International Journal of Advances in Engineering and Management (IJAEM)
Volume 2, Issue 6, pp: 371-378 www.ijaem.net ISSN: 2395-5252

The Effect and Characterization of Styrene-Butadiene (SBR), Polyethylene Bag (PEB) on the Performance of Hot Mix Asphalt

J.A. Ige[1]B.A. Ibitoye[2], S. Bello[3] and N.A. Adeyemoh[4]

[1]Department of Civil Engineering, LadokeAkintola University of Technology, Ogbomoso, Nigeria [2]Department of Civil Engineering, Kwara State University, Malete, Nigeria..
[3]Department of Materials Science and Engineering, Kwara State University, Malete, Nigeria.
[4]Department of Civil Engineering, the Federal Polytechnic Offa, Offa, Nigeria.
Corresponding author: J.A. Ige

Date of Submission: 15-09-2020 Date of Acceptance: 24-09-2020

ABSTRACT; The improper disposal of polymeric materials may cause breast cancer, reproductive problems in humans and animals, genital abnormalities and much more. This study investigates the use of styrene-butadiene (crumb rubber), polyethylene bags (pure water sachet) and combination of both as modifiers on performance of hot mix asphalt. Marshal stability, flow tests,X-ray Florescence (XRF),and Scanning Electron Microscopy (SEM) were conducted on modified asphalt (3, 6, 9, 12 and 15% bitumen modification). The results revealed that the optimum stability of the modified asphalt with SBR (42.2 kN at 12%), PEB (44 kN at 9%) and SBR/PEB (44.7 kN at 6%) were above the minimum stability value of 3.4 kN specified by standard. However, flow of SBR, PEB and SBR/PEB were above thespecified limit (2-4 mm).The microstructures of 3, 9 and 15% PEB/SBR are less porous than 3, 9 and 15% PEB, implying that hybrid of PEB and SBR as bitumen fillers gave modified bitumen with higher integrity than when PEB was used alone and it is noteworthy that recycled SBR addition gave modified bitumen with best structures. Since materials' behaviour depends on its structure, recycled SBR modified bitumen is expected to offer best performance in road surfacing than others. The study concluded that modification of bitumen using SBR, PEB, and SBR/PEB as modifier, will enhance better resistance against road rutting and fatigue cracking, therebyincreasing the lifespan of road pavement.

Keywords: Bitumen, Styrene-butadiene, polyethylene bag, Marshall Stability, SEM, XRF

I. INTRODUCTION

There is an increasing need to strengthen and extend pavement service life, because of daily increasing traffic on the highways. 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. Also, conventional grade of bitumen is not impervious enough not to allow penetration of water, because most pavement in Nigeria failed mostly during the rainy season and it has been proven not to be properly binded with the aggregates as a result low marshal stability is recorded and increase in potholes formation is possible. Additionally, ageing and deterioration may be induced by climatic and environmental factors which include moisture, temperature, irradiation and chemical attack which negatively impacts on physical and chemical properties of asphalt. The properties of conventional hot-mix asphalt such as stability, flow, unit-weight and percent air-voids are insufficient to withstand failures such as rutting and cracking, as a result of changes in climate, increase in axle wheel loads and traffic volumes (Afolayan and Abidoye, 2017).

Today availability of plastic waste is enormous. The use of plastic materials such as carry bags, cups, and so on is constantly increasing. Nearly 50% to 60% of total plastic are consumed for packing. Once used, plastic packing materials are thrown outside and they remain as waste. Plastic wastes are durable and non-biodegradable. The improper disposal of plastic may cause breast cancer, reproductive problems in humans and animals, genital abnormalities and much more. These plastic wastes get mixed with water, disintegrate, and take the forms of small pallets which cause the death of fishes and other aquatic life who mistake them as food material. Sometimes they are either land filled or incinerated. Plastic wastes get mixed with the municipal solid waste or thrown over a land area (Zhu, 2014).

