Int. J. Hum. Capital Urban Manage., 8(1): 83-94, Winter 2023

International Journal of Human Capital in Urban Management
(IJHCUM)

Homepage: http://www.ijhcum.net/

ORIGINAL RESEARCH PAPER

Performance optimization in bitumen properties from different sources modified with shredded tier waste

G. Aladekoyi[1,*], E.G. Olumayede[2], D. Malomo[2]

[1] *Department of Science Laboratory Technology, Rufus Giwa Polytechnic, Owo, Ondo State, Nigeria*

[2] *Department of Industrial Chemistry, Federal University, Oye - Ekiti, Ekiti State, Nigeria*

ARTICLE INFO

Article History:
Received 13 October 2022
Revised 18 November 2022
Accepted 21 December 2022

Keywords:
Marshal stability
Penetration
Phase angle
Putting property
Stiffness

ABSTRACT

BACKGROUND AND OBJECTIVES: Optimization of bitumen with Polymer modification such as a shredded tier, which serves as a waste in the environment has been used for road pavement to minimize common failure mechanisms associated with roads. The objectives aimed at using a shredded tier to modified bitumen (STMB) in ratio10:90, 20:80, 30:70, 40: 60, and 50:50, from Shredded tier were added to bitumen from Agbabu and Loda to study their performances when applied in the construction industry.

METHODS: Bitumen, which was obtained from Odigbo and Irele Local Government Area of Ondo State, Nigeria, was mixed at 3000C for two hours at different proportion with a shredded tier. Characteristics such as Penetration, Viscosity, melting point, marshal Stability, specific gravity and mechanical properties were determined.

FINDINGS: Marshall Stability (kg) at 600C increased with an increase in shredded tier modified bitumen from10% to 40% improved performance in both modifications and reduced in a 50% increase. This indicated that the increased in shredded tier reduced the measured value of penetration after the attainment values of 40:60 blends. This interaction between the bitumen-tier blends has a penetration value adequately agreed with the predicted value by the penetration index model. The rheological properties from different proportions at temperatures ranging from 45^{0}C to 65^{0}C at 40% modification were observed to have the least rutting parameter at 3.9 ($G^*/\sin\delta$ (kPa) in Agbabu and 2.91($G^*/\sin\delta$ (kPa) in Loda for defects accountable to paving deformation and ageing as there was a decrease in the rutting parameter with the increase in temperature generally.

CONCLUSION: Generally, the values obtained for the physico-mechanical properties increased with an increase in modifiers from 10% to 40% modification in the two samples. Though, Agbabu is preferable and economical due to the percentage yield for road construction.

DOI: 10.22034/IJHCUM.2023.01.07

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
37	9	3

*Corresponding Author:
Email: *gbenga_aladekoyi@rugipo.edu.ng*
Phone: +2348034651804
ORCID: 0000-0001-5714-0192

Note: Discussion period for this manuscript open until April 1, 2023 on IJHCUM website at the “Show Article.

INTRODUCTION

Modern society today is looking for a way of dealing with the disposal or recycling of solid waste produced by human activity (Bianchi et al., 2014, Martinez *et al*., 2014). Also, scrap tires have been a great issue due to its major contribution to environmental pollution that they cause as explained by Rowhani and Rainey, (2016). The use of waste tire for modification may be one of the successes in getting them out of the environment instead of burning them. Modification of bitumen with polymer in recent time has become a mutual practice in road pavement (Masson *et al.,* 2005, Behera *et al.,* 2020). Therefore, the failure observed in the use of conventional bitumen as a result of its rheological properties has engendered a cumulative curiosity in finding and usage of polymer-modified binders to enhance conventional bitumen properties (Gonzalez *et al.,* 2010; Mohamed *et al.,* 2009). Most Studies from Anderson *et al.* (1993); Chen *et al*. (2002); have reported that bitumen modification produces products of good and improved performances; which invariably bitumen by itself cannot perform ultimately. Also, report from Yu *et al*, (2019) explained the modification effect of preparation of graphene oxide on base asphalt and Liu et al, (2018) emphasized on the use of graphene oxide and warm mix additive on mechanical performance and modification mechanism of asphalt. Bala *et al.,* 2020; Xin *et al.,* 2020; Wu *et al.,* 2021 have also adopted the composite modification to improve the performance of bare asphalt with the believe that modifying Asphalt by a single polymer may has some defects. These performances include improvement in fatigue resistance and performance in the high temperate regions with heavy traffic conditions, and this reduced the life cycle cost. Also, a softer mixture of modifiers with bitumen can improve the performances at low service temperatures with minimum cracking. According to Anderson *et al* (1993), polymer-modified bitumen augmented the elasticity of the combination and also the viscosity at high temperatures. A study indicated that the addition of Styrene-Butadiene-Styrene (SBS) to bitumen as explained by Chen *et al.* (2002) and Masson *et al.* (2005) observed a reduction in cracking and rutting of the mix. Similarly, the addition of Polyethylene Wax (PW) to bitumen has been explained Garcia-Morales *et al* (2004) and Polacco *et al* (2005), who observed a decrease in the rutting of the asphalt in the pavement. Transitorily, Crumb Rubber had been proven to decline cracking and rutting, but there is a reduced level to what can be reached when using SBS or PW (Gonzalez *et al.,* 2010; Frantzis, 2003; Yildrim, 2007). Although, modification of bitumen is frequently performed by the addition of thermoplastic or elastomers polymers as explained by Munera and Ossa, 2014, using numerous materials. Notwithstanding, the improvements in bitumen properties are not easy to study with the utilization of other Plastomeric polymer materials such as polyethylene and polypropylene as potential fillers in bitumen for use in road paving (Mohamed *et al.,* 2009). Tires contain are made up of large amount of rubber, which is a polymeric material, this can be used as feed stock material renewable polymeric products as explained by Rowhani and Rainey, (2016). To achieve this, the scrap tires (polymeric raw material) is required to be shredded or ground beforehand (Rowhani and Rainey, 2016).

