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INFLUENCE OF POLYETHYLENE FROM WASTE PURE WATER SACHET ON PROPERTIES OF HOT MIX ASPHALT

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ABSTRACT
This work evaluate the influence of waste pure water sachet (WPS) as a modifier in Hot Mix Asphalt (HMA). The properties of the constituent materials were determined. Modified HMA samples were prepared at varying concentration of 2, 4, 6, 8 and 10% WPS content by weight of the Optimum Binder Content (OBC). The properties of the modified HMA were determined using Marshall Method of mix design. The properties of the constituent materials showed that they are suitable for HMA production. The modified bitumen showed an increase in softening point (61 – 73.5%), flash point (258 – 282^{0}C), fire point (289 – 311^{0}C) and ductility (92.67 – 118.67cm) as the WPS content increases from 2% to 10% while decrease in penetration (62.33 – 56.5mm) as WPS content increases from 2% to 6%. Stability and Bulk density increases from 4.64kN to 8.84kN and 2.21g/cm^3 to 2.34g/cm^3 respectively while flow, voids in mineral aggregates (VMA) and Air voids decreases from 3.6 to 2.98mm, 23.85 to 20.16% and 19.73 to 13.97% respectively as the WPS content was increased from 2 to 8%. An optimum polyethylene from WPS modifier content of 8% by weight of the OBC is recommended for use in the HMA.

Keywords: *Bitumen, Hot Mix Asphalt, Pure Water Sachet, modified bitumen, Marshall Properties, Polyethylene.*

1. INTRODUCTION

Road infrastructure is a major component of land-based transportation, thus in order to maintain a good one, a very durable high-quality road pavement is required. Various researches towards improving pavement quality and performance have been conducted [1, 2].

Most of the roads in Nigeria are subjected to heavier loads than designed axle loading due to increase in number of commercial trucks resulting in constant pavement failure. Additionally, ageing and deterioration may be induced by climatic and environmental factors which include moisture, temperature, radiation and chemical attack which negatively impacts on physical and chemical properties of asphalt [3]. Therefore, there is an increasing need to strengthen and extend pavement service life, because of daily increasing traffic on the highways.

Awwad and Shbeeb [4] indicated that the modified mixture has a higher stability and VMA compared to the non-modified mixtures and thus positively influence the rutting resistance of these mixtures. Gawande, *et al.* [5] observed that use of modified bitumen with the addition of processed waste plastic of about 5-10% by weight of bitumen helps in improving the longevity and pavement performance with marginal saving in bitumen usage. Khan and Gundaliya [6] stated that the process of modification of bitumen with waste polythene enhances resistance to cracking, pothole formation and rutting by increasing softening point, hardness and reducing stripping due to water, thereby improving the general performance of roads over a long period of time. Pareek, *et al.* [7] observed a significant improvement in case of rutting resistance, indirect tensile strength and resilient modulus of the bituminous concrete mix with polymer modified

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bitumen. Sabina, *et al.* [8] observed that the results of marshal stability and retained stability of polyethylene modified bituminous concrete mix increases 1.21 and 1.18 times higher than that of conventional mix by using 8 and 15% (by weight of bitumen) polythene with respect to 60/70 penetration grade of bitumen. Vasudevan [9] reported that polymer bitumen blend is a better binder compared to plain bitumen resulting higher Marshall Stability and decreasing the possibilities of potholes formation. Verma [10] reported that while a normal "highway quality" road lasts four to five years, plastic-bitumen roads can last up to 10 years where temperatures frequently cross 50°C and torrential rains create havoc, leaving most of the roads with big potholes. Moghadam and Karim [11] concluded that Polyethylene Terephthalate (PET) reinforced mixtures possess higher stability value, flow, fatigue life in comparison with the mixtures without PET. Sui and Chen [12] concluded that there is improvement on high temperature stability, low temperature cracking resistance and water resistance on modification and evaluation of polyethylene as additive in the technical, economic and environmental aspects. Al-Hadidy and Yi-Qui [13] indicated that modified binders showed higher softening point, keeping the values of ductility at minimum range of specification of (100+cm), and cause a reduction in percentage loss of weight due to heat and air (i.e. increase durability of original asphalt). Panda and Mazumdar [14] observed that penetration, ductility, and specific gravity of the modified binders decreased as compared with unmodified bitumen while the softening point temperature, temperature susceptibility and viscosity increased.

