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Marshall properties evaluation of hot and warm asphalt mixes incorporating dissolved plastic bottle modified bitumen

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ABSTRACT

This study was carried out to investigate the performance of Hot and Warm mix asphalt (HMA and WMA) with dissolved plastic bottle (DPB) modified bitumen. In this study, 1 - 17% @ 2% DPB by weight of bitumen was blended with 60/70 straight-run bitumen to produce hot and warm (+3% Sasobit) DPB modified bitumen blends. The produced binders were subjected to ductility, penetration, softening point, viscosity, flash and fire point and specific gravity tests to understand the effect of this modification. Also, the binders were used in preparing HMA and WMA concrete respectively. Marshall Properties (stability, flow, stiffness, volume of void, void filled with bitumen and bulk specific gravity) were evaluated on HMA and WMA concrete produced. Results revealed that addition of polyethylene terephthalate (PET), in dissolved form (0 – 17%), increased the softening, viscosity, specific gravity, flash and fire points of both hot and warm modified bitumen blends but decreased their penetration and ductility. Addition of DPB improve the stability, flow and stiffness up to 13% for both HMA and WMA concrete. However, the Marshall Stability and flow of all asphalt concrete mixtures satisfied the requirements of both Federal Ministry and Asphalt Institute. Meanwhile, DPB modifier performed better in WMA than HMA concrete.

1 Introduction

Hot-Mix Asphalt (HMA) is the most widely used paving material around the world. It is a combination of two primary ingredients; the aggregates and asphalt binder. Additives are added in small amounts to many HMA mixtures to enhance their performance or workability [1]. Hot Mix Asphalt are usually produced at high temperatures with intolerable high energy consumption, environmental discomfort and occupational health hazard. However, Warm Mix Asphalt (WMA) is a sustainable paving technology used by the HMA industry to reduce the temperature for mixing, placing, and compaction of asphalt mix. The main aim of using WMA is to reduce production temperature and emission of greenhouse gas. Other benefits include reduction in fumes and odours to the environment, reduction in the short term aging of binders and ensure early

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opening of the road to traffic [2]. Assessment of the quality of asphalt concrete used in road construction in Nigeria suggested that the quality of asphalt need to be improved [3]. Modification of HMA and WMA pavements is an essential objective as it increases its performance and service life and decreases its maintenance cost [4, 5].

The performance of asphalt mixtures can be improved with the utilization of various types of additives, such as polymers, latex, fibres and many chemical additives so that the resistance to deterioration can be more assured [6, 7]. It has also been proven that the addition of certain polymer additives, typically exhibits improved durability, greater resistance to permanent deformation in the form of rutting and thermal cracking, increased stiffness and decreased fatigue damage. Plastic bottles (PB) which is mainly composed of High Density Polyethylene (HDPE) has been found to be one of the most effective polymer additives that enhances the life of the road pavement and solve many environmental problems [8-10]. Furthermore, Proliferation of many commercial outfits for portable water supply in dispersed saleable plastic units; sachets, bottles, jars etc. that emerges, especially in all regions of developing economy, has obviously accounted for an increase in production of plastics and eventual generation of wastes after use. These plastics are non-degradable polyethylene Terephthalate, thereby resulting to unmanageable environmental pollution after use, especially without any organized waste management scheme in place in both developed and developing economies.

A research into the evaluation of the plastic bottle as a viable bitumen modifier in fluidal form for pavement works alongside the metrics for its dissolved form will contribute to additional waste recycling strategy by finding useful application of WPB in dissolved form and as a part of solution to the global nauseating environmental problem of a non-degradable waste disposal and also extension of pavement service life. [1] studied utilization of Polyethylene Terephthalate (PET) as an additive to bituminous mixture. The binder was blended with five different proportions of PET (2, 4, 6, 8, and 10%) by weight at the optimum bitumen content. The results showed better resistance against rutting and permanent deformations comparing it with the conventional binder while the increasing amount of PET would increase the softening point of the mixture. In addition, there is no gas evolution when PET is heated in the temperature range of 120ºC- 165ºC and even at temperature of 270ºC when it starts to decompose, there is still no harmful gas evolution [11]. [12] conducted the evaluation of the effect of using waste plastic bottles, a PET on the engineering properties of stone mastic asphalt (SMA) mixture in the laboratory with the focus on the mechanical properties of asphalt mix at varying proportions of blending (0 - 10% at 2% interval). The appropriate amount of PET was found to be 6% by weight of bitumen. Positive results of some evaluation studies of PET as modifier to hot mix asphalt mixes have also been reported at normal temperature and which can indeed promote the re-use of waste material in the industry in an environmentally friendly and economical way [1, 12, 13].