Bitumen Failure in Pavement

The paramount problems that are related to the degradation of bitumen normally used in pavements are grouped into three categories, namely thermal cracking; surface deformations, which are due to the viscoelastic behavior of the material used, and surface defects. The two major failure mechanisms associated with asphalt mixtures are cracking and rutting, which leads to permanent deformation.

Cracking is usually recognized with brittle fracture of bitumen at low temperatures, but rutting is related to plastic or viscous behavior of bitumen at high temperatures. Bitumen has been typically modified by the addition of elastomeric polymers to reduce cracking. This usually requires mixing and shearing at high temperatures for uniform dispersal of the polymers into the bitumen blends (Chen *et al*., 2002; Navarro *et al.,* 2004; Masson *et al.,* 2005). Roberts *et al.,* (1991), describes bitumen behavior in terms of its failure mechanism and describe each failure mechanism as a function of bitumen's basic molecular chemistry.

Aging

Aging can be reversible and irreversible. Irreversible aging is generally connected with oxidation at the molecular level. Oxidation courses increase in bitumen viscosity with age, and it will get to a point when the bitumen will be able to reduce oxidation through the immobilization of the important chemically reactive elements present (Masson *et al.,* 2005). Reversible aging is emanated from the effect of molecular organization. As a result of this, the molecules within bitumen will gradually reorientate themselves into a more shaped and bound system. The result of this is stiffer, and the formation of more rigid material. This form of aging can be reversed by applying heat with constant agitation. The removal of oily constituents like resins or asphaltenes, which is a major component f bitumen by selective absorption of some porous aggregates is termed separation. Also, there are no direct means of measuring bitumen aging, but aging effects are obtained by subjecting bitumen aggregates to simulated aging, and then conducting other known standard physical tests on it such as Viscosity, Dynamic Shear Rheometer (DSR), Bending Beam Rheometer (BBR), and The Direct Tension Test (DTT). Simulating the effect of aging is paramount because bitumen possesses a certain set of properties in its original state, which may show a different set of properties when aging, which is Short-term aging and Long-term aging as described by Vallerga *et al*, (1967). Types of Aging Simulation Tests are the Thin Film Oven (TFO) Test, Rolling Thin-Film Oven (RTFO) Test, and Pressure Aging Vessel (PAV) Test respectively.

Stripping

Polar molecules (positively charged on one side and negative on the other side) allows the bitumen adheres to aggregates because the properties within the bitumen are attracted to the polar molecules on the surface of aggregates (Masson *et al.,* 2005). It is known also that certain polar attractions are known to be interrupted by the water itself, which is polar. Moreover, the polar molecules in bitumen will change in their ability to bind to any particular type of aggregate, and this can result in the disintegration of the molecular structure (Chen *et al*., 2002).

Moisture Damage

Because it is a polar molecule, this reveals that water is readily recognized by the polar bitumen molecules. The presence of water can cause stripping and decrease bitumen Viscosity. It behaves typically like a solvent in bitumen and this results in a reduction in strength and increased rutting (Navarro *et al.,* 2004). A chemical view of it revealed that water should have a greater negative effect on older or aging bitumen. Oxidation causes aging, so, it makes bitumen have more polar molecules than necessary (Chen *et al*., 2002). The more polar molecules residing in bitumen, the more it will readily accept water. Therefore, this will set in an increase in the disintegration of the binding structure of the molecule.

Thermal Cracking

It is observed that normally fluid non-polar molecules begin to organize into a structured form at lower temperatures (Navarro *et al.,* 2004). The combination with the already structured polar molecules makes bitumen more rigid and probable to fracture relatively to deforming elastically under stress. Thermal cracking can emanate in all climates, be it hot or cold (Chen *et al*., 2002). Though, this is pronounced when there is temperature variation between day and night, also between summer and winter creating the risk of cracking increases with aging -induce brittleness.

Fatigue Cracking

Molecular networks can be too organized and rigid, if this exits bitumen will fracture instead of deforming elastically under stress. Therefore, bitumen with a more percentage of polar and network-forming molecules can be more prone to fatigue cracking (Chen *et al*., 2002). Also, cracking can lead to surface damage and road-based deformation. The constant destruction is equally caused or induced by traffic, thereby initiating cracks and ultimately resulting in pothole formation.

Rutting and Permanent Deformation

It is possible for the molecular network to be relatively not interconnected, in this situation, bitumen will tend to deform inelastically under heavy traffic and high temperature, and most of the deformations are irreversible (Navarro *et al.,* 2004). Moreover, bitumen with a higher percentage of non-polar dispersing molecules will flow better and deform plastically because the various polar molecules network pieces can be more relative to one another due to the higher percentage of fluid in non-polar molecules. An unexpected movement of vehicles and deliberate elusive action by driving on the shoulder of the road also results into Rutted roads. Accumulation of water in the ruts resulted in the aqua plane, causing skidding and reduced visibility reflections (Navarro *et al.,* 2004).

Used Tiers

Tiers is made for their use on vehicles; they are not made as a recycling industry feedstock. Their composition makes them difficult to recycle. The Table1 showed the composition of tiers, their toxicity (or lack of

Table 1: Composition of Tier (WRAP, 2006)

Compositions%	Car Tier%	Lorry Tier%	OTR Tier%
Rubber/Elastomers	47.00	45.00	47.00
Carbon Black	21.50	22.00	22.00
Metal	16.50	25.00	12.00
Textile	5.50	--	10.00
Zinc Oxide	1.00	2.00	2.00
Sulphur	1.00	1.00	1.00
Additives	7.50	5.00	6.00
Total Carbon-based materials used = 4			

toxicity), and the likely result of processing for recycling by shredding and grinding for modification.

