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PERFORMANCE EVALUATION OF RECYCLED ASPHALT WITH FLY ASH IN ASPHALTIC CONCRETE PRODUCTION

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Abstract: The use of waste materials in the construction and maintenance of roads is increasing at an alarming rate. Reclaimed asphalt pavement (RAP), a recyclable aggregate produced during the demolition of old flexible pavements and fly ash are examples of industrial wastes. This study examined the suitability of RAP in the production of asphalt concrete to replace natural aggregate partially, and modified with Fly ash. The optimum bitumen content (OBC) 6% was used for the asphalt mix designed. The properties of natural aggregates and RAP were determined. Fly ash was subjected to X – Ray Fluorescence Energy Dispersive Analysis (X–RF) to know its chemical composition, and assessed for the suitability of all the component materials for their use in asphalt concrete. The best performance asphalt concrete with RAP was thereafter treated with 4% fly ash (class f), and Indirect Tensile Strength test was conducted on this sample to know the damage effect on asphalt concrete inform of fatigue cracks and rutting due to traffic load, and its performance resistance to moisture damage. The results of this study showed that asphalt concrete properties can be best improved with the use of 40% RAP content modified by 4% fly ash.
Keywords: bitumen, asphalt concrete, reclaimed asphalt pavement, fly ash, natural aggregates

1. INTRODUCTION

The recycling of the demolition waste from old roadways has been investigated thoroughly in many studies as sustainability. This has been gaining more ground in recent years in the usage of various road and pavement applications as the number of road construction projects increases which results in demand for large amount of construction materials.

Using RAP in pavements has proved its efficiency in enhancing some of the properties of HMA. It is an attractive method to rehabilitate deteriorated flexible pavements due to lower costs relative to new construction and the long–term societal benefits associated with sustainable construction methods. It provides solution to global problem of high cost and diminishing sources of high quality naturally occurring aggregates [16], [22], [7], [19], and also reduces the global environmental pollution due to hydrocarbon and other waste management significantly in most developed countries. Many studies have been conducted to explore the impact of the addition of Reclaimed Asphalt Pavement (RAP) to Hot Mix Asphalt in terms of mechanical and volumetric properties of such mixes [14]; [15].

Moreover, researchers have further established that using RAP aggregate in HMA partially to replace virgin aggregates in the base and sub–base provides cost saving that ranged from 14 to 34 percent [21] especially when RAP content extended from 20 to 50 percent of the total blend [24]. Therefore, the use of RAP can produce economic and environmental profits. Besides, it was stated emphatically that RAP aggregates produced higher modulus of elasticity than conventional unbound aggregates when used in HMA [17], and consequently improves rutting resistance.

However, the aged, stiff, and brittle binder from the RAP as a result of series of chemical transformations that the material has passed through [31] increases the mixture stiffness and can therefore cause fatigue and low–temperature damages [39]; [11]; [33] Concluded that bitumen ageing/oxidation resulting in embrittlement of the binder during construction greatly contributed to cracking. This was confirmed by the very low penetration of the recovered bitumen. Bitumen ageing is thought to have been due to either high processing temperatures (>150 °C) or phenomenon that affects bitumen during the entire service life of the mix, which is subjected to traffic and environmental stresses [26]. Nevertheless, to enhance the strength and stiffness of this material in pavement consequently increase the service life of the rehabilitated pavement is to include the addition of additives such as fly ash [38]. Consequently, using fly ash as an additive promotes sustainable construction and improves the pavement structure [10]; [36].

According to [35], almost one billion tonnes of fly ash is generated annually globally and its landfilling represents a significant environmental problem. And as a material with pozzolanic activity, it has been used widely in a variety of applications such as concrete, soil improvement, and road construction [28]; [29]; [34].

2. MATERIALS AND METHODS

Materials used were coarse and fine aggregates, fillers (stone dust and fly ash), RAP, and binder (bitumen). RAP was collected along Lagos – Ibadan Expressway while others were sourced for.