Reviewing the available literatures on DPB, it shows that the application of DPB in WMA is still missing, thus another knowledge gap has been identified. The study aimed at evaluating the performance of both HMA and WMA concrete with dissolved plastic bottle (DPB) modified bitumen. Different percentage replacement (1, 3, 5, 7, 9, 11, 13, 15 and 17%) of DPB were blended with 60/70 PEN grade bitumen to produce hot and warm DPB modified bitumen. The modified bitumen was used in preparing HMA and WMA concrete that were subjected to Marshall Properties testing.

2 Materials and Methods

2.1 Materials

2.1.1 PET

Waste plastic bottles, a PET, used for this study were procured from ARA Bahnat plastic product company, Station Road, Ede, Osun State. The main properties of plastic used in this study are presented in Table 1.

Table 1 - Dissolved Plastics Bottles Properties

Property	Details
Plastic type	Pelletized Plastic Water Bottles
Plastic material	High Density Polyethylene (HDPE)
Viscosity (*secs*)	48.50
Density (g/cm^3)	1.38
Melting point (°C)	260.00
Boiling Point (°C)	350.00
Specific gravity	0.90

2.1.2 Bitumen

The bitumen used in this investigation was obtained from Reynolds Construction Company Ltd, Lagos-Ibadan Expressway, Oyo state. It was classified as VG-30 which is known as viscosity grade as per [14] equivalent to 60/70 penetration grade bitumen. It has specific gravity of 1.021, its density ranges between 0.95 and 1.00 kg/lit.

2.1.3 Sasobit

The sasobit (Synthetic Hard Wax. WMA Additive) used in this study was obtained from Reynolds Construction Company Ltd, Lagos-Ibadan Expressway, Oyo state.

2.1.4 Aggregates

Aggregates used were obtained from Reynolds Construction Company Ltd, Lagos-Ibadan Expressway, Oyo state. The filler used was also obtained from crushed granite using particles that are finer than 75 μm. The combined particle size distribution of the fine, coarse and mineral filler is presented in Figure 1. The fine aggregate is classified as fine grained aggregates that is poorly graded while the mineral filler and coarse aggregates as a well graded material. The aggregate used (grading envelope) satisfied other requirements of BS 812 specifications.

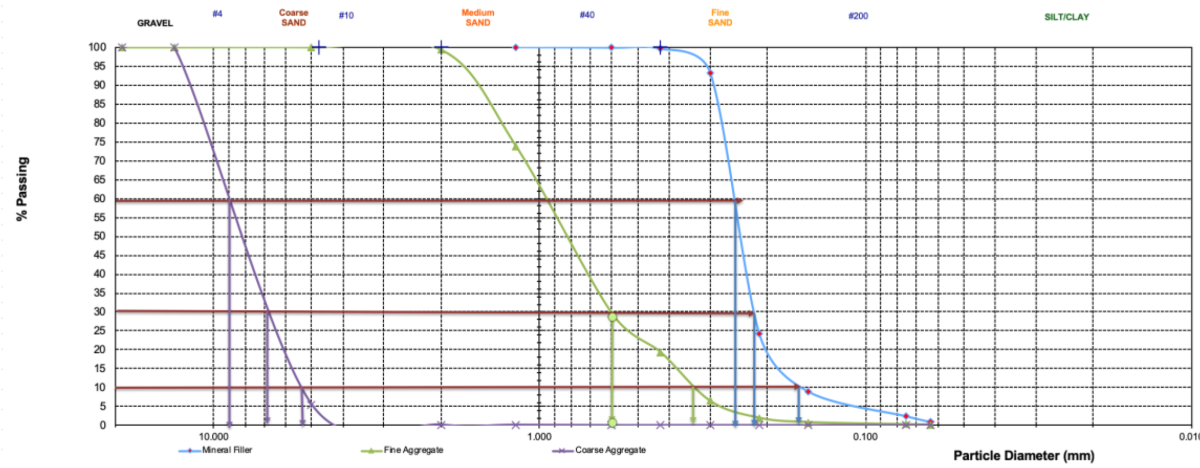

Fig. 1 – Coarse and mineral filler

The other test properties used for evaluating the coarse aggregate include physical and mechanical tests and summarized as presented in Table 2. It was clearly shown that all desired properties are satisfactory with the chosen aggregate for this study.