Tire as Polymeric materials for bitumen modification

Plastomeric polymeric materials, namely Polyethylene (PE) and Polypropylene (PP) have induced great interest among engineers, builders, and manufacturers for use in road paving and roofing felt modification because of their viscoelastic properties and good adhesion to mineral aggregates in the bitumen (Al-Hadidy and Yi-Qiu, 2011; Pasetto and Baldo; 2010 and Yoon *et al*., 2006). The major reason for using polymers in asphalt concrete is to increase binder stiffness at maximum service temperatures and reduce the stiffness of asphalt at low service temperatures (Chen and Qian, 2003; Goodrich, 1991, Mull *et al.,* 2002). Polymer materials normally used for the modification of asphalt concrete can be divided into three major categories: these are thermoplastic elastomers, plastomers, and reactive polymers respectively (Metcalf *et al.,* 2000). Thermoplastic elastomers are ostensibly capable of having high elastic response characteristics and therefore resist permanent deformation by stretching and are able to recover their initial shape on the modified binder layer, whereas, plastomers are reactive polymers modifying asphalt by forming a tough, rigid, and three-dimensional network in order to increase stiffness and decrease deformations (Airey, 2004). The aim of this study is to modify bitumen with shredded tier crumbs for application in road pavement. Since it is difficult to recycle tire directly because of their component, the effective way of removing them from the environment is to use them as modifier of bitumen for road construction. The objectives of the study are to extract bitumen from samples collected from Agbabu and Loda, modify the obtained bitumen using different proportions of shredded tier waste crumbs at different percentages, determine the physico-mechanical properties and rheological parameter of extracted bitumen and polymer modified bitumen and to determine the optimum bitumen content suitable for filler in road construction. The current study has been carried out in chemistry laboratory in Federal University, Oye-Ekiti, chemistry laboratory and civil engineering workshop in Rufus Giwa Polytechnic, Owo, Ondo State in 2022.

MATERIALS AND METHODS

Collection and Preparation of Raw Samples

As indicated in Fig.1, raw bitumen and tar Sand samples used for this work were obtained from Agbabu and Loda in Odigbo and Irele Local Government Area, Ondo State, Nigeria. The two samples were collected randomly at the different point sources, so as to obtain good representative samples. Agbabu, as indicated in the map is located at latitude $6^0$35:19N and Longitude $4^0$50:3E in the tropical savanna of Nigeria. The raw bitumen from Agbabu and tar sands from Loda were extracted using Soxhlet extraction method and carbon disulphide as a solvent. These were stored in a clean container for further analysis.

Collection of Used Tire Waste

Used tier waste was obtained from a local vulcanizing dumpsite (Fig. 2), in Owo town, Ondo state, Nigeria. A shredding machine was used to shred it to particle sizes. Fig. 3 revealed the pieces of tier and Fig. 4 revealed the shredded used tier after shredding.

Preparation of Polymer-Bitumen Blends

The extraction of bitumen samples from the bituminous oil was done using the Soxhlet extraction process and carbon disulphide as a solvent. A method explained by Fawcett *et al.,* (1999) was followed to have a homogenized polymer- bitumen blends. 200grams of shredded tier waste were mixed in ratios 10:90, 20:80, 30:70, 40:60, and 50:50 to extract bitumen sample from both Agbabu and Loda using a mechanical mixer Heidolph model RZR 2020. The mixtures of the different ratios were heated in a thermosetting oven at 300^{0}C for two hours. The temperature ensures that both polymers and bitumen were always above their softening point and temperature. The mixtures were brought out and blended together mechanically while still hot at a speed of 2000±10rpm. Mixing at high temperatures are required in order to have uniformly dispersed polymers in the blends. It was cooled at room temperature to solidify. Rheological properties of the resulting sample were determined: the penetration test, Viscosity, melting point, and marshal Stability were carried out by ASTM (2021), and specific gravity was determined according to AOAC (2000) (contact the textbooks for experimental details).

RESULTS AND DISCUSSION

Fig. 5 shows the variation of measured values of penetration for the different bitumen-tier blends. It can be observed that an increased amount of shredded tier waste (STW) increases the measured value of penetration attainment values (59.40) at 40:60 bitumen blends before diminishing. The interaction between the bitumen-tier blends can be calculated with routine test data Penetration Index (PI) as explained by Munera and Osa (2014) as of Eq. 1:

$$\mathrm{PI}=\frac{1952\text{-}500\log(Pen_{25})\text{-}20SP}{50\log(Pen_{25})\text{-SP-}120.} \quad (1)$$

Where Pen_{25} is the penetration value at a specific softening point (SP).

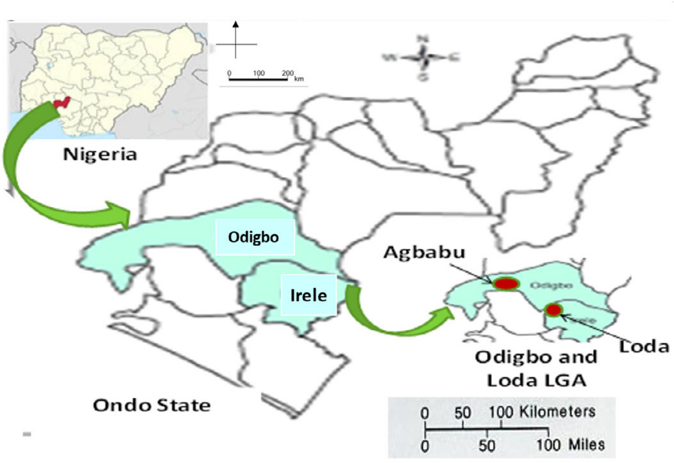

Fig. 1: Geographic location of the study area in Agbabu and Loda in Odigbo and Loda L.G.A., Ondo State, Nigeria

Fig. 2: Vulcanizing Used tyre dumpsite

Fig. 3: Pieces of used tier

Fig. 4: Shredded tier

Intermolecular interaction between the modifiers in Agbabu and Loda with Shredded tier showed that penetration value statistically correlated with polymer concentration. The correlation between the modifiers in Agbabu and Loda bitumen with shredded tier waste showed that penetration value is correlated with polymer concentration.

