passing sieve size of minus No. 200 (75 m) was used to prepare and characterize hot-mix asphalt concrete. The same mix design methods that are commonly used for hot mix asphalt paving mixtures are also applicable to mix in which almond leave ash filler is used. The percentage of filler incorporated into the design mix is in (1%, 2%, 3%, 4% and 5%), respectively replacing a percentage of cement to determine which percentage ratio satisfy all the required design criteria. Test result is shown Table 4.

TABLE 4. Marshall stability results

% Ratio of Almond ash/cement	Stability (KN)	Flow (0.25mm)	G_{mm}	VTM (%)	VMA (%)	VFA (%)
0.0	8.04	6.15	2.576	9.356	17.798	44.061
0.2	6.78	6.13	2.429	5.846	19.487	70.001
0.4	6.42	5.15	2.298	0.87	19.804	95.607
0.8	6.17	5.63	2.18	0.505	23.642	97.864
1.3	5.68	5.32	2.074	0.338	27.232	98.759
2.5	5.65	5.83	2.01	0.348	29.485	98.82

III. RESULT AND DISCUSSION

3.1. Effect of Mineral Fillers on the Volumetric Properties of HMA

The HMA samples were prepared in the laboratory; it was tested in the laboratory to determine the properties of asphalt concrete mixes, such as, Marshall Properties (Stability, bulk density, air voids, voids filled with asphalt, voids in mineral aggregate), to evaluate their effect on the HMA behavior. Figures (1, 2,3,4,5 and 6) shows that the relations between almond ash/cement filler content and Marshall Properties is typical to common trend in asphalt content mixes. It can be seen from Figures, that these volumetric properties are checked against the requirements.

3.1 Effect of Almond leaf Ash on Stability

The relationship between almond leaf ash /cement ratio and stability is presented in Figure 1. It indicates that at 0.2 ratio, the value of stability is 6.78KN which is higher than the other values of stability except (0% almond / 7% cement ratio) with 8.04KN which was used as a control.

3.2 Effect of Almond leaf Ash on flow

The relationship between flow and almond leaf ash/ cement ratio as partial replacement for cement is shown in Figure 2 which shows that there is variation in flow with increment of almond leaf ash content.

3.3 Effect of Almond Leaf Ash on Bulk Density

Figure 3 Indicates that at 0.2 ratio of almond leaf ash/ cement content, the value of bulk density is 2.87g/cm^3 which was higher than the other values of bulk density exception control with bulk density of 2.335g/cm^3. This shows that as the percentage of almond leaf ash increased, there was a corresponding reduction in the value of bulk density. The reason for the reduction in bulk density is in view of the fact that almond leaf ash has low specific gravity.

3.4 Effect of Almond Leaf Ash on Voids in Total Mix

Figure 4 shows that as the percentage of almond leaf ash content increases, there is a corresponding decrease in the percentage of voids in the total mix. Fewer voids are created in the asphalt mix as the percentage of almond leaf ash increases, thus decreasing the volume of voids in the total mix. At control sample the percentage of void in total mix was 9.36% and at 5% replacement the percentage of Voids in total mix was 0.348%. This is due to low specific gravity of almond leaf ash.

3.5 Effect of Almond leaf Ash on Voids in Mineral Aggregate

Figure 5 shows that an increase in percentage of almond leaf ash content, there is also a corresponding increase in percentage of voids in mineral aggregate. The increase in voids in mineral aggregates is as a result of low specific gravity of almond leaf ash 0.375. Thus, a given percentage weight of almond leaf ash will occupy a greater volume than that of Portland cement, the conventional filler.

3.6 Effect of Almond leaf Ash on Voids in Filler Aggregate

Figure 6 shows that with control sample, the percentage of voids in filler aggregate has the lowest value of 44.06% and highest at 2.5 ratio of almond leaf / cement content with 98.82%. This shows that there is an increase in VFA with an increase in almond leaf ash content.