Table 2 - Physical and Mechanical Test of Coarse Aggregate

Test carried out	Obtained Test Results	Standard (Nigerian)	Remarks
Aggregate Impact value	19.2%	30% maximum	Adequate
Aggregate Crushing value	42.4%	45% maximum	Adequate
Los Angeles Abrasion	48.92	60% maximum	Adequate
Flakiness Index	28.62	30% maximum	Adequate
Elongation Index	29.53	30% maximum	Adequate
Density	1500.20 kg/m^3	NA	Adequate
Specific Gravity	3	3 Maximum	Adequate

2.2 Methods

Waste PET bottles were pelletized by hand using scissors. Pelletized waste plastic bottle was fed into pyrolysis machine in order to get it dissolved before being blended with straight-run bitumen. The study adopted usage of PET, dissolved plastic bottles, with different contents (1, 3, 5, 7, 9, 11, 13, 15 and 17% by the weight) to replace an equivalent portion of bitumen.

(a) Marshall samples for testing

(b) samples of shredded plastic bottle

(c) Modified Bitumen samples

(d) Fine aggregate for asphalt concrete production

(e) Coarse aggregate for asphalt concrete production

(f) Filler used for asphalt concrete Production

Fig. 2 – Preparation and Testing of samples.

Sasobit was used as an additive to produce the warm mix bitumen at a constant rate of 3% by weight of bitumen. A 3-percent-addition of Sasobit yields the best results when aiming at a maximum temperature reduction of 30°C. A total of 10 *kg* pure bitumen was weighed into ten (10) different containers for modification. Processed dissolved plastic bottle was weighed and added to the bitumen for 1-17% by weight of bitumen at 2% interval leaving a sample without PET modification as control. The samples were heated for uniformity in mixes. Each samples were further divided into two halves while 3% Sasobit was added to one part of the samples to produce modified warm bitumen blend. The total number of the samples prepared was twenty (20).

Ductility, penetration, softening point, viscosity, flash and fire point and specific gravity tests were conducted on prepared hot and warm bitumen blends in accordance with [14] [14-19 and 21] respectively.

In the preparation of asphalt mixes, the materials successfully tested for compliance as enumerated in Figure 1 and Table 2 were selected. The practical combination done by analytical approach is such that the specified percentages of the aggregates should be combined in such a way that the entire mixture of aggregate falls within the specified grading standard envelope by [22]. The binder content within 5 to 8.0 % at 0.5 % intervals for hot and warm mix was applied for the Marshall testing programme. The procedure enables the development of the trend of the bitumen content as strength and other properties were inter related, which was used to determine the respective optimum binder content (OBC) for the production of the mixes. The obtained OBC were used for the production of samples for the determination of Stability and flow at OBC. The actual testing of each pair of specimen under the Marshall machine was conducted at interval of two minutes as much as possible in accordance with [20]. In other words, at the end of the 30 minutes curing in the hot water (600C), the samples were removed, one after the other allowing the desired 2 minutes' intervals. The highest load to failure of Marshall Specimen, the stability (in kg), and the rate of deformation (in mm) were read appropriately from the loading and flow gauge respectively. Figure 2 shows some picture of the sample preparation and testing for both bitumen and asphalt concrete.

3 Results and Discussion

3.1 Penetration Values

The penetration of bitumen as affected by increase in DPB addition is clearly displayed in Table 2 for hot bitumen blends and Table 3 for warm bitumen blends. The result shows that the consistency and penetration values of plain bitumen decrease on increase of the DPB content for both hot and warm blends. The penetration values for 0, 1, 3, 5, 7, 9, 11, 13, 15 and 17% DPB addition were 77, 75, 73, 71, 67, 61, 56, 52, 45 and 40 mm for hot blend and 77, 71, 69, 68, 68, 64, 61, 58, 52 and 49 mm for warm bitumen blend respectively. The results also showed that the addition of DPB makes the modified bitumen harder and more consistent than plain bitumen which results in improvement in the rutting resistance of the mix. This mix can be suitably used in hotter climatic conditions, especially in the regions where temperature differential is substantially higher. Going by the FMW and ASTM standard specifications (60-70 mm), DPB can be used up to 9% in hot while up to 11% in warm bitumen mixes.

3.2 Softening Point

The softening point is a measure of the temperature at which bitumen begins to show fluidity. Tables 3 and 4 showed that softening point increases with DPB content for both hot and warm blends. The results clearly showed the addition of DPB in the hot bitumen blend increases the softening point value from 47ºC for plain bitumen to 94ºC for DPB modified bitumen. In warm bitumen blends, the softening point increases up to 7% DPB before it started decreasing from 9 to 17%. The increment in the value indicates that the resistance of the binder to the effect of heat is increased and it will reduce its tendency to soften in hot weather. Thus, with the addition of DPB the modified binder will become less susceptible to temperature changes. The study carried by [15] indicated that in case of hot rolled asphalt the rate of rutting in the wheel tracking test at 45°C was halved when softening point increased by approximately 5ºC.

