Global Journal of Engineering and Technology Advances, 2020, 03(02), 019–027

Global Journal of Engineering and Technology Advances

Cross Ref DOI: 10.30574/gjeta

Journal homepage: http://www.gjeta.com

(RESEARCH ARTICLE)

A performance characteristic models of properties of dissolved plastic bottle modified bitumen for hot mix asphalt production

Akinleye Monsuru Tunde [1,*], Jimoh Yinusa Alaro [2] and Laoye Abdulrahman Adewale [3]

[1]*Department of Civil Engineering, Adeleke University, Ede, Nigeria.*
[2]*Department of Civil Engineering, University of Ilorin, Ilorin, Nigeria.*
[3] *Research Department, Tetragrammaton Construction Company Limited, Ibadan, Nigeria.*

Publication history: Received on 20 April 2020; revised on 03 May 2020; accepted on 04 May 2020

Article DOI: https://doi.org/10.30574/gjeta.2020.3.2.0025

Abstract

This paper investigated the effect of recycling Polyethylene Terephthalate (PET) waste bottles in dissolved (liquid) miscible forms (1, 3, 5, 7, 9, 11, 13, 15 and 17% by the weight) on the properties of standard straight-run grade bitumen. Classification, strength & safety compliance properties were carried out, according to provisions of standard testing procedures, at different percentages of (0-17) dissolved PET. Quantitative explanation of models for the trend of the variation of these properties were developed for each property with respect to % PET. Models were later compared with the corresponding statistic. The developed models for ductility, penetration, softening point, viscosity, flash and fire points, and specific gravity of the modified bitumen were -2.185(%PET) + 79.399, 2.456(%PET) + 47.401, -3.149(%PET) + 92.909, 1.244(%PET) + 75.622, 2.6801(%PET) + 254.69, 2.2036(%PET) + 307.65 and 0.0042(%PET) + 0.9589 with R^2 values of 0.976, 0.969, 0.992, 0.976, 0.9917, 0.9774 and 0.9881 respectively. Results revealed that addition of PET (0 – 17 %) increased the softening, viscosity, specific gravity, flash and fire points of bitumen but decreased the penetration and ductility. It is concluded that PET can be used to improve the classification properties only but less for the mechanical properties of asphalt binder. However, satisfactory values which are in conformity with Nigerian, American and British standard specifications can be met at % PET of ≥2.01, ≥3.52, 11.09 – 14.58, 4.92 – 9.20, ≥1.98, ≥5.60, and ≥9.79 for ductility, viscosity, softening point, penetration, flash point, fire point and specific gravity respectively.

Keywords: Performance Characteristic; Dissolved Plastic polymer; Modified bitumen; Hot bitumen blend.

1. Introduction

Highway networks comprise hundred millions of lane-kilometers and accommodating millions of vehicle-kilometers each year in the world [1]. Assessment of the quality of asphalt concrete used in road construction in Nigeria suggested that the quality of asphalt need to be improved because of the premature failure of road pavements in the country. Modification of hot mix asphalt (HMA) pavements material is an essential objective in addressing surfacing material quality. It increases its performance and service life and decreases its maintenance cost [2, 3]. Several traditional additives have been used in modification of HMA with promising returns [4 – 15]. However, using these traditional additives adds supplementary cost. Besides in recent times, there is a revolution in deployment of waste materials in modification of HMA with additional advantage for environmental hazard management, especially with polyethylene, a plastomeric polymer [16, 17].

Due to increase in population, urbanization, development activities, and changes in life style, there is an enormous rise in the generation of plastic wastes which in turn makes the solid waste management as one of the major environmental concerns worldwide. These plastics are disposed in an uncontrolled manner, because of the noticeable rapid depletion of sites available for waste disposal, causing major environmental problems [18]. Therefore, using the Polyethylene

* Corresponding author: Akinleye Monsuru Tunde

Terephthalate (PET) in the modification of HMA can promote sustainable construction, especially when referring to the fact that HMA is one of the most used construction materials for the huge volumes of highway projects. A number of researches were performed in this domain [19, 20]. Pimpan *et al.* [18] with [21] studied the performance of PET modifier of stone mastic asphalt as flexible pavements [22 – 24].

