# PHYSICOCHEMICAL PROPERTIES OF MODIFIED KADUNA REFINERY BITUMEN WITH BAMBOO AND ROSEWOOD FIBERS

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## ABSRACT

The principal limitation of bitumen as an important technological material is its unpredictable thermally dependent properties and other undesirable characteristics that result in its poor service performance. The possibility of using bamboo and rosewood as cheap locally available materials for modifying the refinery bitumen in Nigeria to better properties for applications was conducted with results presented herein. Dry bamboo and rosewood were separately ground to powders of 75µm sieve mesh size and sequentially additively blended in different amounts of 0 to 20% by weight with prepared samples of the bitumen. The basic physicochemical properties of the blended samples were determined to know their respective values in relation to the unmodified bitumen sample. Appropriately determined flash point, fire point, penetration, softening point, viscosity, relative density, and weathering resistance properties in accordance to ASTM or IS standard test procedures indicated marked improvement in the properties with the 10 to 20% bamboo and rosewood contained bitumen samples. Notably, the 15%-bamboo and 15%-rosewood contained samples produced a lot better of the properties than the rest with the bamboo sample as the most prcticable. X-ray fluorescence (XRF) analyses of the two samples were conducted to know the distinct chemical compositions that underlay improvement of their properties and scanning electron micro-structural (SEM) analyses to understand compatibilities of the additives with the bitumen. The XRF results showed that the additives altered the percentage compositions and number of 15 chemical species in the unmodified bitumen to 17. Regular smoother microstructures devoid of marked abnormities and indicative of very high compatibilities of the additives with the bitumen were observed by SEM analysis of the samples.

**Keywords:** Nigerian bitumen, development, low exploitation, research, modification, progress.

## INTRODUCTION

Bitumen is a cheap worldwide available multi-purpose long-standing technological material that is per se unsuitable for most modern engineering applications because of its generally unpredictable thermally dependent properties and other undesirable characteristics that result in its poor service performance. The need to improve these shortcomings in properties has led to modifying bitumen in its usage with small amounts of certain additives. Modified bitumen with satisfactory properties is used for various purposes such as corrosion coat-protection, paving of parking lots, road construction, sealants in transportation systems, and building constructions. Development of new modified bitumen with better properties is seen to be increasingly on demand in industry for greater utilization of the worldwide available bitumen from different sources`. Significant advances in the usage of bitumen have reportedly been found in the literatures involving modified bitumen but only a number out of the much multifarious possible material modifiers in existence have so far been tested and exploited. Although polymers have been used extensively to modify bitumen to some extent, their high cost and environmental impact have made engineers to be in search for cheaper, environmentally friendly, and sustainably available alternatives such as plant fibers [1-7]. Nigeria has the second largest bitumen resources in the world after Canada which if fully exploited can make her have a quantum leap in her economic and technological development. These vast important resources in the country have so far remained unexploited and need much research to be done on it for proper utilization **[7**]. The motive behind this research work was to explore the possibility of individually using bamboo and rosewood as common cheap natural fiber in Nigeria for modifying Kaduna refinery bitumen-the most important synthetic source in the country to satisfactory level for service applications. The objectives were:

i. To test the basic physicochemical of the unmodified and modified bitumen with various contents of bamboo and rosewood fibers by weight
ii. To, analyze the results and provide information on suitability levels of the fibers in modifying the bitumen.

## MATERIALS AND METHODS

### Materials

The main materials used for the study were bitumen, bamboo, and rosewood

### Procurement of materials

i. Freshly manufactured bitumen was sourced from Kaduna Refining and Petrochemical Company (KRPC)
ii. Dry bamboo stalk and dry rosewood timber were procured from the open market at Muda Lawan timber market Bauchi metropolitan area in Bauchi State, Nigeria