3.3 Ductility

The effect of DPB on ductility value of bitumen and the variation of ductility values with the various percentages of modified hot bitumen blends is clearly shown in Tables 3 while that of warm bitumen blends is shown in Table 4. The observation data shows that ductility of plain bitumen decreases with the addition of DPB for both hot and warm blend. It ranges from 90 to 38cm for hot blends while from 90 to 67 cm for warm blends. For 1-17% DPB addition, the decrease in the ductility values were observed as 1.11, 2.25, 11.50, 6.50, 9.72, 10.7, 10.3, 11.53 and 17.40% in hot blends while, 7.78, 11.11, 12.22, 12.22, 14.44, 17.78, 21.11, 22.22 and 25.56% were observed for warm blends as compared to the plain bitumen respectively. Both hot and warm DPB modified bitumen blends satisfied the ductility requirements of ≤100cm [22] and 5 – 100cm [24]. However, warm blends show more ability to undergo significant plastic deformation before rupture than hot modified bitumen blends due to higher values of ductility.

3.4 Viscosity

Table 3 and 4 showed the effect of DPB on viscosity of bitumen and the variation in viscosity with the addition of DPB. It was observed that on addition of DPB, the viscosity of plain bitumen increases from 76 to 98 secs for hot bitumen blends but decreases 75 to 65 secs for warm bitumen blend. The decrease in the viscosity value of warm bitumen blends could be due to the addition of Sasobit. Moreover, the BIS code specified that viscosity of bitumen should be greater than or equal to 70 secs. The values obtained for both hot and warm mixtures satisfied this condition except for 15 and 17% DPB addition in warm bitumen blend. This is in line with assertion of

3.5 Flash and Fire Points

Flash and fire point of VG-30 bitumen is generally observed between 255 to 308^{0}C respectively. From the present investigation, it has been observed that both the flash point and fire point of the blend (PB+1-17% DPB) increases as the percentage of DPB increases (Table 3) for hot bitumen blend but slightly decreases (Table 4) for warm bitumen blend. The decrease in the flash and fire point value of warm bitumen blend could be due to the addition of sasobit. However, the results of both hot and warm bitumen blends satisfied the minimum requirement given in ASTM standard. There will be a linear relationship between flash and fire point and the addition of DPB.

3.6 Specific Gravity

The specific gravity of bitumen as affected by increase in DPB addition is clearly displayed in Table 3 for hot bitumen blend and Table 4 for warm bitumen blend. The values ranges from 0.96 to 1.03 for both hot and warm modified bitumen blends. These values satisfied the requirement of ASTM standard.

Table 3 - Properties of DPB Modified Hot Bitumen blend

% PET	Penetration (*mm*)	Softening (ºC)	Ductility (*cm*)	Viscosity (*secs*)	Flash Point (ºC)	Fire Point (ºC)	Specific Gravity
0	77	47	90	76	255	308	0.96
1	75	53	89	78	256	311	0.96
3	73	57	87	79	262	316	0.97
5	71	59	77	82	267	319	0.98
7	67	62	72	84	276	321	0.99
9	61	67	65	86	279	325	1
11	56	72	58	88	286	329	1.01
13	52	78	52	90	290	336	1.01
15	45	84	46	96	295	344	1.02
17	40	94	38	98	298	346	1.03
FMW	60-70	48-56	≤100	-	Min.250	-	1.01-1.06
ASTM	60-70	47-58	-	-	Min. 230	-	0.97-1.06
BIS	-	-	≥75	≥70	-	-	-
AI	-	>50	5-100	-	-	-	≥ 1

N.B.: FMW is Federal Ministry of Works (2016); ASTM is American Society of Testing and Materials, D5-97 for penetration, D36-95 for softening, and D2041 for specific gravity; BIS is Bureau of Indian Standards (1986); and AI is Asphalt Institute (1991).