According to Zolfaghariet al., (2014), bitumen are modified using additive or replacement of polymer to improve, with regards to the performance related properties such as permanent deformation and fatigue cracking. In addition, polymer additives are commonly added into bitumen and bituminous mixture in order to overcome the problems induced by temperature and trafficloading. Polymer modification of bitumen has been commonly performed in order to decrease bitumen susceptibility to high and low temperatures, allowing reduction in common failure mechanisms as rutting and cracking, (Aadilet al., 2019). Based on interest in used of polymer as bitumen modifier, this study investigatedthe effect and characterization of styrene-butadiene (SBR), polyethylene bag (PEB)and combination of SBR and PEB (based on limitations in Table 1) on the performance of hot mix asphalt.

Polyethylene Bags (PEB) is also the most popular type of plastic. Millions of metric tons of Polyethylene bags are produced every year worldwide to be used mainly in packaging. Polyethylene is durable and degrades very slowly as other plastics. Significant amount of plastics are not disposed properly but rather they are left in the environment. Green industry and recycling waste materials is a global trend nowadays. Therefore, it will be very effective to convert Polyethylene bags used in daily life from a pollutant to a useful material such as bitumen and asphalt modifier (Akinpeluet al., 2013).

Styrene-butadiene or styrene-butadiene rubber (SBR) describe families of synthetic rubbers derived from styrene and butadiene (Seyed, 2013).

Table 1: Summary of Some Previous Study

Author	Title	Conclusion	Limitation
Naskaret al., (2010)	Effect of waste plastic as modifier on thermal stability and degradation kinetics of bitumen/waste plastics blend	The study opined that performance of bitumen can be improved by addition of waste plastic.	Waste plastic was used as modifier
Kumar and Chouksey(2017)	Waste Polyethylene Use in Bituminous Paving Mixes: A Review	The study opined that Low density polyethylene (LDPE) has been found to be a good modifier of bitumen.	Reviewed Article
Hoet al., (2006)	Study of Recycled Polyethylene Materials as Asphalt Modifiers	It was found that asphalt binders modified with recycled LDPE materials performed better than those modified with low molecular PE	Polyethylene was used as modifier
Othman (2010)	Effect of Low-Density Polyethylene on Fracture Toughness of Asphalt Concrete Mixtures	Results of the study showed that asphalt binders modified with LDPE have higher fracture toughness and enhanced physical properties than unmodified asphalt binders.	Polyethylene was used as modifier
Seyed (2013)	The Effect of Styrene-Butadiene-Rubber (SBR) Polymer Modifier on Properties of Bitumen	The study concluded that bitumen modified with 5 percent of SBR has the best performance than the other samples.	Styrene-Butadiene-Rubber (SBR)was used as modifier

International Journal of Advances in Engineering and Management (IJAEM)
Volume 2, Issue 6, pp: 371-378 www.ijaem.net ISSN: 2395-5252

II. MATERIALS AND METHODS

The effect and characterization of styrene-butadiene (SBR), polyethylene bag (PEB) and SBR/PEB on the performance of hot mix asphalt was investigated. The materials used are bitumen (60/70), modifiersSBR and PEB, fine and coarse aggregates, and mineral filler. The bitumen was obtained from EsproAshalt Company, Wasinmi, Nigeria. The SBR was sourced locally and grinded into powdered form before added to the bitumen.The aggregates were obtained from Esuwoye Quarry, Offa, Nigeria. Stone dust was used as mineral filler and was gotten from the same quarry site.PEB was also sourced within the locality, shredded into pieces of size 5 by 5mm, washed and cleaned by putting them in hot water for 3-4 hours. The PEB was further dried and burnt before it was added with bitumenand aggregate in order to ensure proper mixing.