Experimental tests were carried out to determine the physical properties of bitumen, coarse aggregate, fine aggregate and RAP (Tables 1 and 2) and the chemical properties of Fly ash (Table 3). The summary of test results on asphalt and aggregates revealed that they were within ranges specified in the standard specifications (Tables 1 and 2). The summary of the test on bitumen to determine optimum bitumen content was as shown in Table 3, and the optimum bitumen content 6.0% was considered best to meet [8] requirements compared to other bitumen contents.

Table 1: Asphalt Properties

Property	Test Method	Obtained values	Standard values (According to ASTM)
Penetration at 25°C, (1/10 mm)	AASHTO T49 80–100	86	80 –100
Softening point, °C	AASHTO T53	46.00	45 –52
Specific Gravity	AASHTO T228	1.03	1.03 – 1.06
Flash Point	AASHTO T48	205°C	
Fire point	AASHTO T48	347°C	

Table 2: Physical Properties of Aggregates

Test Description	Coarse Aggregates	Fine Aggregates	Stone Dust	RAP	Standard values
Aggregate Crushing Value (%)	25	–			<30
Aggregate Impact Value (%)	23	–			<30
Specific gravity	2.70	1.66	2.86	2.20	2.60 –2.90
Flakiness Index (%)	12	–			<25
Elongation Index (%)	14	–			<25

Table 3: Summary for Optimum Bitumen Content

Bitumen Content (%)	5.0	5.5	6.0	6.5	7.0	Standard Specification (Asphalt Institute, 2003).[8]	
						Min	Max
C.D.M	1.86	2.04	2.35	2.30	2.33		
V.I.M.	4.94	4.93	4.60	4.67	5.70	3	5
V.F.B.	61.17	65.06	74.03	67.80	64.34	65	78
Flow	7.96	8.58	9.37	7.90	6.60	8	16
VMA	28.62	28.49	18.55	17.71	18.49	13	–
Marshall Stability	4.58	7.56	10.45	11.25	13.49	5.34	–

The total mixed aggregates proportion used agreed with [20](Figure 1)

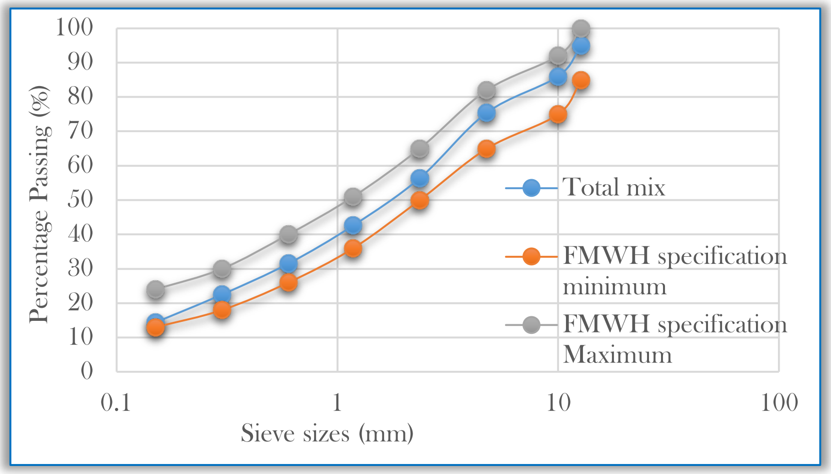

Figure 1: Asphalt Mix Design Curve Envelope

Materials were subjected to tests such as Flash point and Fire point tests [1], Penetration test [2], softening point test [3], Specific gravity test on materials [4], and X – Ray Fluorescence was carried out on fly ash to determine its chemical composition (Table 4).