This indicated that adding a certain amount of modifier to bitumen above 40% can slightly decrease the shear stiffness. This is an indication of the ability to withstand the pressure that may act on it and this is higher in Agbabu bitumen. Fig. 6 shows the result from the specific gravity of bitumen modified with the shredded tier at different compositions. The specific gravity value (0.9754) obtained for raw bitumen in this study was comparably within the permissible limit of >0.99 as set by the Indian Standard Institute for paving bitumen Specification (IS: 73, 2001). However, there was a significant difference from the value (1.03) obtained by Sharma *et al*, (2012). An increase in modifier concentration seems not to show any impact on the specific gravity of modified bitumen. The result revealed that modified bitumen remains constant despite an Increase in modifier concentration, though there is a significant difference between the raw bitumen and the modified bitumen. The value obtained in raw bitumen indicated that there is no significant difference from the raw value (0.9517) obtained by Sharma *et al*, (2012). The value was comparably within the permissible limit of >0.99 as set by the Indian Standard Institute for paving bitumen Specification (IS: 73, 2001).

From the Fig. 7, there is no significant increase in the

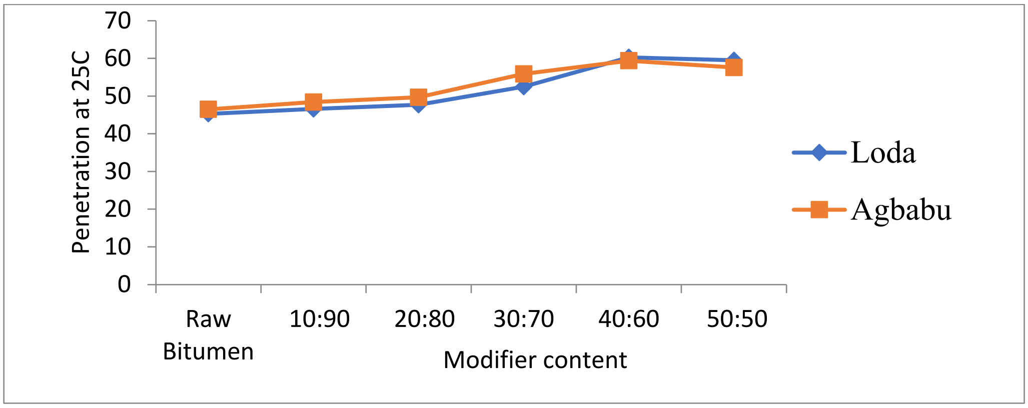

Fig. 5: Penetration in raw bitumen and modifier content

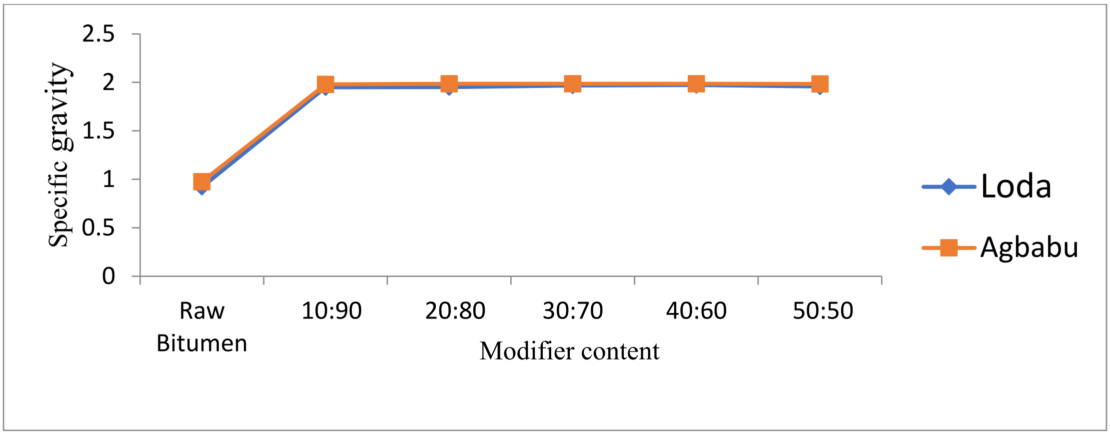

Fig. 6: Specific gravity in raw bitumen and modifier content

bitumen modification from Loda from the raw sample, but there is a slight increase in viscosity in Agbabu modification at 30:70 (11.571) before reduction. The reduction in viscosity can be attributed to a significant reduction in the surface tension between the bitumen aggregate and binders which results in expelling air and increasing interfacial cohesion between the bitumen properties and modifier aggregate as explained by Huh, (2012) that when the surface tension is reduced, air is expelled, and viscosity is affected between the aggregates and binders.

Fig. 8 presents the softening point measured for each of the blends as a function of modifier concentrations. A suggestion by Highway engineers have indicated 2°C temperature difference as the maximum temperature for monitoring polymer modifies bitumen stability (Huh, 2012). It was observed from the results that the blend with 40:60 had the highest softening point temperature, reaching up to 65^{0}C. At a 40:60 ratio, blends increase the softening point to 73.2 and 67.16 in Agbabu and Loda bitumen modifications. Similarly, at 50:50 blends the decreases in softening point are 72.78 and 64.01 in the bitumen-shredded tier from both samples respectively. This implies that at 40:60 loading, the shredded tier showed appreciable softening for Loda and Agbabu. This is an indication that shredded tier modifiers are compatible with raw bitumen.