2.1Sample Preparation of the Pure Hot-Mix Asphalt

Preparation of test specimens was done according to ASTM D-1559 (2005). Aggregate mix were pre-heated to a temperature of 165^{o}C for about 15minutes, with the required bitumen content added to the hot aggregate and mixed thoroughly until there was a homogenous mix. The coarse aggregate, fine aggregate, and the filler material should be proportioned so as to fulfill the requirements of the relevant standards. The required quantity of the mix is taken so as to produce compacted bituminous mix specimens of thickness 63.5 mm approximately. 1200gm of aggregates and filler are required to produce the desired thickness. The aggregates are heated to a temperature of 175° to 190°C the compaction mould assembly and rammer are cleaned and kept pre-heated to a temperature of 100°C to 145°C. The bitumen was heated to a temperature of 121°C to 138°C and the required amount of first trial of bitumen was added to the heated aggregate and thoroughly mixed. The mix is placed in a mould and compacted with number of 75 blows specified. The sample is allowed to cool for 25minutes after compaction before extraction from the mold.

2.2 Sample preparation of the modified hot-mix asphalt

The modified hot-mix asphalt was prepared similarly to the pure hot-mix; the only difference is the inclusion of the modifier which was added in percent variations of 3, 6, 9, 12 and 15% by weight the optimum bitumen content (control) to sum up to a total of 1200g.

2.2.1 Experiments on the modified hot-mix asphalt

The laboratory tests conducted on the pure hot mix asphalt (Figure 1) were the Marshal stability (Figure 2) and flow tests which conducted in accordance to ASTM D1559 (2005), X-ray Florescence (XRF)using energy dispersive X-ray spectroscopy and Scanning Electron Microscopy (SEM) which was conducted in accordance to ASTM E 986 – 04 (2017).

Figure 1: Asphalt Mix Samples

Figure 2: Marshal Stability

2.2.2 Void Analysis on the modified hot-mix asphalt

The void analysis of the modified hot-mix asphalt is similar to that of the pure hot-mix asphalt as described in the pure hot-mix asphalt. The only difference is that the modified bitumen is the binder in place of pure bitumen. It involved the determination of the percent air void in the compacted paving mixture (Vv) and the voids filled with modified bitumen (VFB).The absorbed bitumen is an important parameter, which is ignored in bituminous mix design in many cases (Chakroborty and Das, 2005).

III. RESULTS AND DISCUSSION

3.1 Effect of SBR, PEB and SBR/PEB on Modified Hot-mix Asphalt

The results of stability and flow of modified asphalt are presented in Table 2 while the corresponding graph are as presented in Figures 3 to 4. The stability and flow values for SBR, PEB and SBR/PEB were 30.0-42.2 kN and 5.4-7.1 mm; 24.3-44.0 kN and 5.0-9.0 mm; and, 21.3-44.7 kN and 5.8-8.2 mm, respectively (Table 2).

The optimum stabilities of the modified asphalt with SBR (42.2 kN at 12%), PEB (44 kN at 9%) and SBR/PEB (44.7 kN at 6%) are above the minimum stability value of 3.4 kN specified by ASTM D6927 (2006). The improvement in stability of PEB is due to increase adhesion and cohesion properties of the binder which will enhance higher fatigue resistance, improved thermal stress cracking, decrease in temperature susceptibility and reduction of rutting as reported by (Akinpeluet al., 2013;Gonzalezet al., 2006). However, modified bitumen with SBR will have better performance against some distresses such as rutting and fatigue cracking (Seyedet al., 2013).

The minimum and maximum flow of SBR, PEB and SBR/PEB (Table 2) are above the limiting value (2-4 mm) specified by ASTM D6927 (2006) and the range of 2-4.5 mm reported by Eme and Nwaobakata (2019). However, the behavior of the flow (Figure 4) correlate with previous study by Shiva et al.,(2012).

Table 2: Stability and Flow characterization of bitumen admixtures

Modified Asphalt	Stability (kN)			Flow (mm)		
	SBR	PEB	SBR/PEB	SBR	PEB	SBR/PEB
3%	33.7	35.3	35.0	5.4	7.3	8.2
6%	37.8	29.3	44.7	7.1	5.0	6.2
9%	30.0	44.0	38.3	6.3	5.3	6.0
12%	42.2	30.3	21.3	6.3	5.7	6.0
15%	32.0	24.3	24.0	7.0	9.0	5.8