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Table 4: Grading of RAP

Sieve size(mm)	Total Mixed Passing	FMWH specification[20]	
		minimum	Maximum
12.7	83	85	100
10	78	75	92
4.75	67	65	82
2.36	52	50	65
1.18	44	36	51
0.6	40	26	40
0.3	35	18	30
0.15	25	13	24

The asphalt used in the study was purchased from the local distributor and it has penetration grade 60/70. Determination of optimum bitumen content (OBC) suitable for the mix design was carried out for various sets of specimens at 4.5, 5.0, 5.50, 6.0, and 6.50%, and the mix designed was thereafter prepared with 0%, 20%, 40%, 60%, 80%, and 100% RAP of the total aggregate mixture with the virgin aggregates.

Reclaimed asphalt pavement was blended and pulverized before usage, and the best performing RAP percentage was later on prepared with 0,2,4,6, 8, and 10% fly ash to evaluate the effect of fly ash on recycled asphalt.

Indirect Tensile Strength (ITS) test was performed on the optimum performing RAP prepared with fly ash to assess the damage effect on asphalt concrete in respect of fatigue and rutting as a result of traffic load, and how durable the test material would be due to the presence of water.

3. RESULTS AND DISCUSSION

Evaluation of Recycled Asphalt Pavement Properties

The mix design of RAP was optimized with virgin aggregates to meet the [20] (Figure 2).

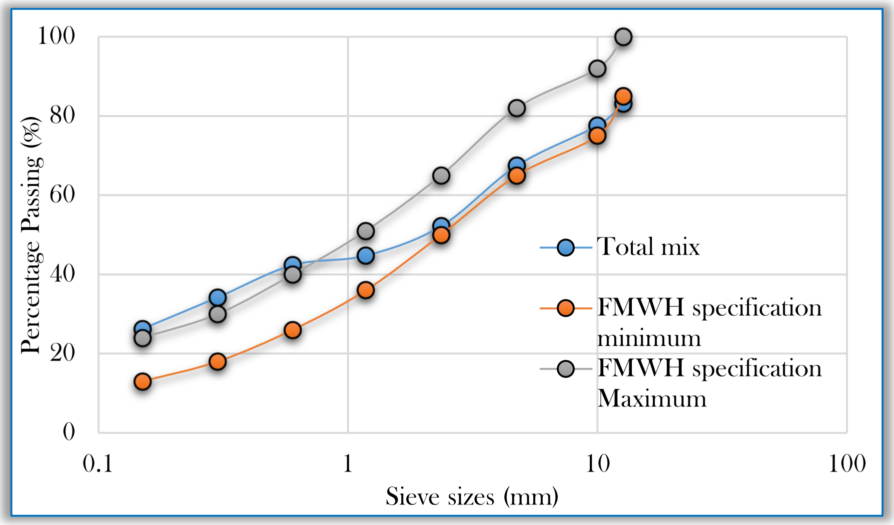

Figure 2: Grading of RAP

The results established an increase in pavement properties as the RAP content increased, and the RAP contents of 40% gave the best performance (Figure 3). This result was similar to the findings by [14], and [40]. The increase in Marshall Stability could be as a result of increase in fines present in RAP due to crushing, and the same finding was noted by [23]. Also, there was reduction in flow values and invariably reduced the viscosity with increase in percentage replacement of RAP materials, and consequently improved the workability behavior. This observation agreed well with the results of [37].

Increase in VMA values was observed as percentage replacement of rap increased (Figure 3), and this corresponded to decrease in VIM. The results could be attributed to the angular aggregates present in the mixed which created more void space during compaction from the increased number of sharp edges and fractured faces. Consequently, since VMA includes air voids and the effective asphalt content, increased air voids noted in the compacted mixture has increased the VMA by 4.10% at 40% rap replacement compared with control (0% rap replacement). Hence, more asphalt was allowed into the mix, and this gave 2.61% increase in VIM at the same 40% rap replacement.