### Equipment

The under listed equipment available at the Transportation Engineering Laboratory of the Department of Civil Engineering, Abubakar Tafawa Balewa Univeristy, Bauchi were used for the study:

i. Industrial grinding machine
ii. SYD-3536 Cleveland open cup flashpoint tester manufactured by Shanghai Changji Geological Instrument Co. Ltd China
iii. Semi-automatic dial penetrometer type B057-10 manufactured by Matest S.P.A. Treviolo, Italy
iv. ELE Ring and ball apparatus 46-4605 manufactured by ELE International UK.
v. Digital water bath model DK420 manufactured by HARRIS England.
vi. Saybolt 81-B0121 single tube viscometer
vii. Kerro BL200001 electronic compact Balance
viii. Laboratory thermometer
ix. Petri dishes
x. X-Ray Fluorescence spectrometer made by Skyray Instruments USA Inc
xi. Scanning Electron Microscope
xii. Optical Emission Spectrometer
xiii. Hot air oven manufactured by Deluxe Scientific surgico PVT. Ltd. (DESCO)
xiv. Set of Test sieve manufactured by BENT
xv. ELE Bitumen ageing machine

## Methodology

### Preparation of bamboo and rosewood fibres

The procured dry bamboo stalk was first pounded in a mortar with a pestle to tiny particle size-form for grinding and latter processed into powder form at a commercial grinding mill in Yalwan Tudu in Bauchi. A sieve with a mesh-size of 75 microns was used to sift the ground bamboo to produce fine powder particles. Plate I shows the sieving container used and plate II the sieving process as it was done manually. The wood was similarly prepared likewise the bamboo but only after reducing any moisture content in it using an electric dryer in the laboratory and a pulverizer at a commercial grinding mill in Yalwan Tudu also in Bauchi. Plate III shows the produced bamboo and rosewood powder for the study. The produced powders were stored in clean metal containers prior to use.


Plate I: The sieve container used

Plate II: Process of sieving of ground bamboo into requisite powder particle size

Plate III: Produced bamboo and rosewood powders for the study

### Preparation of fiber modified bitumen samples

Modified bitumen samples were produced with 0, 5, 10, 15, and 20% by weight compositions of the prepared bamboo and rosewood powder respectively. To prepare the samples, bitumen was heated and maintained at 150 ±2$^{o}$C using an electric heating unit as shown in plate IV, and 95g of the liquefied bitumen mixed and blended with 5g of bamboo fibre to produce a material of 5% bamboo and 95% bitumen-weight composition. The portions were thoroughly mixed manually in the laboratory at that temperature with a manual inert steel stirrer at a frequency of about 100rpm as shown in Plate V until the colour and consistency of the mixture appeared to be uniform. The typical time used for the blending was 2 hours. Similar procedure was used for other proportions using appropriate pre-determined masses of bamboo and bitumen. The 10%-weight bamboo blend sample was made with 10g of bamboo powder to 90g the bitumen, the 15%-bamboo blend with 15g bamboo and 85g bitumen and the 20%-bamboo blend with 20g bamboo powder and 80g bitumen. The modified bitumen samples with rosewood (RMB) were prepared in a similar way used for producing the bamboo modified bitumen samples (BMB). Plate IV shows the mixing container used and the modified bitumen samples of different percentage composition of modifier material in five smaller containers.

Plate IV: Mixing containers with modified bitumen samples in smaller containers

**Experimentation**

The physicochemical and mechanical properties of the prepared modified bitumen samples with bamboo and rosewood were determined as follows:

**Flash and fire points**

This test was conducted in accordance with the international standard IS: 1209 – 1978 using the SYD-3536 Cleveland open cup flashpoint tester with a test cup, thermometer, and Bunsen burner. A sample of unmodified bitumen was poured into the cup to a standard level and heated electrically at a constant temperature increment rate of $5^{0}$C/min, while periodically passing a small flame from a gas burner across the surface of the bitumen. The flash point was taken as the temperature at which vapour given off by the bitumen gave a momentary ignition while the fire point taken as the temperature at which the further heated bitumen ignited and continued to burn for at least five second. The two temperatures were instantly read from the control panel of the electric heating unit. The procedure was repeated with each of the different bamboo and rosewood modified bitumen. Plate V shows the experimental setup.