Plastics wastes are on the rise yearly and are creating a nuisance in the immediate environment. Today, availability of plastic waste is enormous; because nearly 50% to 60% of total plastic are consumed as packing material [15]. Utilization of this waste for purpose of construction will no doubt be a welcome development. This work was to evaluate the influence of polyethylene from WPS as a modifier for bitumen in HMA.

2. MATERIALS AND METHODS

The materials used are bitumen, modifier (polyethylene from WPS) and aggregates. Experimental methods that were employed are: Penetration [16], flash and fire point [17], Softening point [18], Ductility [19], Viscosity [20], Specific gravity [21] and Marshall Stability tests [22].

The following tests were conducted on the coarse aggregate. Aggregate impact value [23], Aggregate crushing value [24], Los Angeles abrasion [25], Flakiness index [26], Elongation index [27] and Specific gravity [28]. Particle size analysis [29, 30] and specific gravity [31] were conducted on the fine aggregates and mineral filler.

The WPS were collected; washed and cleaned by putting them in hot water for 3-4 hours. They were then dried. The dried WPS were cut into tiny pieces of size 50 x 5mm maximum.

3. RESULTS AND DISCUSSION

3.1 Aggregates

The results of quality control tests conducted on the aggregates are as presented in Table 1. Based on its index properties, the aggregate is of low plasticity and falls within the range specified by the Nigerian standards for Roads and Bridges, [32] to be used for asphalt concrete construction purposes.

3.1.1 Particle Size Analysis of Aggregates

The result of the particle size analysis conducted on the aggregates materials are as presented in Figure 1. It was observed that a predominant percent of approximately 90.5% were retained on sieve No.8 (2.36mm) for the coarse aggregate material, and 92.611% passed sieve No.8 (2.36mm) but retained on sieve No 200 (0.075mm) for the fine aggregate material and 74.627% passed sieve No.200 and was retained on the pan for the mineral filler material respectively. This is according with the required limits specified for aggregates material [33].

The proportioning of aggregate was done using the trial-and-error method. The proportions that finally gave the required gradations were obtained to be 52.6, 38.4, and 9.0 % for coarse, fine aggregates and mineral filler respectively

3.2 Pure Bitumen

The results of tests carried out on the bitumen are as presented in Table 2. The grade of the bitumen is 60/70 which make suitable for use in HMA production.

Table 1: Results of the Quality Control Tests Performed on Aggregates

S/N	Test Conducted	Results	Unit	Specification [32]	Comment
1.	Impact value	29.19	%	< 30	Satisfactory
2.	Crushing value	28.00	%	< 30	Satisfactory
3.	Abrasion value	24.00	%	< 30	Satisfactory
4.	Elongation index	24.48	%	< 35	Satisfactory
5.	Flakiness index	24.87	%	< 30	Satisfactory
6.	Specific gravity (fine)	2.63	Nil	2.5-2.9	Satisfactory
7.	Specific gravity (coarse)	2.94	Nil	2.5-2.9	Satisfactory