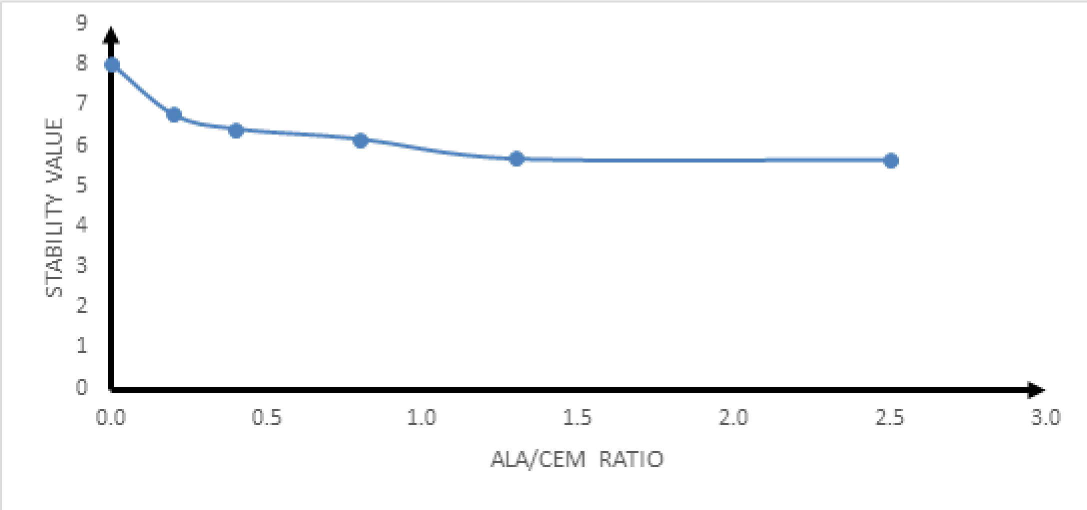

Fig. 1. Variation of Almond Leaf Ash/Cement Content (%) with Stability (KN)

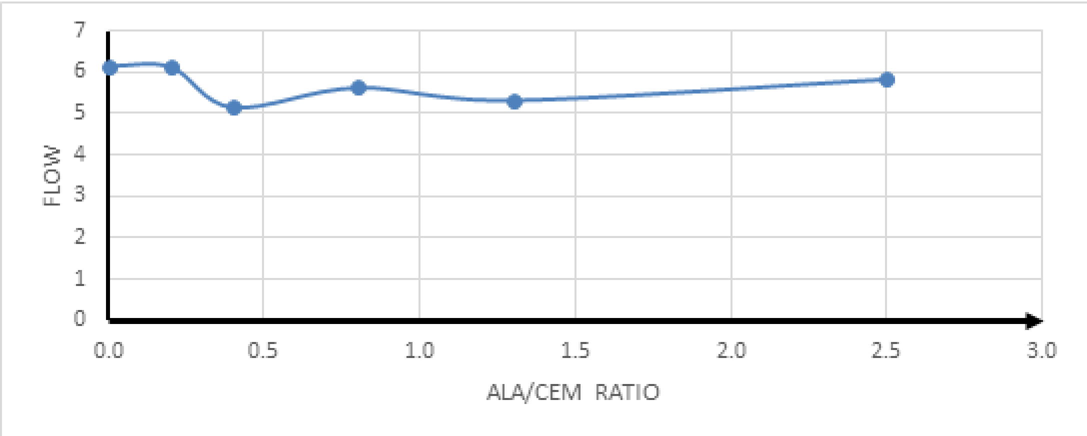

Fig. 2. Variation of Almond Leaf Ash /Cement Content (%) with Flow (mm)

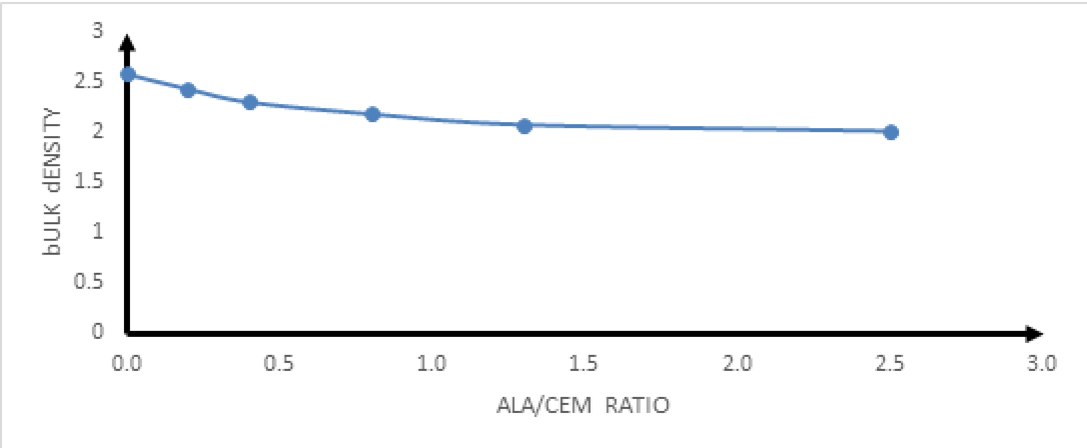

Fig. 3. Variation of Almond Leaf Ash / Cement Content (%) with Bulk Density (g/cm^3)