Table 4 - Properties of DPB Modified Warm Bitumen Blend

% PET	Penetration (*mm*)	Softening (ºC)	Ductility (*cm*)	Viscosity (*secs*)	Flash Point (ºC)	Fire Point (ºC)	Specific Gravity
0	77	47	90	74	255	308	0.96
1	71	54	83	75	254	307	0.98
3	69	51	80	74	251	306	0.99
5	68	51	79	74	251	306	1
7	68	51	79	73	250	305	1.01
9	64	50	77	73	250	305	1.01
11	61	49	74	72	250	305	1.02
13	58	46	71	70	249	303	1.03
15	52	44	70	65	245	302	1.03
17	49	42	67	65	244	302	1.03
FMW	60-70	48-56	≤100	-	Min.250	-	1.01-1.06
ASTM	60-70	47-58	-	-	Min. 230	-	0.97-1.06
BIS	-	-	≥75	≥70	-	-	-
AI	-	>50	5-100	-	-	-	≥ 1

N.B.: FMW is Federal Ministry of Works (2016); ASTM is American Society of Testing and Materials, D5-97 for penetration, D36-95 for softening, and D2041 for specific gravity; BIS is Bureau of Indian Standards (1986); and AI is Asphalt Institute (1991).

3.7 Determination of Optimum Bitumen Content for Polymer-Modified HMA and WMA

The summary of Marshall Test results of hot bitumen blend at different proportion of Dissolved Plastic Bottle for the determination of OBC design mix is presented in Table 5.

Table 5 - Determination of Optimum Binder Content (OBC) of HMA

% DPB	Stability (kN)	Flow (mm)	Vol. of Void (%)	Void filled with Bitumen (%)	G. M.	Specific Gravity	Optimum Bitumen Content (%)
0	31.34	12.44	4.471	76.21	2.389	0.97	6.1
1	28.22	11.66	2.209	65.59	2.221	0.97	5.2
3	36.60	10.88	3.628	79.91	2.304	0.97	6.3
5	41.80	10.70	5.860	70.46	2.253	0.98	6.2
7	51.40	9.68	6.540	71.79	2.241	0.99	5.5
9	51.80	9.80	8.710	62.29	2.191	1.00	6.7
11	43.80	10.46	4.119	77.04	2.306	1.01	5.4
13	40.00	8.80	5.570	70.81	2.271	1.01	6.4
15	41.00	10.36	7.621	66.35	2.224	1.02	6.0
17	38.40	11.64	8.350	61.24	2.210	1.03	6.4

Likewise, the results of the corresponding Marshall properties for the DPB modified warm mix asphalt for the determination of optimum binder content are shown in Table 6.

Table 6 - Determination of Optimum Binder Content (OBC) of WMA

% PET	STABILITY (*kN*)	Flow (*mm*)	Vol. of Void	Void filled with Bitumen	G. M.	SG (Bitumen)	Optimum Bitumen Content (%)
0	31.34	12.44	4.471	76.210	2.389	0.97	6.1
1	47.00	10.00	4.170	77.650	2.289	0.97	5.8
3	53.20	8.46	3.508	80.133	2.307	0.97	6.1
5	37.80	7.08	3.505	79.950	2.310	0.98	6.0
7	38.00	7.42	3.862	79.103	2.305	0.99	6.1
9	37.00	8.86	3.975	77.991	2.305	1.00	5.7
11	44.00	9.05	2.948	82.728	2.334	1.01	5.6
13	42.40	8.40	4.994	73.452	2.285	1.01	5.6
15	25.40	8.28	6.812	67.629	2.245	1.02	6.0
17	30.40	7.80	6.156	68.608	2.263	1.03	6.2

3.8 Marshall Properties of DPB Modified HMA and WMA Concrete

3.8.1 Stability

Figure 3 presented the results of stability of both HMA and WMA. The figure shows that the stability of HMA increases as the amount of DPB increases up to a maximum level of 11% before it started decreasing. Similarly, for WMA, the stability increases as the amount of DPB increases up to a maximum level of 7% before it started decreasing from 9 to 17% DPB addition. This shows that to get highest stability, DPB can be used up to 11% in HMA and 7% in WMA. Although, the stability values of WMA were higher than HMA in most replacement levels. The stability of both HMA and WMA satisfied the FMW (≥3.5) and AI (≥9) requirements.