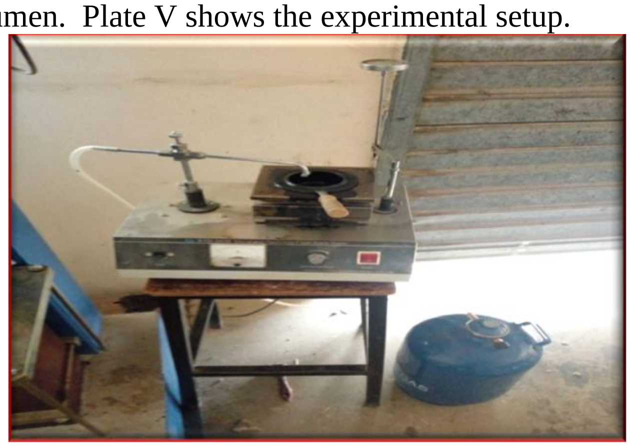


Plate V: SYD3536 clever cup flash point tester

**Penetration Test**

The penetration test was carried in accordance with the ASTM D5-97 procedure using Semi-automatic dial penetrometer type B057-10. A prepared sample was immersed in a standard bath containing water and heated to $90^{O}$C to soften it and poured to a depth of 15mm into a cylindrical flat-bottomed steel container and allowed to cool to $25^{O}$C. A one-millimetre diameter standard needle of hardness number C54-C60 under vertical load of 100g was released from a calibrated height on the penetrometer and allowed to fall and penetrate the prepared sample at

$25^{O}C$ in the steel container. The indicator scale of the penetrometer instantly gave the penetration value in millimetres. The obtained value was converted to decimetres by multiplying by 10 to obtain the penetration value in terms of number of 0.1mm. This was repeated twice with the same sample and average of three values found as penetration of the sample. This was carried out with the unmodified bitumen sample and each modified bitumen sample containing different weight percentages of bamboo, and similarly rosewood. Plate VI shows the penetrometer used for the test.

Plate VI: The penetrometer used for the study

**Relative Density**

The relative densities of the prepared samples were determined in accordance with the ASTM D70-17 procedure for determining relative density of semi-solid bituminous materials. A 250-milllitre glass container of internal diameter 75mm, electronic digital weighing scale,, a venier depth gauge, and a small steel slab that could fit in the container were used for determining the relative densities of the prepared bituminous samples. By procedure, the slab was immersed in water poured to a suitable level in the container and the mass of the container and its content $(M_1)$ determined with the digital weighing scale as shown in Plate VII. The change in volume of water in the container $(V_1)$ was also determined in cubic millimetres as;

$$V_1 = \frac{\pi D^2}{4}(H_2 - H_1) \quad \dots\dots\dots\dots\dots\dots.\dots\dots (1)$$

Where, $D$ = 75mm, and $H_2$ and $H_1$ were the measured depths of water in the container in millimetres with the venire depth gauge after and before the slab was immersed in it respectively. The slab was thence removed and wiped off any moisture on it with a dry towel. A small portion of prepared bituminous sample whose density was to be measured was detached at room temperature from it and placed on the slab and immersed in fresh water poured to the same depth level $(H_1)$ , and the foregoing procedure repeated to obtain another depth$(H_2)$, mass $(M_2)$, and volume $(V_2)$. The relative density $(\rho)$ of the sample was thus determined as,

$$\rho = \frac{M_2 - M_1}{V_2 - V_1} \quad \dots\dots\dots\dots\dots\dots\dots.\dots\dots\dots (2)$$

Plate VII: Weighing process for determining relative density using a digital weighing machine

**Softening point**

The softening points of the prepared samples were determined in accordance to ASTM D36-95 procedure using the ELE Ring and ball apparatus and digital water bath. The bituminous sample whose softening point was to be measured was heated until it boiled and was able to be poured. The sample was then poured into the brass ring and allowed to cool and set for 30 minutes. The ring assembly and two ball bearings were placed in fresh distilled water bath filled to a depth of 600±3mm and the whole system maintained at a temperature of 25±1°C for 15 minutes. A 9.53mm diameter steel ball bearing of weight 3.50±0.05g was placed centrally on the specimen and the bath heated electrically so as to raise its water temperature by 5±0.5°C per minute. The bath temperature at which the sample material surrounding the ball moved downwards in the bath and touched the base plate 25mm below the ring was recorded to the nearest 0.2°C with a thermometer as the softening point. The test was repeated for each prepared bituminous material and result values obtained in pairs. The corresponding pair averages were reported as softening points for all the tested samples. Plate VIII shows the ball and ring apparatus used for the test.