Fig. 9, presents the mean values of Marshall Stability for various blends of shredded tier. The highest mean value was observed at a ratio of 40:60 modification. This ratio has the most significant impact on the Marshall characteristics of the blends. This trend can be attributed

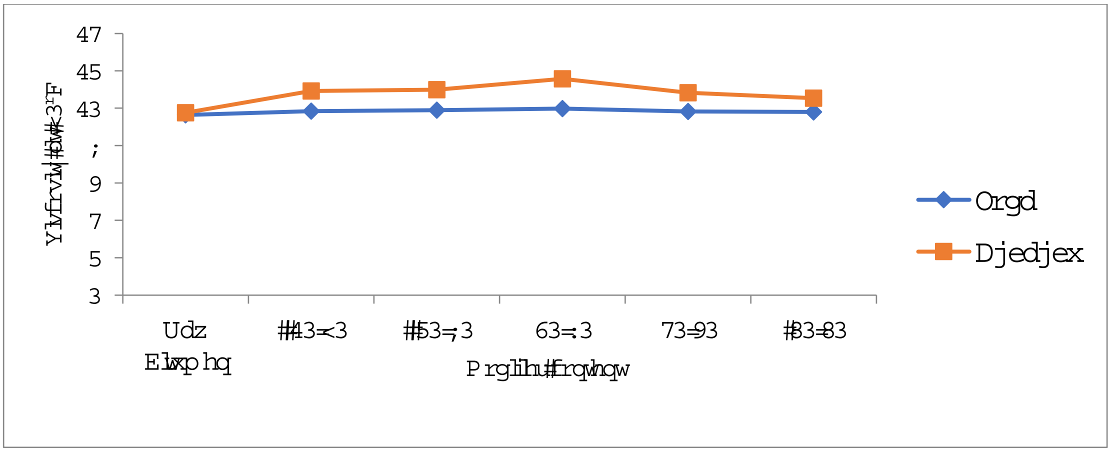

Fig. 7: Viscosity in raw bitumen and modifier content

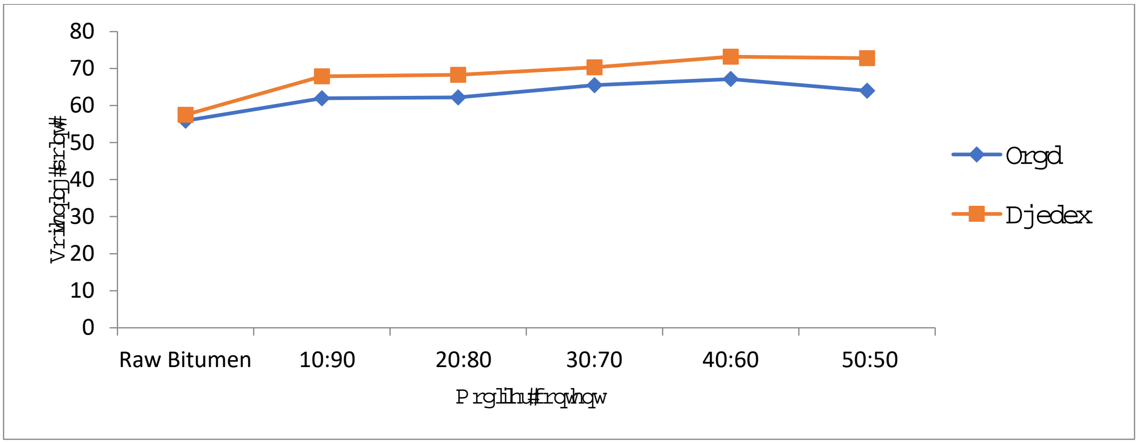

Fig. 8: Softening point in raw bitumen and modifier content

to the size effect of the modifiers used. The implication of this is that there might have been an increased in the stiffness of the modified bitumen to soil aggregates.

Rheological properties

Rheological properties (complex modulus, phase angle, and rutting) of bitumen polymer blends as a function of modifier concentrations are shown in Tables 2 and 3 for Shredded Tier-Modified Bitumen (STMB) from Agbabu and Loda respectively.

a) Complex modulus: The complex shear modulus (G*) is defined as a measure of a material's total resistance to deformation when it is constantly sheared. In this study, the complex modulus (G*) was measured as a function of the frequency at a temperature of 40^{0}C for base bitumen and at various blends. The maximum complex modulus was 3.90 at a 40:60 ratio at 65 ^{0}C in both Agbabu and Loda, subsequent to this, there was a considerable decrease in complex modulus as modifier concentration increased. This is a suggestion that maximum shear stress and shear strain due to improvement in intermolecular forces binding modifier to bitumen is at a 40:60 ratio and at 65 **^{o}C**.

b) Phase angle: Phase angle (**δ**) measurements are generally considered to be more profound to the chemical structures as can be observed in the Tables 2 and 3 for STMB respectively. The trend observed