Indeed, the statistics of various performance studies indicates that useful life of bituminous pavement overlay with traditional non-modified binders has declined from average value of 6 – 8 years in the past to about 3 – 5 years in recent years. It is well known that under the prevailing heavy traffic and extreme climatic conditions, overlays made up of traditional bituminous binders, in general, are not meeting the durability requirements. On the other hand, polymer modified bitumen (PMB) known as higher performance binder, allows the design and build of durable bituminous surface. These higher performance binders have better field performance, and are economical, when life cycle cost is taken into consideration [18 – 20].

In many of these studies, attempt was made to investigate the use of plastic bottles in the modification of bitumen in different shapes and states of matter. A series of tests was performed on specimens prepared with plastic waste and bitumen. Results showed that the increase in percentage of polymer causes some improvement in the physical properties of bitumen. Rokade [25] studied the comparative use of plastic waste and waste rubber tyres, both non-degradable, in flexible pavements. The semi dense bituminous concrete (SDBC) was prepared by Marshall Method using viscosity grade (VG)-30 grade bitumen and the various mix design characteristics were calculated. The author observed that with 5 % bitumen content, higher value of Marshall stability and density was achieved. An experimental program to study the improvement in the strength of flexible pavement by adding plastic waste in different percentages was conducted by [26]. It was observed that 10 % of bitumen can be replaced by plastic waste in bituminous layer for satisfactory performance.

However, the research in above enumerated domain were essentially with respect to the polymer in solid, grinded (dry) powder and pellet forms. However, there is need to extend to cover more effects of PET on the engineering properties of bituminous mixtures when in dissolved liquid forms. Therefore, this study aims to fill the gaps left in the other researches through adoption of dissolution of waste plastic bottle (PB), an example of a polymer using pyrolysis method to convert it to miscible liquid with bitumen. The PET waste plastic bottles are greatly available everywhere. This paper showed that pyrolysis is the best way of modifying bitumen with waste plastic bottles and upon addition of PET (0 – 17%), the softening, viscosity, specific gravity, flash and fire points of bitumen increased while the penetration and ductility decreased.

2. Material and methods

2.1. Materials

The materials used for this research were PET and bitumen. They are explicitly discussed below.

2.1.1. PET

This is the most used thermoplastic polyester. PET is an acronym for a long-chain polymer belonging to the generic group of polyesters and also a semi-crystalline, thermoplastic polyester [27]. It is a semi-crystalline polymer with high tensile strength, high chemical resistance, and melting point of 260 ± 10 ^{o}C [28]. PET bottles, in this study, were procured from Ara Bahnat plastic product company, Station Road, Ede, Osun State. The main properties of plastic and bitumen used in this study are presented in Table 1.

2.1.2. Bitumen

The bitumen used in this investigation was obtained from the stocks of Messrs Reynolds Construction Company Ltd, the contractor currently undertaking the rehabilitation of the Lagos-Ibadan Expressway, Oyo state, Nigeria. It was classified as VG-30 as per [29], equivalent to 60/70 penetration grade bitumen. It has specific gravity of 1.021, density ranges between 0.95 and 1.00 kg/lit, and presently used as a binder in the present civil/road works project.

Table 1 Waste Plastics and Bitumen Properties

PROPERTY	DETAILS		
	PLASTIC BEFORE SHREDDING	PLASTIC AFTER SHREDDING	BITUMEN
Type	Plastic bottle	Pelletized plastic water bottles	VG-30
Colour	White	White	Black
Material	High density Polyethylene (HDPE)	High density Polyethylene (HDPE)	
Size (mm)		15.00 – 25.00	
Density (g/cm^3)	1.38	1.38	0.98
Melting point (°C)	260	260	-
Penetration	-	-	60-70 dmm
Temperature	-	-	25°C

2.2. Methods

Waste PET bottles were pelletized by hand using scissors to 15 – 25 mm in length, diameter of 63 mm and thickness of 0.1 mm. 50 kg of pelletized waste plastic bottle were fed into pyrolysis machine at a temperature of 450 °C to produce a mass of 42 kg of pyrolysed liquid before being blended with straight-run bitumen. The study adopted usage of PET waste bottles with different contents (1, 3, 5, 7, 9, 11, 13, 15 and 17 % by the weight) to replace an equivalent portion of bitumen. The following tests were conducted to investigate the effects of PET on the properties bitumen as described in the following subsections:

- Classification test: These are penetration and specific gravity tests.
- Strength (mechanical) test: These are ductility, penetration, softening point and viscosity tests.
- Safety compliance test: These are flash point and fire point tests.