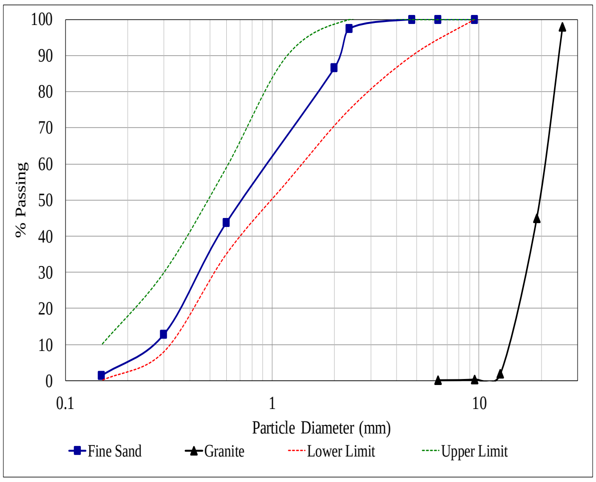

Figure 1: Particle Distribution Curve

3.3 Effects of the WPS on the Properties of Bitumen

The effect of addition of waste polyethylene bags in form of water sachets has been studied by varying concentrations of polyethylene from 0% to 10% at an increment of 2%. The summary of the results of the tests carried out are as presented in Table 3.

3.3.1 Effects of Modifier on the Penetration

From Table 3, it was observed that the penetration value decreases with an addition of WPS. This decreasing trend is in line with the works of [34], [35] who worked on virgin waste polymer modified bitumen for HMA. Panda and Mazumdar [14] observed that the penetration of modified bitumen decreased as compared with unmodified bitumen.

3.3.2 Effects of the Modifier on the Softening point

Table 3 shows that as the WPS increases, the softening point also increases. This phenomenon can be attributed to the fact that the bitumen becomes less susceptible to temperature changes as the modifier content increased which is an indication of high rutting resistance and bleeding of binder at temperatures above the softening point. This trend is in line with [6, 13, 14, 34, 36, 37] who observed that the softening point of the modified binders increased as compared with unmodified bitumen.

Table 2 Consistency Test Results on Pure Bitumen

S/N	Test Conducted	Unit	Result	Specification
1	Penetration	0.1mm	68.9	60 -70
2	Softening point	°C	48.5	48-56
3	Ductility @ 25 °C	Cm	105	100 (Minimum)
4	Specific gravity	NIL	1.013	1.01-1.06
5	Flash-point	°C	230	250 (Minimum)
6	Fire-point	°C	256	NIL
7	Viscosity @ 60 °C	Secs	674	NIL

Table 3: Summary of Results of the Consistency Test for the Modified Bitumen

S/NO	PEB (%)	Penetration (mm)	Ductility (cm)	Softening Point (°C)	Flash Point (°C)	Fire Point (°C)
1	0	68.89	105.00	48.50	230.00	256.00
2	2	62.33	92.67	61.00	258.00	289.00
3	4	59.33	100.35	64.50	263.00	297.00
4	6	56.50	105.33	66.50	270.00	305.00
5	8	68.33	118.67	70.00	276.00	307.00
6	10	104.50	97.00	73.50	282.00	311.00

3.3.3 Effects of the Modifier on the Ductility
From Table 3, the effect of WPS on ductility exhibits a decreasing fashion with increasing percentage in the modifier content. This can be attributed to the fact that as the percentage of modifier increases the bitumen became harder and less ductile. This concurs with [14, 34, 35] whose works were on the effects of virgin polymer as a modifier of bitumen for HMA.

3.3.4 Effects of the Modifier on the Flash and Fire point
The variation of flash and fire point with modifier content is as shown in Table 3. It was observed that the effect of the modifier on the temperature increases with increasing percentage in modifier content. Panda and Mazumdar [14] observed that the temperature susceptibility of the modified binders increased as compared with unmodified bitumen.

3.4 Influence of Polyethylene from WPS in HMA
The Stability and flow values of the modified HMA are is as presented in Figures 2 and 3 while Figure 4 depicts the unit weight. The summary of result of Marshall Stability and Volume-void analysis are as presented in Table 4.