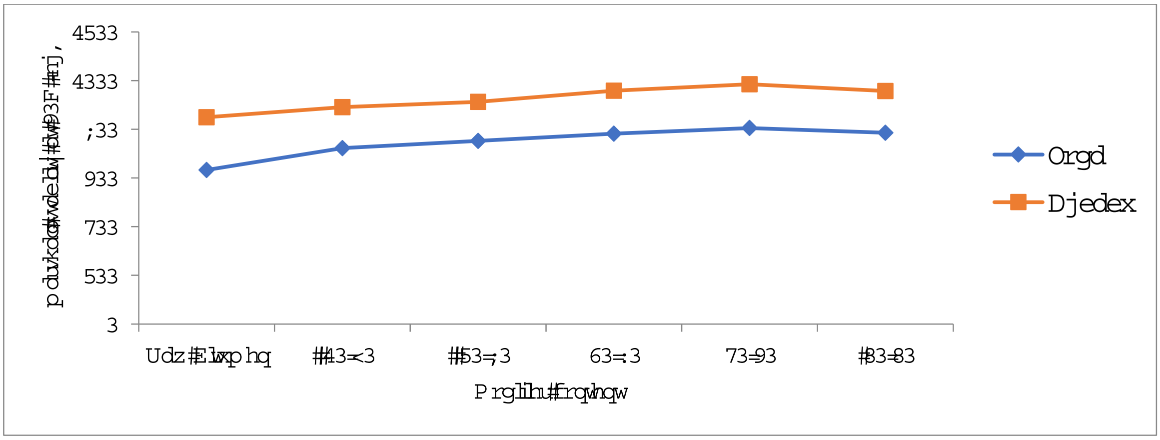

Fig. 9: Marshall Stability in raw bitumen and modifier content

Table 2: Result of Rheological Properties of Shredded Tier Modified Bitumen (STMB) from Agbabu.

Waste/ Bitumen %	Temp ^{0}C	Complex modulus G* (kPa)	Phase angle(δ)	Storage modulus G' (kPa)	Loss modulus G" (kPa)	Rutting parameters G*/Sin δ (kPa)
10:90	45	28.10	71.50	2.60	28.00	29.63
	55	11.50	73.20	0.30	11.40	12.01
	65	3.50	75.50	0.06	3.40	3.62
20:80	45	28.80	77.20	2.50	28.70	29.53
	55	11.80	77.70	0.35	11.60	12.15
	65	3.85	80.30	0.05	3.80	3.91
30:70	45	30.30	79.20	2.57	30.10	30.85
	55	10.50	78.90	0.42	10.40	10.70
	65	3.83	82.10	0.05	3.80	3.87
30:70	45	31.50	81.80	3.00	31.50	31.83
	55	12.20	82.90	0.50	12.10	3.18
	65	3.70	84.50	0.04	3.50	3.72
40:60	45	32.50	88.30	3.50	32.40	32.51
	55	12.70	91.40	0.35	12.70	12.70
	65	3.90	92.80	0.02	3.80	3.90
50:50	45	32.40	86.40	3.40	86.30	32.47
	55	12.50	90.10	0.30	12.45	12.51
	65	3.70	91.60	3.40	3.50	3.70

showed that phase angle increases with increasing temperature and the maximum attainment was 92.80δ in Agbabu and 80.50δ in Loda before depreciation. This observation agrees with the reported trend for Unaged Polyethylene Modified Bitumen (PMB-70) (Ashok *et al.,* 2012). However, the result showed that phase angle increases with increased modifier concentration up to 40:60 and thereafter declines by almost 1.8% for shredded tier-modified bitumen respectively.

Rutting Parameters: Rutting is evaluated by determining the ratio of the complex shear modulus (G*) to the sin of phase angle (δ). Rutting measures, the aging period in bitumen as a result of a deformity of the surface tension due to temperature changes. The lowest value was observed in Loda modification (2.91) at 65 ^{0}C temperature range and 40:60 ratio. This was a little lower than that of Agbabu (3.90) in the same range. However, the values obtained at these levels indicated the good performance of both bitumen modifications at that temperature.

The relative increase in the penetration test in Agbabu bitumen-modified samples may be ascribed

Table 3: Result of Rheological Properties of Shredded Tier Modified Bitumen (STMB) from Loda.

Waste/ Bitumen %	Temp ^{0}C	Complex modulus* (kPa)	Phase angle(δ)	Storage modulus G' (kPa)	Loss modulus G" (kPa)	Rutting parameters G*/Sin δ (kPa)
10:90	45	27.90	68.70	2.70	27.80	29.95
	55	8.70	72.90	0.41	8.70	9.10
	65	2.90	75.30	0.05	2.70	3.00
20:80	45	29.10	70.20	2.75	29.00	30.93
	55	9.50	75.10	0.40	9.50	9.83
	65	3.20	76.20	0.06	3.10	3.30
30:70	45	30.10	75.90	2.86	30.00	31.03
	55	9.70	77.20	0.40	9.50	9.95
	65	4.20	77.90	0.08	4.10	4.29
40:60	45	32.70	78.80	3.50	32.60	33.33
	55	11.50	79.80	0.57	11.30	13.66
	65	3.90	80.50	0.07	3.60	2.91
50:50	45	31.50	78.10	3.45	31.40	32.19
	55	10.20	79.20	0.55	10.00	10.71
	65	3.50	79.85	0.07	3.40	3.56

to the augmentation in sheared Stress in shredded tier waste content as a result of its intermolecular forces. The rutting parameters obtained from the rheological properties revealed that Shredded tire modified bitumen samples can withstand many of the defects accountable to paving deformation and aging as there was a decrease in the rutting parameter with an increase in temperature from 45°C to 65°C due to considerable reduction in rutting parameters with an increase in temperatures. Complex modulus decreased while there is an increase in the phase angle of the modified bitumen from both modifiers in ratio 10:90 to 40: 60 due to a decline in shear stress and shear strain at ratio 50:50 at the same range of temperature. The decrease in Complex modulus begins and the phase angle is an indication of the maximum shear stress and shear strain as explained by Mohamed *et al.*, (2009).