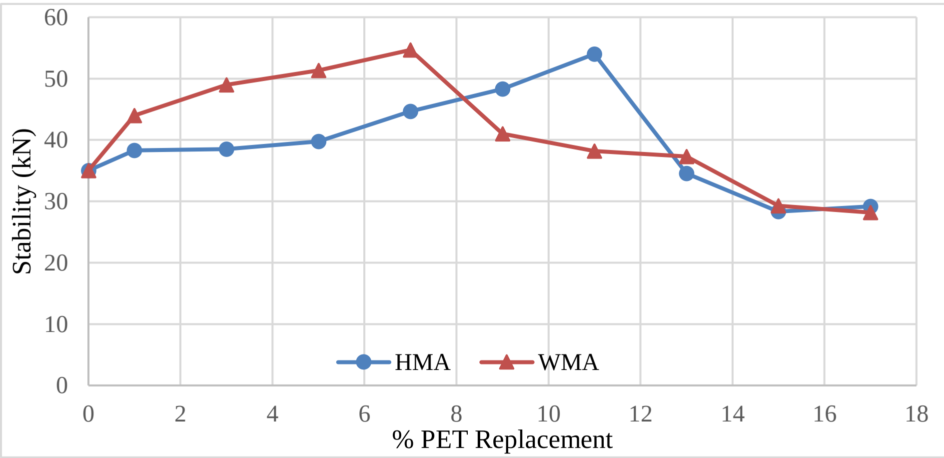

Fig. 3 - Stability of HMA and WMA

3.8.2 Flow

The results of the flow are shown in Figure 4. The flow of 11.00, 10.47, 10.13, 8.63, 10.53, 10.40, 9.37, 12.27 and 10.70 were obtained for HMA while 9.17, 9.23, 9.47, 8.70, 7.20, 5.43, 9.20, 12.13 and 12.20 were obtained for WMA for 1, 3, 5, 7, 9, 11, 13, 15 and 17% DPB addition respectively. This showed that the flow values decrease from 0 to 7% DPB addition for HMA before increasing again but the highest flow was at 15% DPB. In the case of WMA, the flow values were lower than that of HMA. It decreases up to 11% DPB addition before increasing to a maximum of 12.2 mm at 17% DPB addition level. However, the flow for both HMA and WMA satisfied the requirement of 8 – 16 mm flow stated in AI standard.

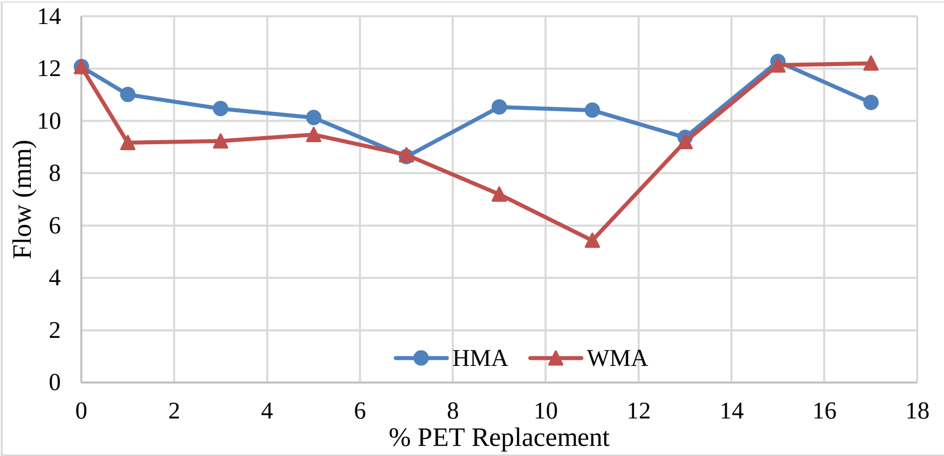

Fig. 4 - Flow of HMA and WMA

3.8.3 Stiffness

Figure 5 presented the results of stiffness of both *HMA* and *WMA* concrete. Comparing the results, it could be seen that the values of WMA were significantly higher than those for *HMA*. The stiffness values obtained for HMA at 0, 1, 3, 5, 7, 9, 11, 13, 15 and 17% *DPB* were 2.90, 3.48, 3.68, 3.93, 5.18, 4.59, 5.19, 3.69, 2.31 and 2.90 *kN*/*mm* while that of *WMA* were 2.90, 4.80, 5.31, 5.42, 6.28, 5.69, 7.03, 4.06, 2.41 and 2.90 *kN*/*mm* respectively. This means that *DPB* modified *WMA* can resist deformation in response to applied force more than the *DPB* modified *HMA*. The optimum stiffness for both mixes was obtained at 11% *DPB* addition.