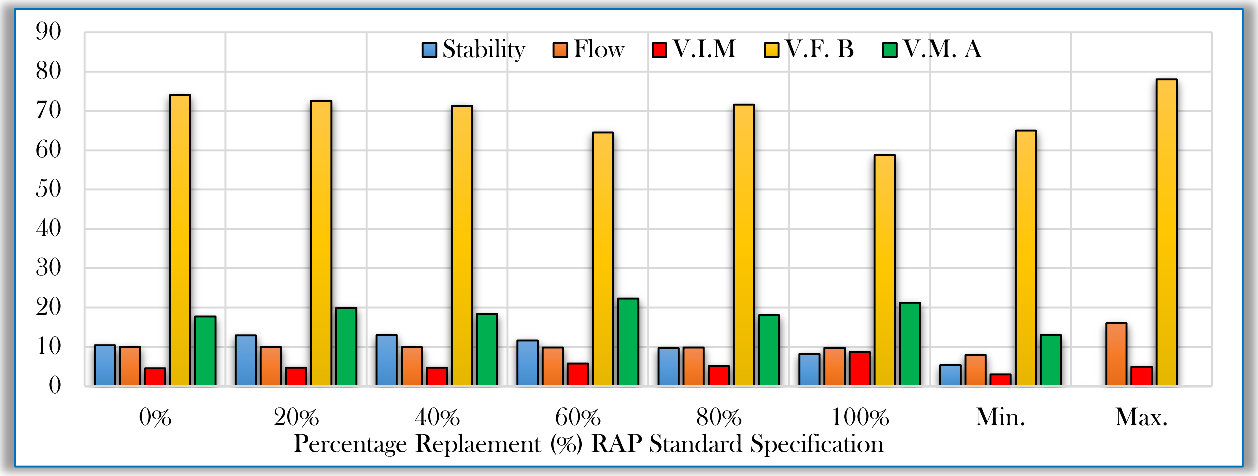

Figure 3: Effect of RAP on Properties of Asphalt Concrete

Chemical composition of Fly ash

The analysis from the XRF revealed the chemical composition of the fly ash (Filler) used as class F in accordance with [9] requirements, and both physical and chemical properties of fly ash (Tables 4 and 5) were found to be satisfactory and conform to the requirements for class F pozzolana [18].

Table 4: Physical and Mechanical Properties of Fly Ash

Property	Fly Ash
Colour	Grey
Particle shape	Mostly spherical
Particle size distribution (passing through sieve opening, mm) (%)	Mostly smooth
Specific gravity	2.50

Table 5: Chemical Composition of Fly Ash

Chemical Compounds	% Composition
SiO_2	59.27
Al_2O_3	27.22
Fe_2O_3	4.90
CaO	1.37
MgO	0.63
SO_3	0.00
K_2O	1.13
Na_2O	0.00
M_2O_5	0.17
P_2O_5	0.35
TiO_2	2.48
LOI	0.74
Total	98.26

Evaluation of Recycled Asphalt Concrete with Fly Ash

The addition of fly ash improved the stability of asphalt concrete with RAP content. Increase in stability and reduction in flow were observed with increasing fly ash content (Figure 4). The best improvement was achieved by adding 4% of fly ash, the highest stability (14.23 kN) with 9.29% increase compared with control value. Higher stability and lower flow value of all mixtures with fly ash could be as a result of the stiffening effect that fly ash has on mastic and the mixture. The increase in stability and reduction in flow agreed with [6] and [12].

The void in mix (VIM) of all the increase in fly ash content of the asphalt concrete with Rap designed was consistently lower than the control except at 2% which is higher than the control value. Similarly, there was reduction in flow value for increase in fly ash content was observed and this could be as a result of increase in viscosity of the mix along with inclusion of filler in the mix (Figure 4).