CONCLUSION

Bitumen modification has been practicing for ages, but there is not logical conclusion on a specific modifier at a given temperatures that can withstand change in temperatures in the temperate and cold region of the globe. Studies on modified bitumen from Agbabu and Loda at different temperatures and deferent percentages of shredded tier modifier for their rheological properties proved a success. Physico-mechanical characteristics such as Marshall Stability at 60^{0}C, viscosity at 90^{0}C, and penetration at 60^{0}C were also studied for appropriate application in the construction industries. Modifier from Agbabu in ratio10:90 and 40:60 indicated an increase in the intermolecular activities between the bitumen and shredded tier than Loda respectively. These showed the differences in their chemical properties, but better than the base bitumen at the given temperatures and modifications. Generally, the tensile strength of the Shredded tier modified bitumen at 40:60 modification is higher at 45 °C, which contributed to the maximum rutting parameters obtained and will provide good performance in road paving. This demonstrated that bitumen modified with shredded tier can withstand environmental stress more than base bitumen when the temperature at 45 °C is equally put into consideration, most especially the temperate regions. For maximum rutting parameters, modification at 40% shredded tier with %60 base bitumen at45 °C should be encouraged, most especially in the construction industries for better performance. Application of used of waste tire as the aggregate for modification at the stipulate temperature and the modification ratio will help to reduce its impact in environmental pollution.

AUTHOR CONTRIBUTIONS

G. Aladekoyi sought study authorization from the relevant government institutions. G. Aladekoyi, E.G. Olumayede, and D. Malomo developed the study methodology that also comprised preparing a checklist that was used in data collection. G. Aladekoyi and E.G. Olumayede analysed the samples and interpreted the data. E.G. Olumayede and D. Malomo undertook the literature review that included the introductory background information and the theoretical context. All authors edited the paper to ensure completeness and consistency with the journal's formatting guidelines.

ACKNOWLEDGEMENT

The authors would like to thank The Director, The Research Unit of Federal University, Oye-Ekiti, Ekiti State, and The Director, Rufus Giwa Polytechnic, Owo, Ondo State, Nigeria for granting the permit to undertake the study. Special acknowledgment correspondingly goes to Mr. Ogunmola, a native of Ilutuntun in Irele Local Government Area who provided the survey maps that were used to determine the spatial extent of conformity with the approved land subdivision regulations.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript. In addition, the ethical issues; including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors

CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

OPEN ACCESS

ABBREVIATIONS (NOMENCLATURE)

%	Percentage
BBR	Bending beam rheometer
°C	Degree celsius
DTT	Direct tension test
DSR	Dynamic shear rheometer
G*	Complex modulus
G*/Sin δ	Rutting parameters
G’	Storage modulus
G’’	Loss modulus
Kg	Kilogram
Kpa	Kilo pascal
PI	Penetration index
PMB	Polyethylene modified bitumen
PW	Polyethylene wax
rpm	Revolution per minute
RS	Rapid setting
RTFO	Rolling thin film oven
RC	Rapid curing
SBS	Styrene—butydiene styrene
SC	Slow curing
SP	Soft point
SS	Slow setting
STMB	Shredded tyre modified bitumen
STW	Shredded tyre waste
Temp.	Temperature
TFO	Thin film oven
δ	Phase angle

REFERENCES

Airey, G.D., (2004). Styrene butadiene styrene polymer modification of road bitumen. J. Mat. Sci., 39(3): 951-959 (9 pages).

Al-Hadidy, A.I.; Yi-Qiu, T., (2011). The effect of plastomers polymer S and concentration on asphalt and moisture damage of SMA mixtures. Al-Rafidain Eng., 19: 1-11 (11 pages).

Rowhani, A.; Rainey, T.J., (2016). Scrap tyre management pathways and their use as a fuel—a review Energies, 9(11): 126 (26 pages).

Anderson, D.A.; Kennedy, T.W.; Thomas, W., (1993). Development of SHRP binder specification.

J. Assoc. Asphalt Paving Tech., 62: 481-507 (27 pages).

AOAC, (2000). Official Methods of Analysis. Association of Official Analytical Chemists 15th edition, Washington DC, USA.

Ashok, P.; Sharma, R.K.; Trilok, G., (2012). Performance of polymer modified bitumen for flexible pavements. Int. J. Strict. Civil Engr., 1(1): 77-87 **(11 pages).**

ASTM, (2021). Standard test method for industrial determination of carbon, hydrogen, and nitrogen in petroleum products and lubricants. ASTM International d-5291, West Conshohocken, USA.

Bala, N.; Napiah, M.; Kamaruddin, I., (2020). Nanosilica Composite Asphalt Mixtures Performance-Based Design and Optimisation Using Response Surface Methodology. Int. J. Pavement Eng. 21 (1), 29-40 **(12 pages).**

Baldo, N.; Pasetto, M., (2010). Recycling of steel slags in road foundations. Environ. Eng. Manage. J., 9(6): 773-777 **(5 pages).**

Behera, H.K.; Giri, D.; Das, S.S., (2020), November. Modification of Bitumen Using Sustainable Materials for Pavement Design. In IOP

Conference Series: Materials Science and Engineering 970(1): p. 012022). IOP Publishing. 1-10 **(10 pages)**.

Bianchi, M.; Bortolani, G.; Cavazzoni, M.; De Pascale, A.; Montanari, I.; Nobili, M.; Peretto, A.; Tosi, C.; Vecci, R., (2014). Preliminary design and numerical analysis of a scrap tires pyrolysis system. Energy Procedia, 45: 111-120 **(10 pages)**.

Chen, F.; Qian, J., (2003). Studies of the thermal degradation of waste rubber. Waste Manage., 23(6): 463–467 **(5 pages).**

Chen, J.S.; Liao, M.C.; Shiah, M.S., (2002). Asphalt modified by styrene–butadiene–styrene triblock copolymer: morphology and model. J. Mater. Civil Eng., 14(3): 224-229 **(6 pages**).