Plate VIII: Ball and ring apparatus used for the test

**Kinematic viscosity**

The kinematic viscosity of each prepared bituminous material was determined at $60^{O}C$. The test was carried in accordance to ASTM D2170 standard test method for determining kinematic viscosity of bitumen using the Saybolt viscometer. The apparatus consisted of a constant temperature bath, silicone bath oil, vacuum system, thermometer, stop watch, and the viscometer as shown in Plate IX. A portion of material whose viscosity was to be determined was heated at a constant temperature of $70^{O}C$ in the vacuum system and allowed to cool to $61^{O}C$. The viscometer was cleaned with carbon tetrachloride and a cork inserted in its bottom. The material was poured into the viscometer to such a height that the levelling peg on the viscometer was just immersed when the viscometer was vertical. The viscometer was then immersed in the bath oil under constant bath medium temperature of $60 \pm 0.01^{O}C$ by controlled heating with electric heaters. The time it took the material to flow through the orifice of the viscometer at the bath temperature was measured with the stop watch and taken as the viscosity of the material in Poise.

Plate IX: Saybolt 81-B0121 single tube viscometer

**Weathering resistance**

Accelerated weathering resistances of the prepared bitumen samples was conducted in principle to ASTM G154, ASTM D4329, ASTM D4587, ISO 4892 to simulate effects of their service-time outdoor exposure to weather conditions. 12 test samples were each produced with given prepared bituminous material. This was achieved by heating each material to 100$^{O}$C to soften it and using it to produce more or less similar coatings in standard disks of 50mm inner diameter and 60mm outer diameter and 4mm thickness. The samples were mounted in the QUV test chamber and subjected to one-hour cycle of exposure to intense ultraviolet radiation at heater-controlled chamber temperature of 60$^{O}$C followed by one hour forced condensation with cold water at 8-12$^{O}$C. Measurements were made of the coating thicknesses of the samples initially and after the condensation with a venire calliper. This was repeatedly carried out for 10 hours. The weathering resistance of the samples was taken as measure of levels of changes in the coating thicknesses relative to the initial values. Plate X shows the weathering resistance facilities used for the test.

Plate X: Weathering resistance test facility showing the frame structure housing the chamber, a pile of the disks, and disks with the prepared coatings

## RESULTS AND DISCUSSIONS

### Results

Results of the conducted tests to determine the flash points, fire points, penetrations, relative densities, softening points, and kinematic viscosities tests are presented in Figs. 1, .2, 3, .4, 5, and 6 respectively. Results for the weathering resistance tests are shown n in Figs. 7 and 8.