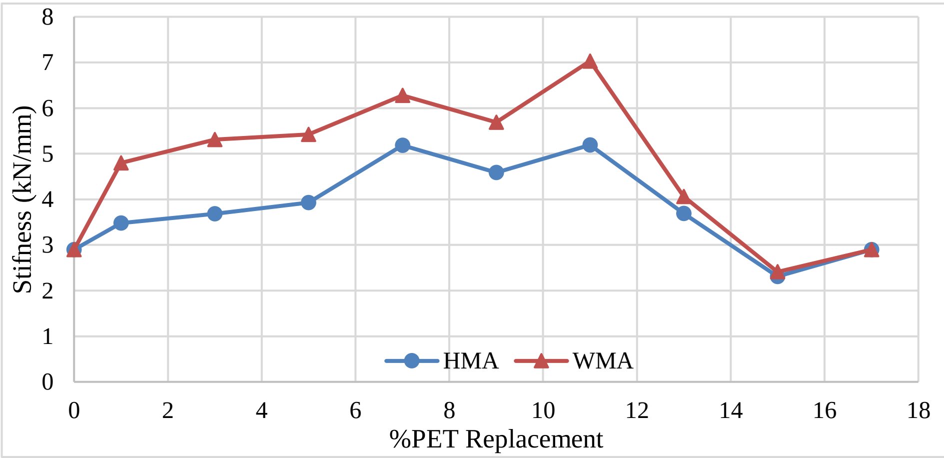

Fig. 5 - Stiffness of HMA and WMA

3.8.4 Volume of Voids, Void Filled with Bitumen and Bulk Specific Gravity

The results of volume of voids is presented in Figure 6. Figure 7 shows the values obtained for void filled with bitumen while Figure 8 gave the bulk specific gravity of both HMA and WMA concrete. The volume of voids was at its peak at 5% DPB for HMA while at 3% for WMA (Figure 6). The minimum volume of voids was at 17% and 7% for HMA and WMA respectively. The FMW specified 3-8% while AI specified 3-5% volume of voids. The WMA meet the requirements of the stated standard for all the DPB addition levels while only 17% DPB addition failed to meet up with the requirement in HMA.

The void filled with bitumen in HMA were 64.39, 82,94, 63.47, 65.19, 68.89, 81.13, 72.73, 79.63 and 14.58% while that of WMA were 63.96, 55.66, 61.32, 82.79, 60.29, 66.71, 58.63, 70.70 and 60.91% for 1, 3, 5, 7, 9, 11, 13, 15 and 17% DPB respectively (Figure 7). However, FMW specified 65-82% while AI specified 65-80% void filled with bitumen. This indicated that, 1, 5, and 17% DPB addition failed to meet the requirement in HMA while 1, 3, 5, 9, 13 and 17% DPB addition failed to meet the requirement in WMA respectively. The bulk specific gravity (Figure 8) ranged from 2.18 to 2.36 in HMA while 2.18 to 2.32 in WMA. The specific gravity of HMA were slightly higher than those of WMA.