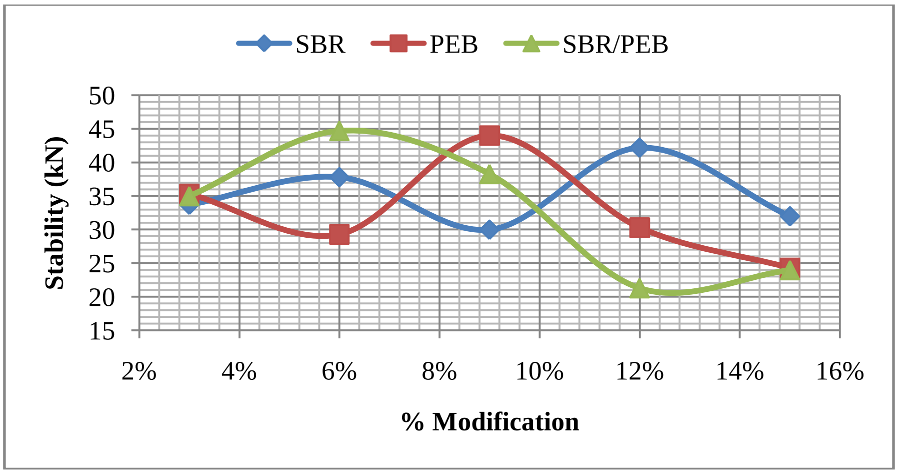


Figure 3: Stability against Modified Asphalt Mix

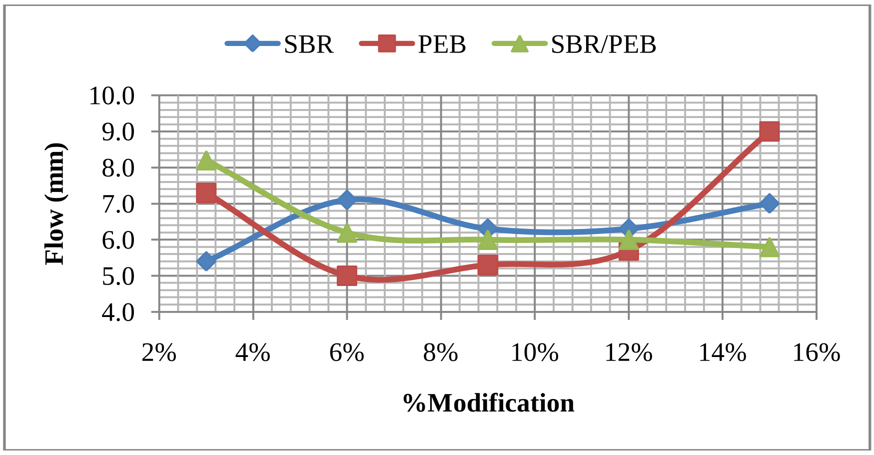


Figure 4: Flow against Modified Asphalt Mix

The Volume of Void (Vv) and Void Filled with Bitumen (VFB) results are presented in Figures5to 6. The Vv and VFB values for SBR, PEB and SBR/PEB were 1.6-3.4% and 78.9-89.7%; 1.4-4.9% and 71.3-90.1%; and, 2.3-3.9% and 76.5-83.8%, respectively (Table 3).

The void record of the mix with various percentage of SBR, PEB and SBR/PEB reported in Figure 5 shows that the percentage air void in the mix initially increases with increase in percentage (at 6% optimum) additives for SBR, PEB and SBR/PEB on bitumen content but later witness reduction with further increase in additives. The optimum percentage of 6% modified binder satisfies the limiting value (3 to 5%) of percentage of Vv specified by The Asphalt Institute (1984) and Mathew and Rao (2017).

According to Mathew and Rao (2017), the specified values of VFB are 75 - 85%. From Table 3, 6 and 15% modified binder with SBR met the specified range, 6, to 15% of PEB conforms to the limiting range while all percentage of SBR/PEB are within the limiting range.