2.2.1. Classification test

Penetration Test

The test determines the hardness of bitumen by measuring the depth (one hundredths of a mm) to which a standard, and loaded needle will vertically penetrate in 5 seconds, in a sample of bitumen and at room temperature. The test was carried out in accordance with the procedure laid down in [30].

Specific Gravity Test

The test is a fundamental test frequently required in classing binders for paving jobs. It is also used in identifying the source of bitumen binder and in making volume corrections based on temperature. This test is carried out at a temperature of 25 °C. The test was carried out in accordance with [31].

2.2.2. Strength (mechanical) test:

Ductility Test

The Ductility test is an empirical test which measures the cohesive strength of bitumen and its ability to stretch. The test was conducted as per [32].

Softening Point Test

The softening point is an empirical test and denotes the temperature at which bitumen would behave more like a liquid and less like a solid under standard conditions of heating and loading. The test was conducted as per [33].

Viscosity Test

Viscosity is a fair indicator of the ability of bitumen to coat the aggregates properly. In order to get best coating the viscosity has to be optimum. Too viscous bitumen would result in inadequate and non-uniform coating of the aggregates.

Very low viscosity would again result in inadequate coating as the bitumen will tend to bleed. Therefore, viscosity at 135 °C is a true reflection of the quality of bond that is likely to be formed with the aggregate. The test was conducted as per [29] by using tar viscometer with 10 mm orifice.

2.2.3. Safety compliance test:

Flash and Fire Point Tests

Bituminous materials leave out volatile gases at high temperatures depending upon their grade. These volatile vapour catch fire causing a flash. This condition is very hazardous and it is therefore, essential to check this temperature for each bitumen grade, so that the paving engineers may restrict the mixing or application temperatures well within the limits. The tests were conducted as per [34] respectively.

3. Results and discussion

The results of ductility, penetration, softening point and viscosity were presented in Figure 1 while that of flash and fire point were presented in Figure 2 and Table 2.

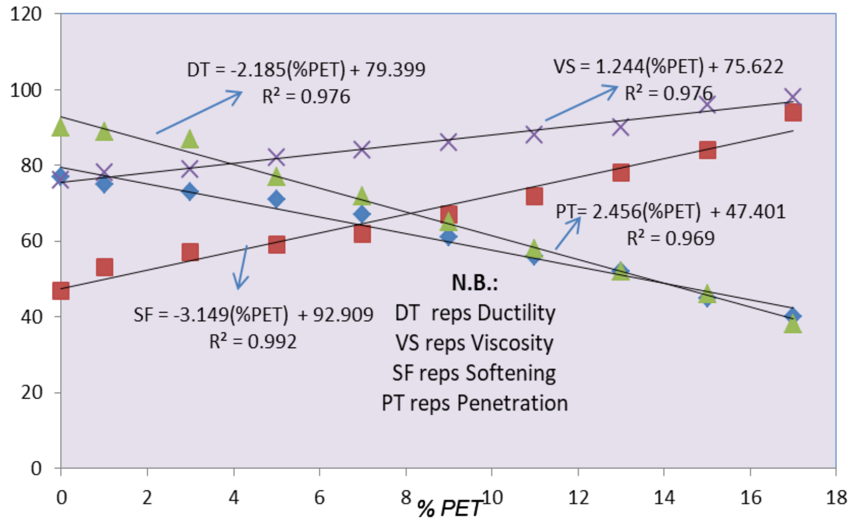

Figure 1 Influence of % PET on Ductility, Penetration, Softening Point and Viscosity of Modified Bitumen