3.4.1 Stability – WPS content relationship
From Figure 2, it was observed that highest stability value was obtained at 8% WPS content with an optimum value of 8.84kN. This means that the addition of the modifier to the mix improved the stability of the HMA which could be attributed to hardening and decrease in the penetration of the pure bitumen in the mix. This translates to a hot-mix with an increased resistance to plastic permanent deformation (rutting). The study agrees with the work of [4, 8, 38] who study the effect of additives in HMA.

3.4.2 Flow – WPS content relationship
Figure 3 shows that the flow of the modified HMA decreases with increasing modifier content. This as a result of increased resistance to displacement the modifier had on the binder in the mix. This shows that modification of HMA using WPS reduces the rate of deformation. This agrees with the result of [39] who noted that reduction in flow suggests that polymer content has increased effect on the internal friction of the mix. It was observed that at optimum WPS, the flow was 2.98mm. This flow value lies within the specification (2mm – 6mm) stated in the [32].

Table 4: Strength Properties of Polyethylene Modified Asphalt Concrete

S/No	% PEB	Stability (kN)	Flow (mm)	VMA	Pa	Bulk density, (g/cm^3)
1	0	4.20	4	28.82	22.18	2.12
2	2	4.64	3.6	23.85	19.73	2.21
3	4	5.66	3.53	22.91	17.99	2.27
4	6	6.23	3.12	21.52	16.85	2.29
5	8	8.84	2.98	20.16	13.97	2.34
6	10	7.13	3.23	22.51	13.6	2.33

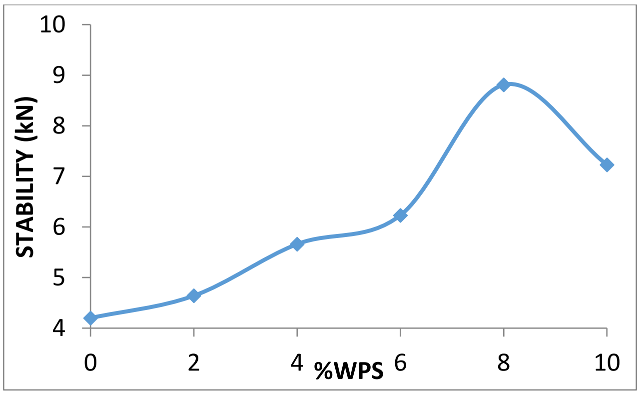

Figure 2: Variation of Stability with polyethylene from WPS on HMA

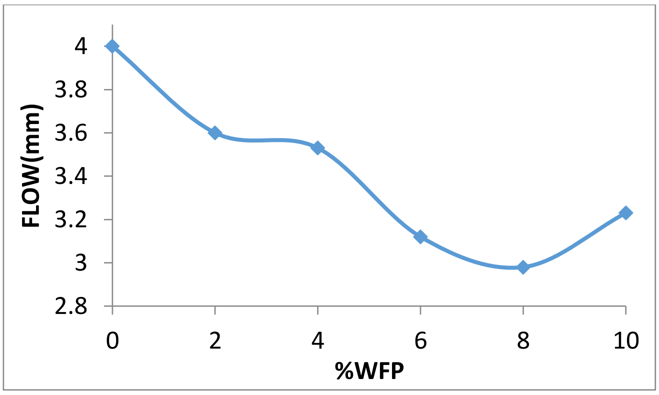

Figure 3: Variation of Flow with polyethylene from WPS on HMA

3.4.3 Unit Weight – WPS content relationship

The behaviour of the bulk unit weight with the varying percent in modifier content is shown in Figure 4. It was observed that the optimum WPS content was 8%. At this point, the effect of WPS has increased the unit weight, bulk volume and compactness of asphalt concrete materials by filling up void spaces, thereby leading to reduction in voids. The study shows similar pattern with [39]and [38].