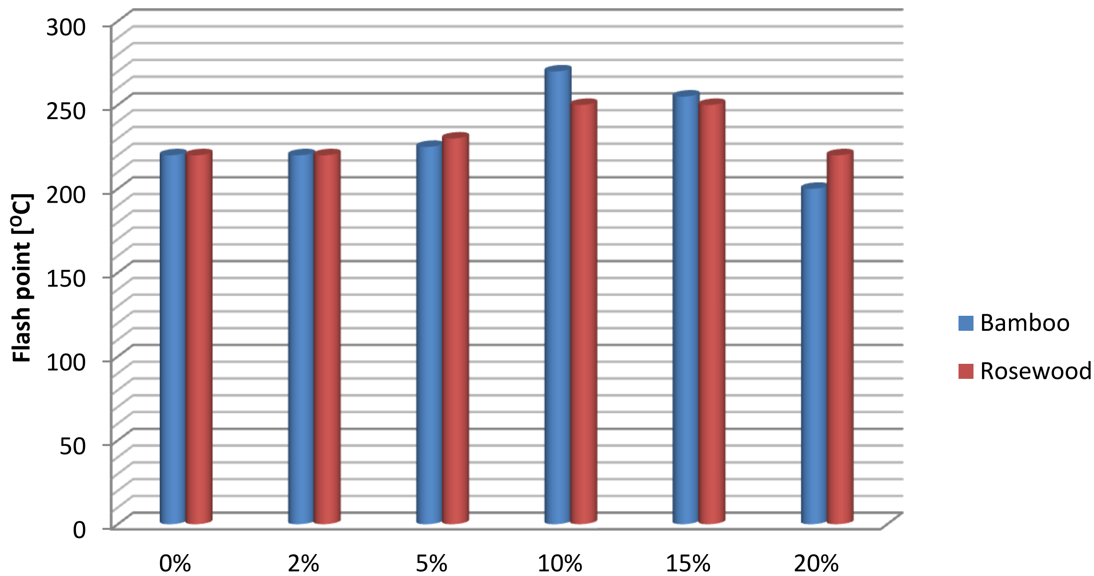



**Fig. 1: Flash points of the modified bitumen samples containing various levels of bamboo and rosewood**

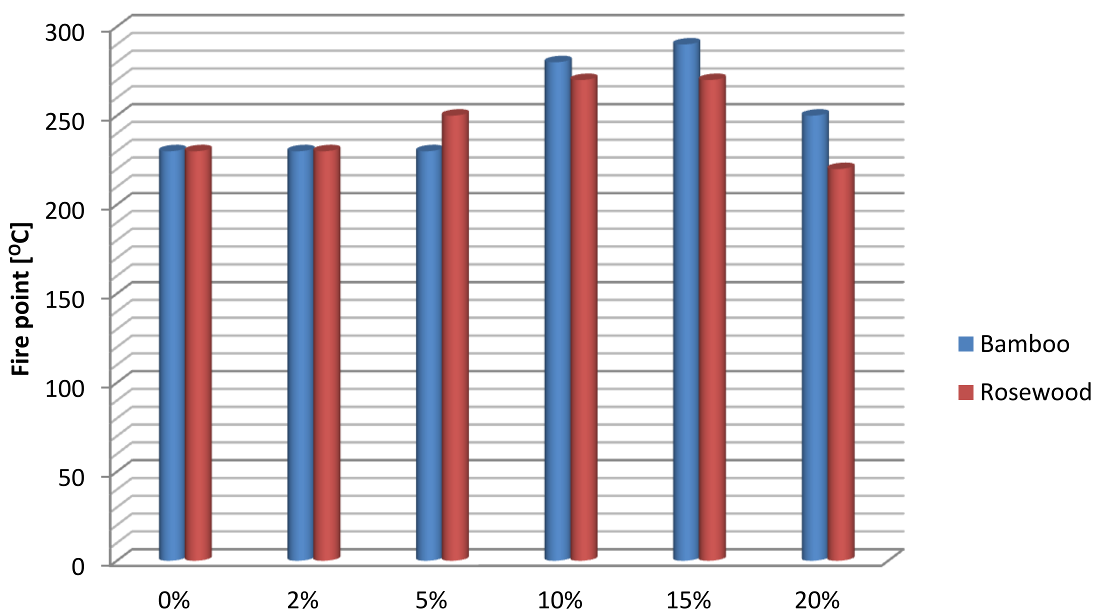



**Fig 2: Fire points of the modified bitumen samples containing various levels of bamboo and rosewood**

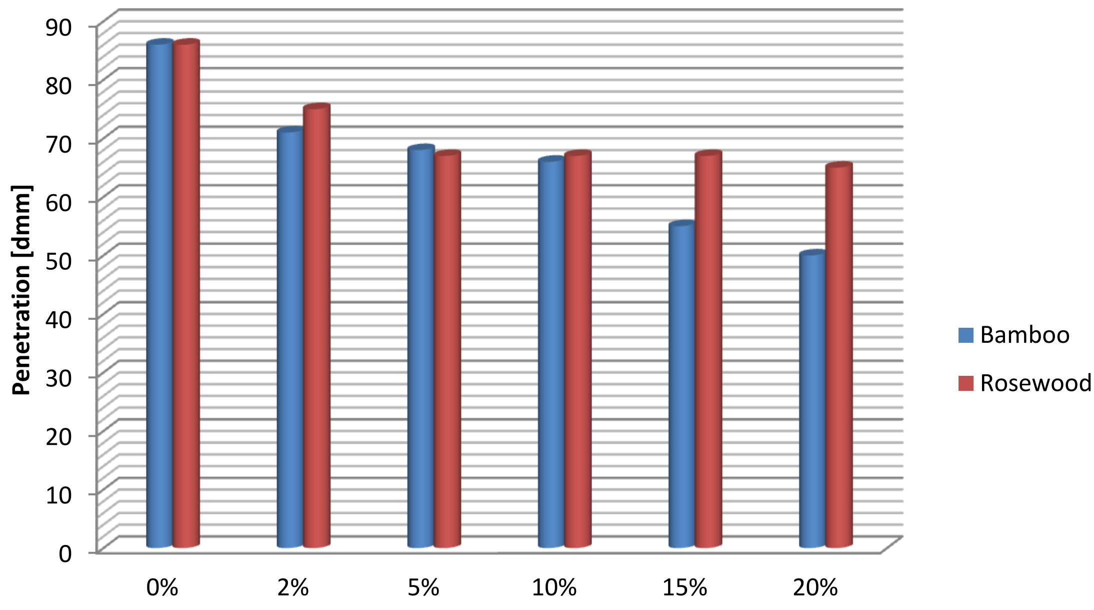