Table 3: Vv and VFB characterization of bitumen admixtures

Modified Asphalt	Vv (%)			VFB (%)		
	SBR	PEB	SBR/PEB	SBR	PEB	SBR/PEB
3%	1.6	1.4	2.8	89.7	90.1	82.7
6%	3.4	4.9	3.9	78.9	71.3	76.5
9%	2.3	3.5	2.6	85.1	78.4	82.4
12%	2.2	2.6	2.3	85.4	82.9	83.8
15%	2.7	2.9	2.7	82.1	80.7	81.4

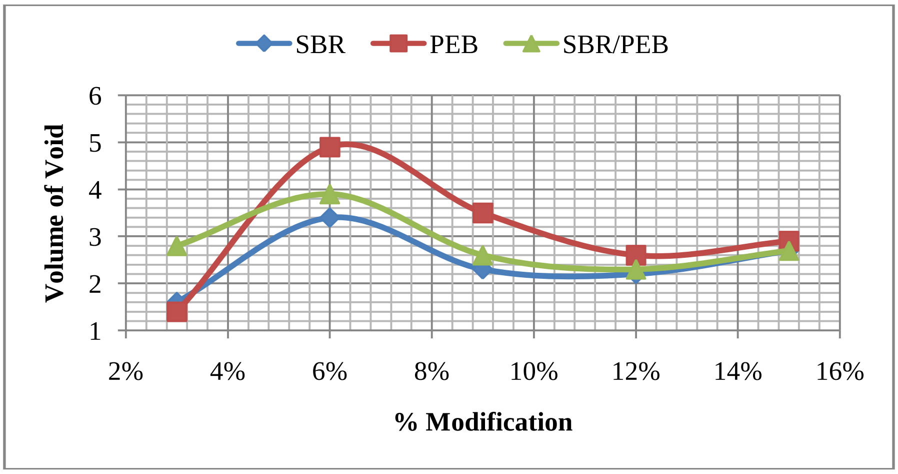


Figure 5: Volume of Void (Vv)

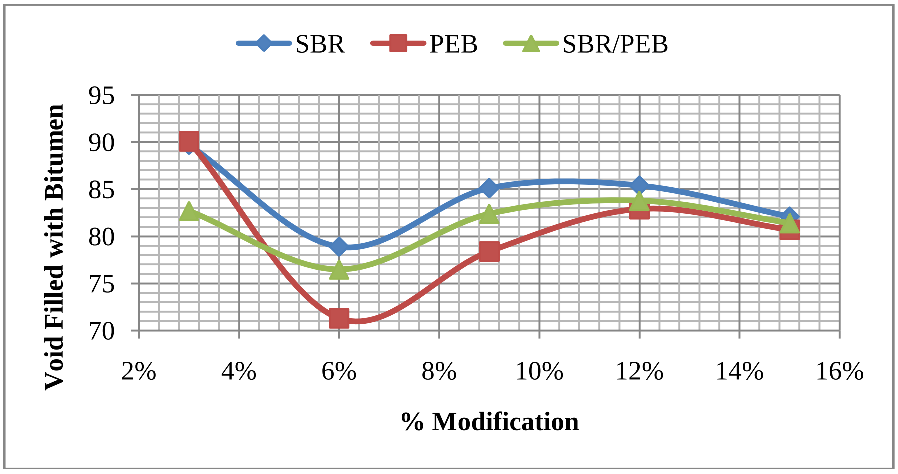
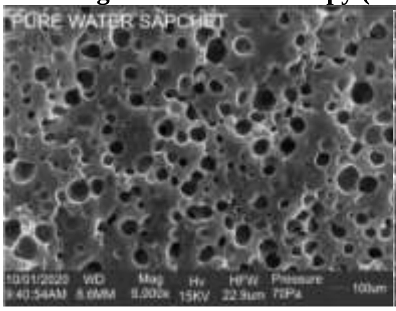
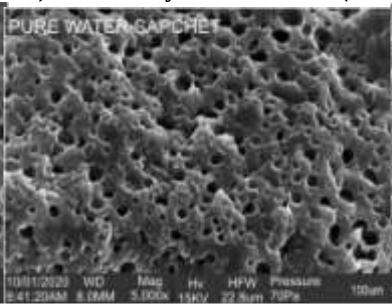