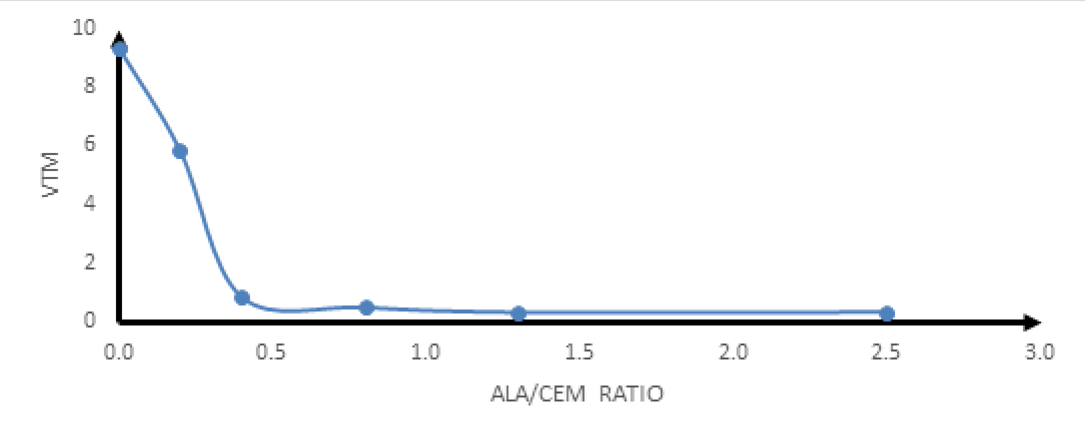

Fig. 4. Variation of Almond Leaf Ash/ Cement Content (%) with Voids in Total Mix (%)

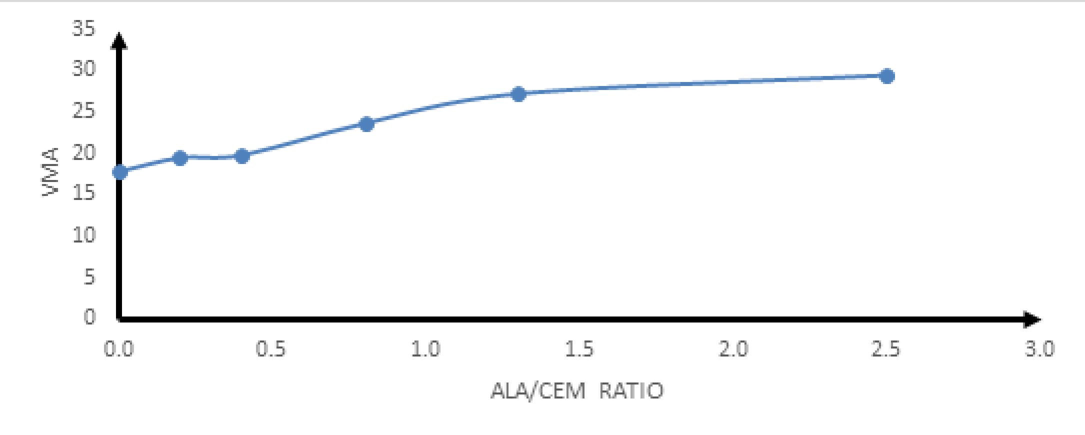

Fig. 5. Variation of Almond Leaf Ash /Cement Content (%) with Voids Mineral Aggregate (%)

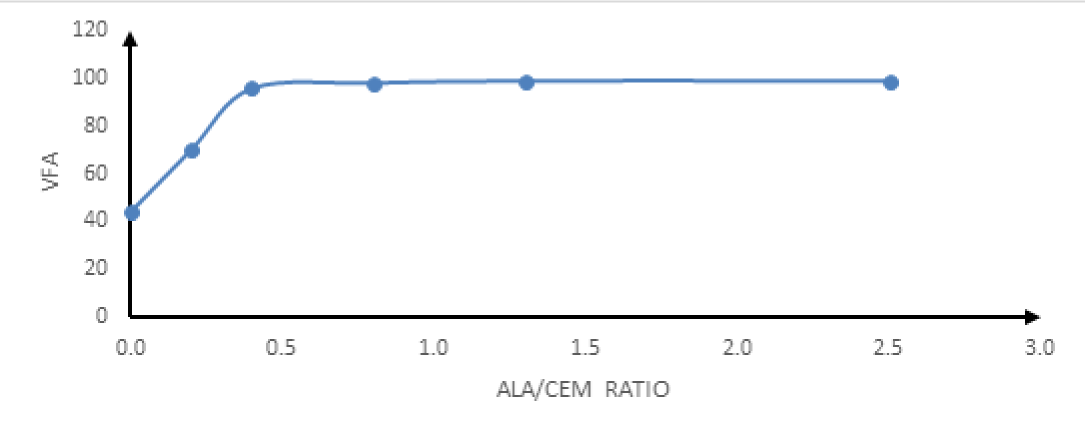

Fig. 6. Variation of Almond Leaf Ash Content (%) with Voids Fill in Aggregate (%)

IV. CONCLUSION

Based on the general findings and results of tests carried out on asphalt concrete modified with almond leaf ash as partial replacement of mineral filler, the following conclusions are made:

1) Almond leaf ash when used as partial replacement for Portland cement does not improve the properties of asphalt mixture compared to the control used, but if it should be used as a partial replacement 0.2 ratio of almond leaf ash / cement can be used since it gives the optimum stability and satisfy other criteria of marshal test for medium traffic after replacement.
2) Almond leaf ash can be successfully incorporated as mineral filler in HMA without degrading the engineering properties of the mix because the stability and flow values were above that of light and medium traffic.

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