Fawcett, A.H.; McNally, T.; McNally, G.M.; Andrews, F.; Clarke, J., (1999). Blends of bitumen with polyethylenes. Polymer, 40: 6337-6349 **(13 pages).**Frantzis, P., (2003). Development of crumb rubber reinforced bituminous binder under laboratory conditions. J. Mat. Sci., 38: 1397-1401 **(5 pages).**

Garcia-Morales, M.; Partal, P.; Navarro, F.J.; Martinez-Boza, F.; Mackley, M.R.; Gallegos, C., (2004). The rheology of recycled EVA/LDPE modified bitumen. Rheol Acta., .43: 482-490 **(9 pages).**

Gonzalez, V.; Martinez-Boza, F.; Navarro, F.; Gallegos, C.; Perez-Lepe, A.; Paez, A., (2010). Thermomechanical properties of bitumen modified with crumb tire rubber and polymeric additives. Fuel Proc. Tech., 91 (9):1033–1039 **(7 pages).**

Goodrich, J.L., (1991). Asphalt binder rheology, asphalt concrete rheology and asphalt concrete mix properties. Asphalt Pav. Tech. J., 60: 80–120 **(41 pages).**

Huh, J. D., (2012). Temperature-Adjusted and Modified Recycled ASCON Composition for Reusing 100% of Waste ASCON for Road Pavement, and Method for Manufacturing Same.

Indian Standard, (2001). Paving bitumen specification Indian Standard Institute. New Delhi, India.Sp:73

Liu, K.; Zhang, K.; Wu. J.; Muhunthan, B.; Shi, X., (2018). Evaluation of mechanical performance and modification mechanism of asphalt modified with graphene oxide and warm mix additives J. Cleaner Prod. 193**:** 87-96 **(10 pages)**.

Masson, J.; Polomark, G.; Collins, P., (2005). Glass transitions and amorphous phases in SBS bitumen blends. Themo. Chim. Acta., 436: 96-100 **(5 pages).**

Martinez, J.D.; Veses, A.; Mastral, A.M.; Murillo, R.; Navarro, M.V.; Puy, N.; Artigues, A.; Bartroli, J.; Garcia, T., (2014). Co-pyrolysis of biomass with waste tyres: Upgrading of liquid bio-fuel. Fuel Process. Technol., 119, 263-271 (10 pages).

Metcalf, J. B.; Gopalakrishnan, K.; Waters, M.D., (2000). An initial investigation of the use of a rubber waste (EPDM) in asphalt concrete mixtures. Waste Manage. Series, 1: 940- 952 **(12 pages).**

Mohamed, A.A.; Husaini, O.; Hamzah, M.O.; Ismail, H., (2009). Rheological Properties of Crumb Rubber modified Bitumen Containing Antioxidant. Arab. J. Sci. Eng., 1-11 **(11pages).**

Mull, M.; Stuart, A.K.; Yehia, A., (2002). Fracture resistance characterization of chemically modified crumb rubber asphalt pavement. J. Mat. Sci. 37(3): 557-566 **(10 pages).**

Munera, J.C.; Ossa, E.A., (2014). Polymer modified bitumen: Optimization and selection. J. Mat. Des., 91-97 **(7 pages).**

Navarro, F.J.; Partal, P.; Martinez-Boza, F.; Gallegos, C., (2004). Thermo-rheological behaviour and storage stability of ground tire rubber-modified bitumen. Fuel 2004; 83: 2041–2048 **(8 pages).**

Polacco, G.; Berlincioni, S.; Biondi, D.; Stastna, J., (2005). Asphalt modification with different polyethylene-based polymers. Euro. Polymer. 2005; 41: 2831-2844 **(14 pages).**

Roberts, F.L.; Kandhal, P.S.; Brown, E.R.; Lee, D.Y.; Kennedy, T.W., (1991). Hot mix asphalt materials, mixture design, and construction. Nat. Asphalt Pavement Assoc. Edu. Found. Lanham, MD. 1-603 **(603pages)**

Sharma, R.; Ashok, P.; Trilok, G., (2012). Performance of polymer modified bitumen for flexible pavements. Int. J. Strut. Civil. Engr., ISSN 2319 – 6009 1(1):77-86 (**9 pages).**

Vallerga, B.A.; Finn, F. G.; Hicks, R. G., (1967). Effects of asphalt aging. Proceedings, Second Int. Conf. Struct. Des. Asphalt Pavement, 2: 4-6 **(3 pages)**.

WRAP, (2006). Composition of Tyre. The Waste & Resources Action Programme, the Old Academy, 21 Horse Fair, Banbury. 1-5 **(5 pages)**.

Wu, C.;Li, L.; Wang, W.; Gu, Z., (2021). Experimental Characterization of Viscoelastic Behaviors of Nano-TiO2/CaCO3 Modified Asphalt and Asphalt Mixture. Nanomaterials 11 (1), 1- 106 **(106 pages)**.

Xin, X.; Yao, Z.; Shi, J.; Liang, M.; Jiang, H.; Zhang, J., (2020). Rheological Properties, Microstructure and Aging Resistance of Asphalt Modified with CNTs/PE Composites. Constr. Build. Mater. 262, 120100. 1-11 **(11 pa**ges).

Yoon, S.; Prezzi, M.; Siddiki, N.Z.; Kim, B., (2006). Construction of a test embankment using a sand-tire shred mixture as fill material. Waste Manage., 26(9):1033–1044 **(12 pages).**

Yu, R.; Zhu.; Hu, J.; Zhao, W.; Fang, C., (2019). Preparation of graphene oxide and its modification effect on base asphalt. Fullerenes, Nanotubes Carbon Nanostructur., **27** 256-264 **(9 pages).**

HOW TO CITE THIS ARTICLE

Aladekoyi, G.; Olumayede, E.G.; Malomo, D., (2023). Performance optimization in bitumen properties from different sources modified with shredded tier waste. Int. J. Hum. Capital Urban Manage., 8(1): 83-94.

DOI: 10.22034/IJHCUM.2023.01.07

url: https://www.ijhcum.net/article_699856.html