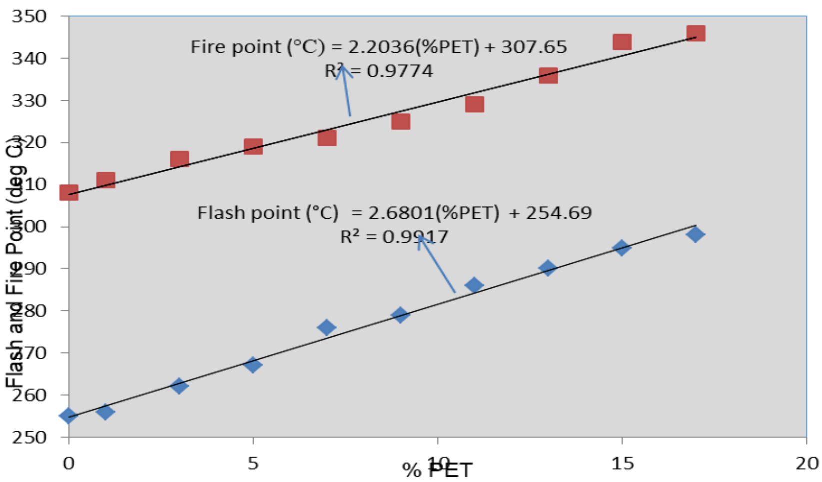

Figure 2 Influence of % PET on the Flash Point and Fire Point of Modified Bitumen

Table 2 Properties of DPB Modified Bitumen

% PET	Penetration (mm)	Softening (°C)	Ductility (cm)	Viscosity (secs)	Flash Point (°C)	Fire Point (°C)	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	1.00
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	-	-	-	-	-	-
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; ASTM is American Society of Testing and Materials, D5-06 for penetration, D36-06 for softening, and D70-03 for specific gravity; BIS is Bureau of Indian Standards; and AI is asphalt institute.

3.1. Effect of PET on Ductility of Bitumen

Figure 1 shows the effect of PET on ductility value of bitumen and the variation of ductility values with the various percentages of bitumen modified PET. The observation data shows that ductility of plain bitumen decreases with the addition of PET. The decrease in the ductility values were observed as 1, 3, 13, 18, 25, 32, 38, 44 and 52 cm on addition of PET from 1-17 % respectively, as compared to the plain bitumen. The model developed for the ductility of the modified bitumen is given in Eq. 1 and the critical %PET must not be less than 2.01 % for a ductility ≥ 75 mm from Bureau of Indian Standards (1986) specification as given in Table 3.

$$DT = -2.185(\%PET) + 79.399 \qquad eq. 1$$

Table 3 Optimum %PET of Strength Properties of Hot mix Bitumen

Properties	%PET	Critical %PET
Ductility (cm)	≥ 2.01	> 2.01
Viscosity (secs)	≥ 3.52	> 3.52
Softening point (°C)	11.09 – 14.58	14.58
Penetration (mm)	4.92 – 9.20	9.20
Flash point (°C)	≥ 1.98	> 1.98
Fire point (°C)	≥ 5.60	> 5.60
Specific gravity	≥ 9.79	> 9.79

3.2. Effect of PET on Penetration Values of Bitumen

The penetration of bitumen as affected by increase in PET addition is clearly displayed in Figure 1. The result shows that the consistency and penetration values of plain bitumen decrease on increase of the PET content. The decrement is about 2, 4, 6, 10, 16, 21, 26, 32 and 37 mm with the addition of 1, 3, 5, 7, 9, 11, 13, 15 and 17 % of PET respectively, as compared with the plain bitumen. The results also showed that the addition of PET 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. The developed model for the penetration of the modified bitumen is given below in Eq. 2 and the critical %PET is 4.92 – 9.20 % for a penetration of 60 - 70 mm given in Table 2 from Federal Ministry of Works (2012) specification.

$$PT = 2.456(\%PET) + 47.401 \qquad eq. 2$$

3.3. Effect of PET on Softening Point of Bitumen

The softening point is a measure of the temperature at which bitumen begins to show fluidity. Figure 1 shows that softening point increases with PET content. The results clearly show the addition of PET in the bitumen increases the softening point value from 47 °C for plain bitumen to 94 °C for PET modified bitumen. It has also been observed that the increase in the softening point of plain bitumen was significant when PET is added in percentages from 13 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 PET the modified binder will become less susceptible to temperature changes. The study carried by Fernando and Guirguisl [35] 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 5 °C. The model developed for the softening of the modified bitumen is given in Eq. 3 and the critical %PET is 11.09 – 14.58 % for a softening of 47 – 58 °C from American Society of Testing and Materials specification as given in Table 3.