Figure 6: Void Filled with Bitumen (VFB)

3.2 Scanning Electron Microscopy (SEM) and X-Ray Fluorescence (XRF)





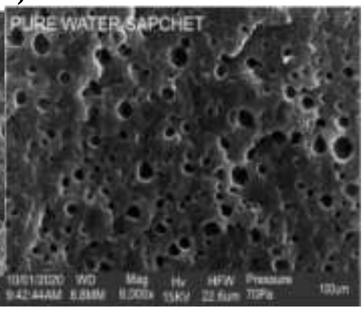
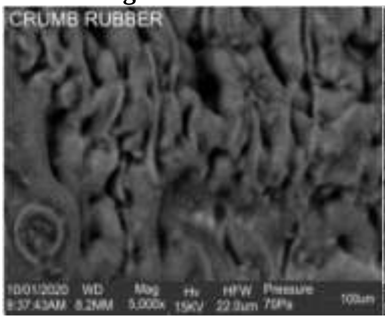
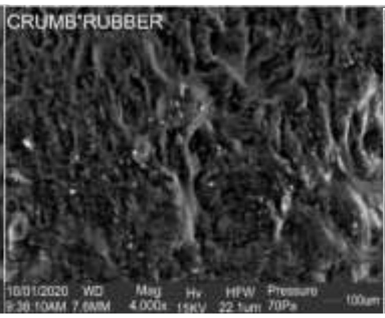


Figure 7: PEB-1 of 3% **8:** PEB-2 of 9% **9:**PEB-3 of 15%





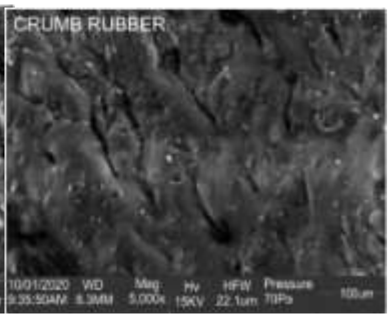
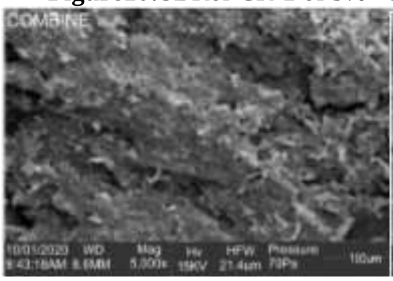
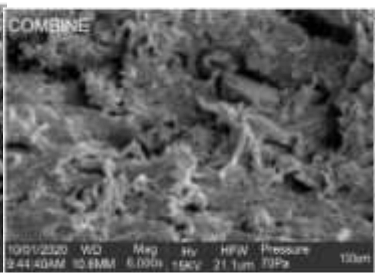


Figure10:SBRor CR-1 of 3% S **11:** SBR or CR-2 of 9% **12:**SBR or CR-3 of 15%





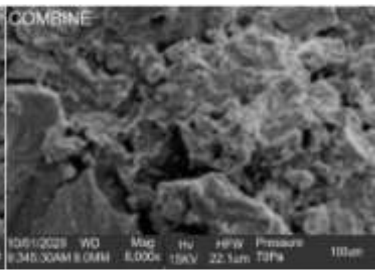
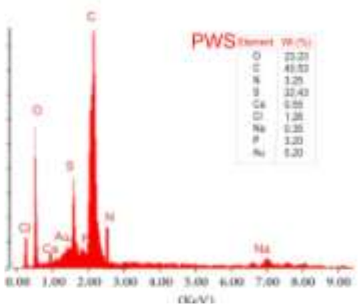
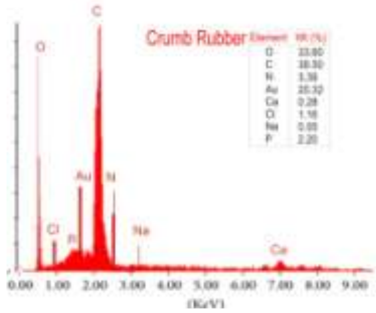