3.4.4 VMA – WPS content relationship

Figure 5 depicts the variation of VMA with modifier content. It can be observed that VMA decreases with increasing percentage WPS content up to 8%, thereafter, further addition increases the value of VMA. This shows proper mixing of aggregate with the WPS in the mix. This showed a similar trend to that of [40] as VMA decreased to 17.5% at 2.5% before showing an increased pattern. Awwad & Shbeeb [4] indicated that modified mixture has a lower VMA compared to non-modified mixtures and thus positively influence the rutting resistance of these mixtures.

3.4.5 VIM – WPS content relationship

Figure 6 depicts the variation of voids in the mix with modifier content. It can be observed that as percentage WFP contents increases, voids in the total mix lie within the specified range of 3 – 8%. There's a sharp decline in the percentage of air voids at 6% and 8% WPS because more voids have been occupied by the mineral filler and the polyethylene bag. This follows a similar trend to the work of [41].

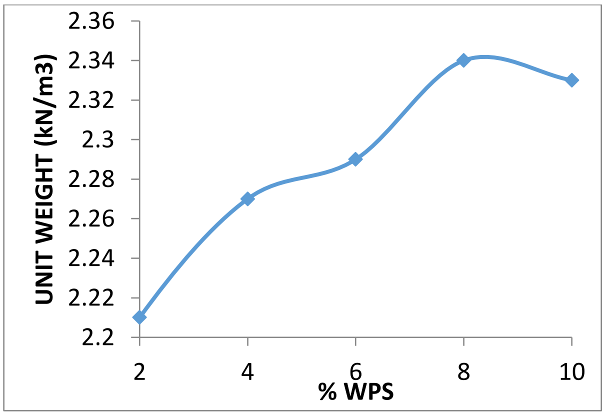

Figure 4: Variation of Unit Weight with polyethylene from WPS on HMA

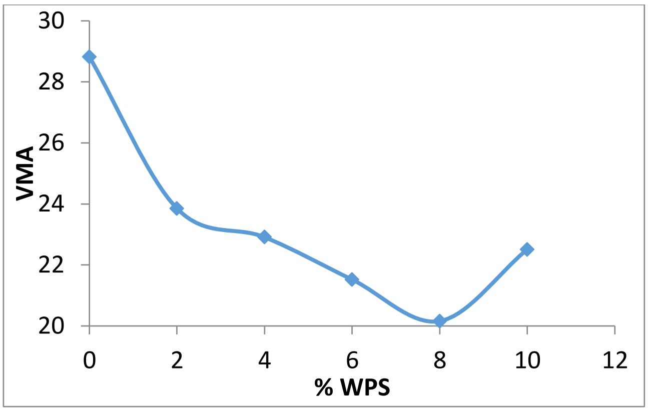

Figure 5: Variation of VMA with polyethylene from WPS on HMA

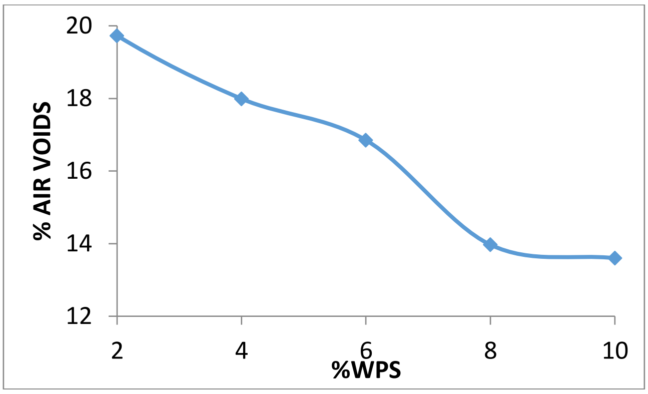

Figure 6: Variation of Percentage Air Voids with Polyethylene from WPS on HMA

4. CONCLUSIONS

1. It can be concluded that the optimum percentage polyethylene from waste pure water sachet in the modified mix was 8% of the total bitumen weight.
2. Polyethylene modifier offers better engineering properties and its usage as bitumen modifier which could serve as a means of managing the waste menace, and also increase its consistencies.

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