$$SF = -3.149(\%PET) + 92.909 \qquad eq. 3$$

3.4. Effect of PET on Viscosity of Bitumen

Figure 1 shows effect of PET on viscosity of bitumen and the variation in viscosity with the addition of PET. It is observed that on addition of PET the viscosity of plain bitumen increases. The increase in the viscosity value is found to be significant when PET is added up to 13 %. It has also been observed that the increase in the viscosity values after addition of PET in the plain bitumen was up to the order of 25 to 29 secs, which indicates that the modified binder became neither too soft nor too viscous, as it was observed that if the viscosity of bitumen is too high, the binder may not completely coat the aggregate in the bituminous mixture. On the other hand, if it is too low, binder drainage is likely to occur during the storage and transportation of the mix. On the basis of the present study it can be said that the PET modified bitumen may have better workability as compared to plain bitumen. The model developed for the viscosity of the modified bitumen is given in Eq. 4 and the critical %PET must not be less than 3.52 % for a viscosity ≥ 70 secs from Bureau of Indian Standards (1986) specification as given in Table 3.

$$VS = 1.244(\%PET) + 75.622 \qquad eq. 4$$

3.5. Effect of PET on Flash and Fire Point of Bitumen

Flash and fire point of VG-30 bitumen is generally observed between 255 to 308 °C, respectively. From the present investigation, it has been observed that both the flash point and fire point of the blend (PB+1-17 % PET) increases as the percentage of PET increases (Figure 2). It has also been observed that the flash point value of plain bitumen was increased by more than 20% when PET was added beyond 13 %. The similar trend was also observed in case of fire point. The value of fire point significantly increases up to 17 % of PET. There is a linear relationship between flash and fire point and the addition of PET. The developed models for the flash and fire points of the modified bitumen are given below in Eqs. (5, 6) and the critical %PET are ≥ 1.98 % and ≥ 5.60 % for flash and fire points of ≥ 260 °C and ≥ 320 °C respectively given in Table 3.

$$Flash\ point\ (°C) = 2.6801(\%PET) + 254.69 \qquad eq. 5$$

and

$$Fire\ point\ (°C) = 2.2036(\%PET) + 307.65 \qquad eq. 6$$

3.6. Effect of PET on Specific Gravity of Bitumen

It was observed that specific gravity of the modified bitumen increases as the percentage of PET increases (Figure 3). It has also been observed that the specific gravity value of plain bitumen was increased by 1.0, 2.1, 3.1, 4.2, 5.2, 5.2, 6.3 and 7.3 % for PET addition of 3, 5, 7, 9, 11, 13, 15 and 17 % respectively but remained constant for PET addition of 1 %. The developed models for the specific gravity of the modified bitumen is given in Eq. 7 and the critical %PET is ≥ 9.79 given in Table 2 for specific gravity of ≥ 1.