Figure 13:PEB/SBR or CR-1 of 3% **14:**PEB/SBR or CR-2 of 9% **15:**PEB/SBR or CR-2 of 15%





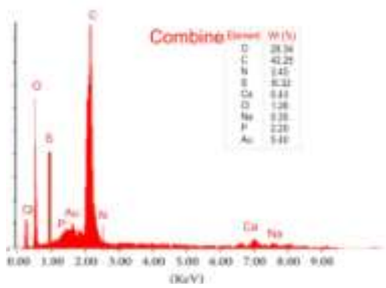


Figure 16: XRF-PEB **17:** XRF-SBR or CR **18:** XRF-SBR/PEB

Microstructural features of bitumen modified with polyethylene appear as porous bodies though levels and geometries of pores vary with an increment in the amount of polyethylene added to the bitumen. Structures in Figures 7 and 9 appear flat while 8 shows repeated goose and dimple appearance. The structural changes may be attributed to different factors including amount of added polyethylene, degree of stirring and exposure to atmosphere leading to air absorption. Generally, air entrapment in material lowers the material density and impair mechanical properties. It has pros and cos depending on area of application. In melt infiltration for fabricating ceramic fibre composite, it is advantageous to allow liquid flow intended to bind ceramic solid together. However, in this case of bitumen for road surfacing, air entrapment leading to porosities as observed in Figure 7may give room for rainwater to flow into the road inner layers, giving rise to detachment of top road layer from remaining layer. This results in road condemnation and waste of money. Although some of air pockets may be forced out during compaction, some remain, being detrimental to the road body. Stirring in the inert environment is recommended to prevent the air entrapment. More compact structures free from porosities are observed with bitumen filled with recycled SBR tyre. However, as the weight percent of the SBR increases, porosities within the modified bitumen decreases. Moreover, 9wt% addition of the SBR is the best due to the fine-grained structure of the modified bitumen obtained. Addition of both PEB and SBR gave rise to modified bitumen having different structures from those in Figures 7-12. This is attributed to interaction of PEB and SBR synergistically influence the structure of the bitumen. Elements as revealed by energy dispersive X-ray spectroscopy (as shown in Figures 16-18) are indicative of compounds present in the mixture. Carbon (C) belongs to bitumen originated from petroleum, recycled SBR and PEB, oxygen (O) and nitrogen (N) may form part of the entrapped air while other elements may be from additives incorporated into SBR and PEB during their initial processing.

IV. CONCLUSION

The effect and characterization of styrene-butadiene (SBR), polyethylene bag (PEB) and SBR/PEB on the performance of hot mix asphalt has been investigated. The results revealed that the optimum stability of the modified asphalt with SBR (42.2 kN at 12%), PEB (44 kN at 9%) and SBR/PEB (44.7 kN at 6%) were above the minimum stability value of 3.4 kN specified by standard. This improvement in stability (above minimum limit) with SBR, PEB and SBR/PEB will enhance better resistance against some distresses such as rutting and fatigue cracking.However, flow of SBR, PEB and SBR/PEB were above thespecified limit (2-4 mm).The microstructures of3, 9 and 15% PEB/SBR are less porous than 3, 9 and 15% PEB, implying that hybrid of PEB and SBR as bitumen fillers gave modified bitumen with higher integrity than when PEB was used alone and it is noteworthy that recycled SBR addition gave modified bitumen with best structures. Since materials' behaviour depends on its structure, recycled SBR modified bitumen is expected to offer best performance in road surfacing than others.

ACKNOWLEDEMENTS

The authors acknowledge the help of Dr.Sefiu Bello of Materials Science, Engineering Department, Kwara State University for his assistance in interpreting the SEM results.

REFERENCES

[1]. ASTM D-1559 (2005). Standard method of Test for Resistance to Plastic Flow of Bituminous Mixturesusing MarshallApparatus. American Society for Testing and Materials (ASTM International), West Conshohocken, PA 19428-2959, United States.