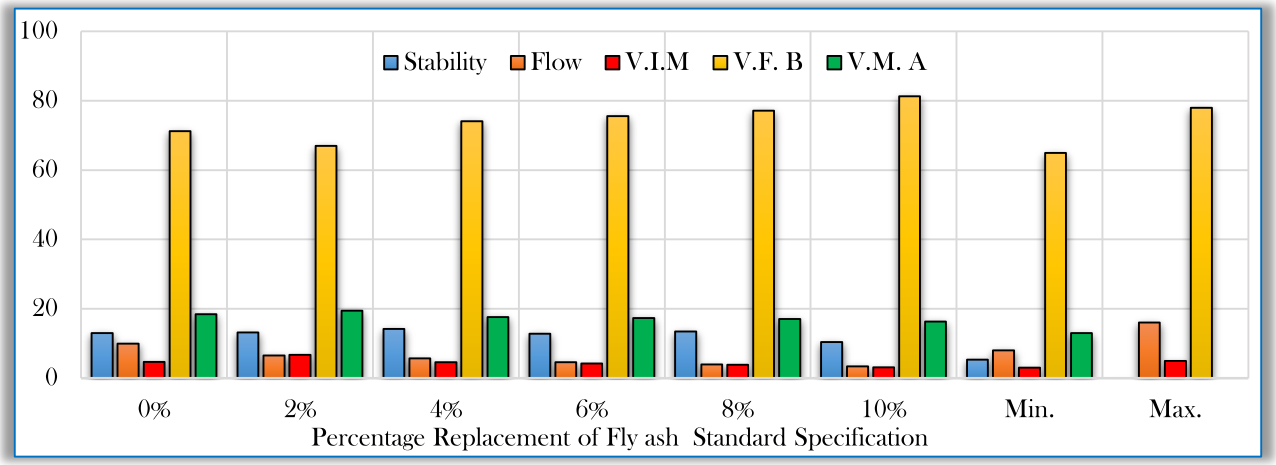

Figure 4: Effect of Fly Ash Content on Properties of Asphalt Concrete with RAP

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Water Resistance Effect on Asphalt concrete with RAP modified by fly ash

The ITS test was used to evaluate the resistance of the Asphalt concrete with RAP modified by fly ash to moisture damage, and the ITSR denotes moisture susceptibility.

The increase in fly ash content gave an increase in ITSR up to 4% compared with the control value (Table 6), this revealed that the fly ash used to modify the asphalt concrete with RAP improved the resistance to moisture of asphalt mixtures. This trend agreed with [27] findings. The values obtained satisfied [5] code (80 percent minimum value of ITSR).

Table 6: ITS and ITSR values obtained for the tested asphalt with RAP modified by Fly ash

Fly ash (%)	0	2	4	6	8	10
ITS (MPa) wet	0.81	0.83	0.88	0.80	0.78	0.78
ITS (MPa) dry	0.98	1.00	1.0	0.99	0.97	1.06
ITSR (%)	82.65	83.00	86.00	80.80	80.41	73.58

4. CONCLUSION

This study investigated the performance evaluation of recycled asphalt with fly ash in asphaltic concrete production, and conclusions were summarized as follows:

— The addition of reclaimed asphalt pavement (RAP) content of 40% gave the best performance, and improved the pavement performances of the asphalt mixtures.

— There was an increase in Marshall Stability by 24.59%, reduction in flow and void in mineral aggregates (VMA) by 18.40% and 7.23% respectively. The implication of this was that the space to accommodate the asphalt and the volume of air voids necessary in the mixture is decreased with increase in RAP content.

— Fly ash used was class F, and has positive effect on properties of asphalt concrete with RAP content. The best improvement was achieved at 4% fly ash content with 9.29% increase stability and 42.79% reduction in flow. It showed the stiffening and strength enhancement effects that fly ash has on mastic and the asphalt concrete with RAP.

— Increase in fly ash content gave an increase in ITSR for all mixtures value. The addition of 4% fly ash to asphalt concrete with RAP increased ITSR slightly by 2.52% compared with control value which indicated an improvement in pavement performance resistance to moisture damage

The findings of this study established the possibility of having a satisfactory performance of asphalt concrete with Reclaimed Asphalt Pavement partially replaced of mineral filler with 4% fly ash (class F)

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