$$Specific\ gravity = 0.0042(\%PET) + 0.9589 \qquad eq. 7$$

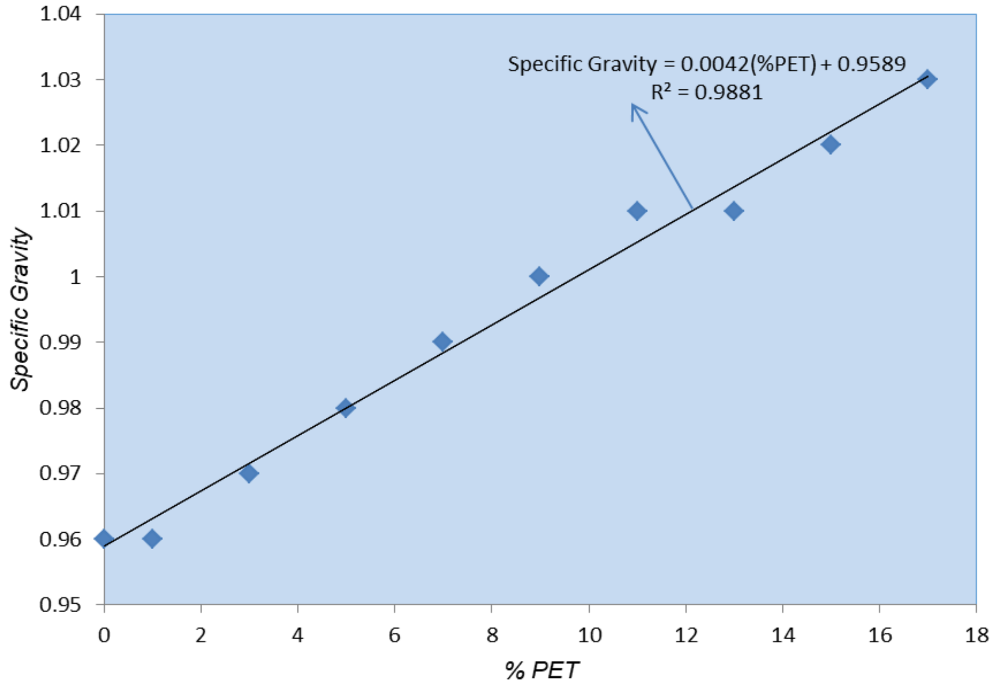

Figure 3 Influence of % PET on the Specific Gravity of Modified Bitumen

4. Conclusion

Experimental study on properties of dissolved plastic modified bitumen was carried out in order to find useful application for waste plastic bottles and extend pavement service life. Plastic bottles were pelletized and dissolved by pyrolysis. Physical, mechanical and thermal properties of modified and unmodified bitumen specimens with various proportions of PET modifier were evaluated. The results showed that addition of PET (0 – 17 %) increased the softening, viscosity, flash and fire points of bitumen but decreased the penetration and ductility of bitumen. It is concluded that PET can be used to improve the properties of asphalt binder at satisfactory values which are in conformity with American, British and Nigerian standard specifications.

Compliance with ethical standards

Acknowledgments

The authors wish to express their profound gratitude to the entire staff of Department of Civil Engineering, University of Ilorin, Ilorin, Nigeria; Department of Civil Engineering, Adeleke University, Ede, Nigeria; and the research department of Tetragrammaton Construction Company Limited, Ibadan for their immense support during materials testing, data collection and processing.

Disclosure of conflict of interest

On behalf of all authors, I, M. T. Akinleye, is hereby confirming that that there is no conflict of interest.

References

[1] Mazumder M, Sriraman V, Kim HH and Lee SJ. (2016). Quantifying the environmental burdens of the hot mix asphalt (HMA) pavements and the production of warm mix asphalt (WMA). International Journal of Pavement Research and Technology, 9(3), 190-201.

[2] Akinleye MT and Tijani MA. (2017). Assessment of quality of asphalt concrete used in road construction in South West Nigeria. Nigerian Journal of Technological Development, 14(2), 52–55.

[3] Arslan D, Gürü M and KürşatÇubuk M. (2012). Performance assessment of organic-based synthetic calcium and boric acid modified bitumen. Fuel, 102, 766-772.

[4] Tapkın S. (2008). The effect of polypropylene fibers on asphalt performance. Building and Environment, 43(6), 1065-1071.

[5] CongP, YuJ, Wu S and Luo X. (2008). Laboratory investigation of the properties of asphalt and its mixtures modified with flame retardant. Construction and Building Materials, 22(6), 1037-1042.

[6] Aksoy A, Şamlioglu K, Tayfur S and Özen H. (2005). Effects of various additives on the moisture damage sensitivity of asphalt mixtures. Construction and Building Materials, 19(1),11-18.

[7] Su N and Chen JS. (2002). Engineering properties of asphalt concrete made with recycled glass, Resources, Conservation and Recycling, 35(4), 259-274.

[8] Magadi KL, Anirudh N and Mallesh KM. (2016). Evaluation of bituminous concrete mixture properties with steel slag, Transportation Research Procedia, 17, 174-183.

[9] Cheriet F, Soudani K and Haddadi S. (2015). Influence of natural rubber on creep behavior of bituminous concrete. Procedia - Social and Behavioral Sciences, 195, 2769-2776.

[10] Tapkın S. (2013). Optimal polypropylene fiber amount determination by using gyratoy compaction, static creep and Marshall stability and flow analyses. Construction and Building Materials, 44, 399-410.

[11] M Panda, Suchimita A and Giri JP. (2013). Utilization of ripe coconut fiber in stone matrix asphalt mixes. International Journal of Transportation Science and Technology, 2(4), 289-302.

[12] Sengul CE, Aksoy A, Iskender E and Ozen H. (2012). Hydrated lime treatment of asphalt concrete to increase permanent deformation resistance. Construction and Building Materials, 30, 139-148.

[13] Karacasua M, Er A and Okur V. (2012). Energy efficiency of rubberized asphalt concrete under low-temperature conditions. Procedia - Social and Behavioral Sciences, 54, 1242-1249.

[14] Arslan D, Gürü M, KürşatÇubuk M and Çubuk M. (2011). Improvement of bitumen and bituminous mixtures performances by triethylene glycol based synthetic polyboron. Construction and Building Materials, 25(10), 3863-3868.