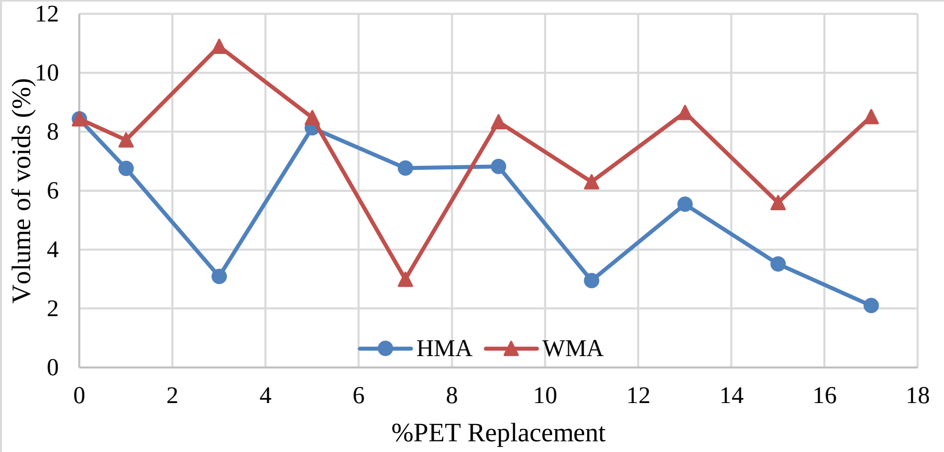

Fig. 6 - Volume of voids of HMA and WMA

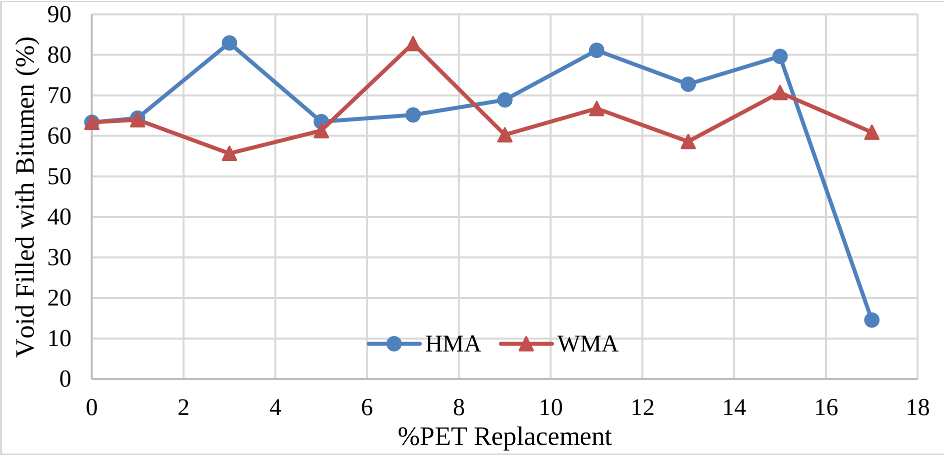

Fig. 7 - Void Filled with Bitumen of HMA and WMA

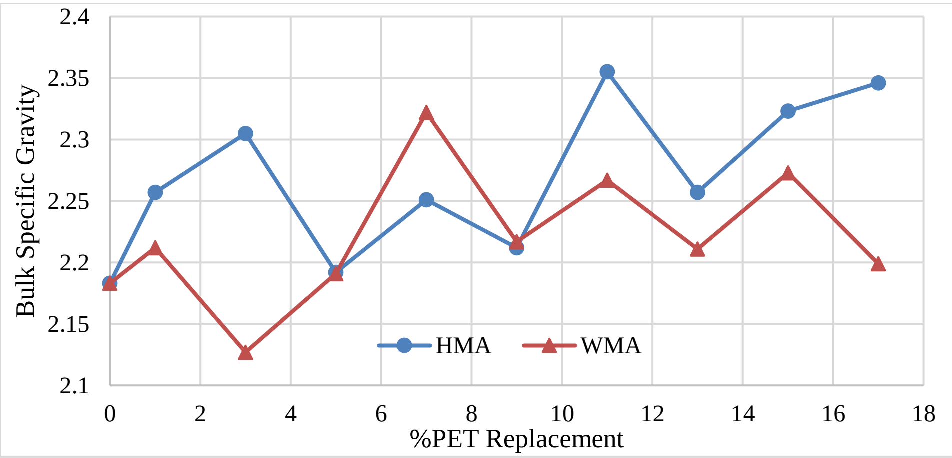

Figure 8 - Bulk Specific Gravity of HMA and WMA

4 Conclusion

Evaluation of the performance of Hot and Warm mix asphalt with dissolved plastic bottle modified bitumen was carried out to produce a new product (WMA apart from HMA) on a laboratory scale modified with a dissolved PET in the fluidal form as against the benefits over hot mix asphalt modified either in powdery, pelletized, shredded or crystallised forms. Proportions of 1, 3, 5, 7, 9, 11, 13, 15 and 17% of DPB were blended with 60/70 PEN grade bitumen to produce hot and warm dissolved plastic bottle modified bitumen. The produced binders were subjected to ductility, penetration, softening point, viscosity, flash and fire point and specific gravity tests to understand the effect of this modification. Also the binders were used in preparing HMA and WMA concrete at OBC respectively. Marshall Properties (stability, flow, stiffness, volume of void, void filled with bitumen and bulk specific gravity) were evaluated on Hot and Warm mix asphalt concrete produced. Results revealed that addition of DPB (0 – 17%) increased the softening point, viscosity, specific gravity, flash and fire points of both hot and warm modified bitumen blends but decreased their penetration and ductility. The obtained OBC of the DPB modified hot and warm mixes up to 17% modifier additions were in the range of 5.4-6.7, all within the specification requirements. Addition of DPB improve the stability, flow and stiffness up to 13% for both HMA and WMA concrete. Marshall Stability, Flow and Stiffness at optimum binder modifier were 54.67 *kN*, 8.70 *mm*) and 6.28 *kN*/*mm* for the WMA and 54.00 *kN*, 10.40 *mm* and 5.19 *kN*/*mm* for the HMA. However, the Marshall Stability and flow of all asphalt concrete mixtures satisfied the requirements of both Nigerian General Specification for Road and Bridges, Federal Ministry of Works and Housing, 2016 and Asphalt Institute, 1991. Meanwhile, DPB modifier performed better in WMA than HMA concrete. It can be concluded that dissolved plastic bottle is a suitable material for both WMA and HMA modifications as it improved the performance characteristics of both asphalt mixes.

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