[2]. ASTM D6927 (2006). Standard Test Marshall Stability. Annual Book ofAmerican Society for Testing and Materials (ASTM International), West Conshohocken, PA 19428-2959, United States.
[3]. ASTM E 986 – 04 (2017).Standard Practice for Scanning Electron Microscope Beam Size Characterization.American Society for Testing and Materials (ASTM International),West Conshohocken, PA 19428-2959, United States.
[4]. Aadil, P.M.,Ram, E.S., andAhmad, P.S. (2019).Utilisation of Modified Bitumen in Road Construction.International Research Journal of Engineering and Technology (IRJET), 6(6):2533-2542.
[5]. Afolayan, O.D., and Abidoye, A.O. (2017). Causes of failure on Nigerian roads;A review. Journal for advancement in engineering and technology,5(4): 1-5.
[6]. Akinpelu, M., Dahunsi, B.I.O., Olafusi. O., Awogboro, O., and Quadri, A. (2013). Effect of polythene modified bitumen on properties of hot asphalt. ARPN Journal of Engineering and Applied Sciences, 8(4), 290-295.
[7]. The Asphalt Institute (1984). Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types. 6th Edition, Asphalt Institute, Lexington, KY, USA.
[8]. Chakroborty, P., and Das, A.(2005).Principles of Transportation Engineering, Published by Asoke K. Ghosh, Prentice-Hall of India Private Limited.
[9]. Eme, D.B., and Nwaobakata, C. (2019). Effect of Low Density Polyethylene as Bitumen Modifier on Some Properties of Hot Mix Asphalt.Nigerian Journal of Technology (NIJOTECH), 38(1): 1-7.
[10]. Gonzalez, O., Munoz, M. E., and Santamaria, A. (2006). Bitumen/polyethylene blends: using m-LLDPE toimprove stability and viscoelastic properties. Rheological Act Journal. 45(5): 603-610.
[11]. Ho, S., Church, R., Klassen, K., Law, B., MacLeod, D., andZanzotto, L. (2006). Study of Recycled Polyethylene Materials as Asphalt Modifiers. Canadian Journal of Civil Engineering, 33, 1-26.
[12]. Kumar, S., andChouksey, A. (2017). Waste Polyethylene Use in Bituminous Paving Mixes: A Review. International Journal of Advanced Technology in Engineering and Science, 5(4), 257-263.
[13]. Mathew, T.V., and Rao, K.V.K. (2017 **Lec-26**).Introduction to Transportation Engineering(Chp.26): Marshall Mix Design. National Programming on Technology Enhanced Learning (NPTEL), Mumbai, India. p.26.5.
[14]. Naskar, M., Chaki, T.K. and Reddy, K.S. (2010). Effect of waste plastic as modifier on thermal stability and degradation kinetics of bitumen/waste plastics blend. ThermochimicaActa, 509(1-2): 128–134.
[15]. Othman, A. (2010). Effect of Low-Density Polyethylene on Fracture Toughness of Asphalt Concrete Mixtures. Journal of Materials in Civil Engineering, 22(10), 951-967.
[16]. Seyed, A.T., Alireza K.,andFerdows, K.A. (2013). The Effect of Styrene-Butadiene-Rubber (SBR) Polymer Modifier on Properties of Bitumen. International Journal of Materials and Metallurgical Engineering, 7(10), 785-788.
[17]. Shiva,P.K.,Manjunath, K.R., and Prasad,K.V.R (2012).Study on Marshall Stability Properties of BC Mix Used In Road Construction by Adding Waste Plastic Bottles.IOSR Journal of Mechanical and Civil Engineering (IOSRJMCE), 2(2): 12-23.
[18]. Zhu, J. (2014). Polymer Modification of Bitumen: Advances and Challenges. European Polymer Journal, Vol. 54, 18-38.
[19]. Zolfaghari, F. A., Zolfaghari, F., and Javid, M. (2014). “Modification of Bitumen by Varying Size of the Crumb Rubber in Coarse”.International Journal of Science, Engineering and Technology Research. IJSETR, 3(22): 4435-4444.