[15] Kok BV and Yilmaz M. (2009). The effects of using lime and styrene–butadiene–styrene on moisture sensitivity resistance of hot mix asphalt. Construction and Building Materials, 23(5), 1999-2006.

[16] Arabani M and Pedram M. (2016). Laboratory investigation of rutting and fatigue in glassphalt containing waste plastic bottles. Construction and Building Materials, 116, 378-383.

[17] Akçaözoğlu S and Atiş CD. (2011). Effect of granulated blast furnace slag and fly ash addition on the strength properties of lightweight mortars containing waste pet aggregates. Construction and Building Materials, 25(10), 4052-4058.

[18] Pimpan V, Sirisook R and Chuayjuljit S. (2003). Synthesis of unsaturated polyester resinfrompost consumer PET bottles; effect of type of glycol on the characteristics of unsaturated polyester resin. Journal of Applied Polymer Science, 88, 788-792.

[19] BaghaeeMoghaddam T, Karim MR and Syammaun T. (2012). Dynamic properties of stone mastic asphalt mixtures containing waste plastic bottles. Construction and Building Materials, 34, 236-242.

[20] Flynn E. (1993). Recycled plastic finds home in asphalt binder. Journal of Roads and Bridges, 58(2), 32-34.

[21] Ahmadinia E, Zargar M, Karim MR, Abdelaziz M and Ahmadinia E. (2012). Performance evaluation of utilization of waste polyethylene terephthalate (PET) in stone mastic asphalt. Construction and Building Materials, 36, 984-989.

[22] Ahmadinia E, Zargar M, Karim MR, Abdelaziz M and Shafigh P. (2011). Using waste plastic bottles as additive for stone mastic asphalt. Materials & Design, 32(10), 4844-4849.

[23] Rahman MN, Ahmeduzzaman M, Sobhan MA and Ahmed TU. (2013). Performance evaluation of waste polyethylene and pvc on hot asphalt mixtures. American Journal of Civil Engineering and Architecture, 1(5), 97–102.

[24] Ravi Shankar AU, Koushik K and Sarang G. (2013). Performance studies on bituminous concrete mixes using waste plastics. Highway Research Journal, 6(1), 1–11.

[25] Rokade S. (2012). Use of waste plastic and waste rubber tyres in flexible highway pavements. International Conference on Future Environment and Energy, IACSIT Press, Singapore, 28, 105-108.

[26] Rahmani E, Dehestani M, Beygi MHA, Allahyari H and Nikbin IM. (2013). On the mechanical properties of concrete containing waste pet particles. Construction and Building Materials, 47, 1302-1308.

[27] Webb HK, Arnott J, Crawford RJ and Ivanova EP. (2013). Plastic Degradation and Its Environmental Implications with Special Reference to Poly(ethylene terephthalate). Polymers, 5(1), 1-18.

[28] Ranadive MS and Tapase AB. (2012). Improvement in strength of flexible pavement: An experimental approach. Journal of Environmental Research and Development, 6(3A), 844-852.

[29] American Society for Testing and Materials. (2018). "Standard Test method for Viscosity of bituminous Materials", ASTM D2170, Philadelphia, US.

[30] American Society for Testing and Materials. (2006). "Standard Test method for Penetration of bituminous Materials, ASTM D5", Philadelphia, US.

[31] American Society for Testing and Materials. (2003). "Standard Test method for Specific Gravity and density of Semi-solid bituminous Materials (Pycnometer Method)", ASTM D70, Philadelphia, US.

[32] American Society for Testing and Materials. (1999). "Standard Test method for Ductility of bituminous Materials", ASTM D113, Philadelphia, US.

[33] American Society for Testing and Materials. (2006). "Standard Test method for Softening Point of Bitumen (Ring and Ball Apparatus)", ASTM D36, Philadelphia, US.

[34] American Society for Testing and Materials. (2002). "Standard Test method for Flash and Fire Point of bitumen by Cleveland Cup", ASTM D92, Philadelphia, US.

[35] Fernando MJ and Guirguis HR. (1984). Natural rubber for improved surfacing. Proceedings 12th ARRB conference, Part 2, 121-130.

How to cite this article

Akinleye MT, Jimoh YA and Laoye AA. (2020). A performance characteristic models of properties of dissolved plastic bottle modified bitumen for hot mix asphalt production. Global Journal of Engineering and Technology Advances, 3(2), 19-27.