**Fig 3: Penatrations of the modified bitumen sample containing various levels of bamboo and rosewood**

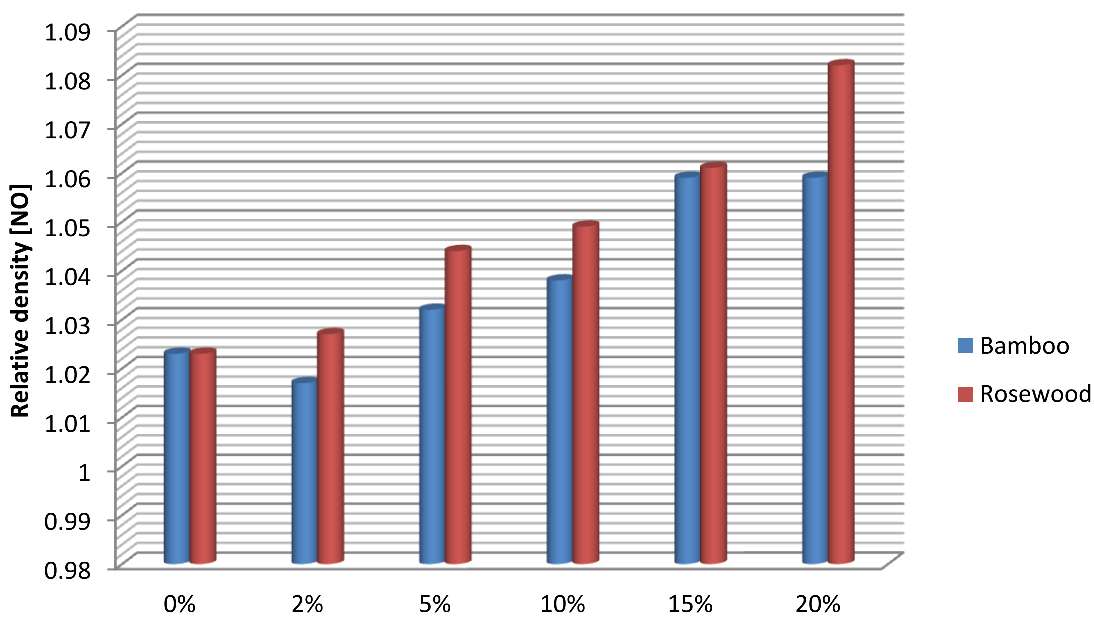
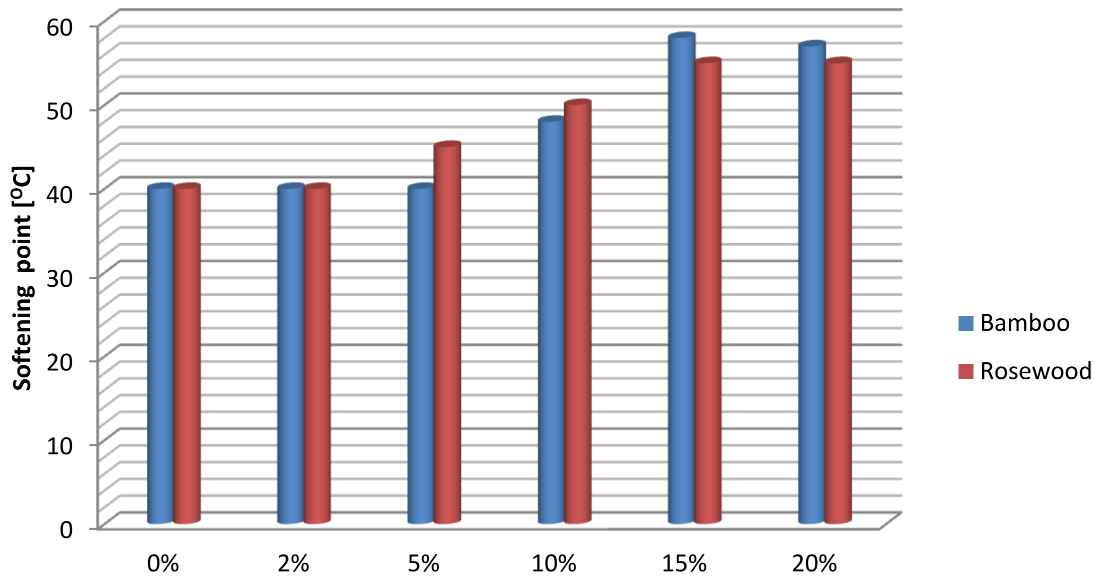
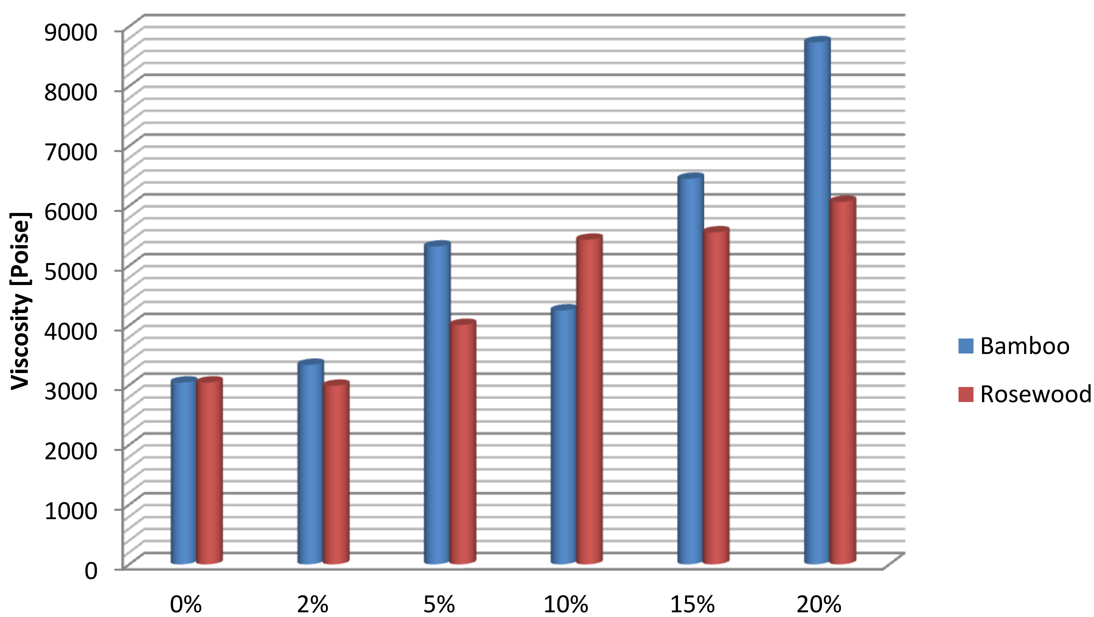



**Fig 4: Relative densities of the modified bitumen samples containing containing various levels of bamboo and rosewood**




**Compositions of bamboo and rosewood in the modified bitumen samples**

**Fig 5: Softening points of the modified bitumen samples containing various levels of bamboo and rosewood**




**Compositions of bamboo and rosewood in the modified bitumen samples**

**Fig 6: Viscosities at 60$^{o}$C of the modified bitumen samples containing various levels bamboo and rosewood**

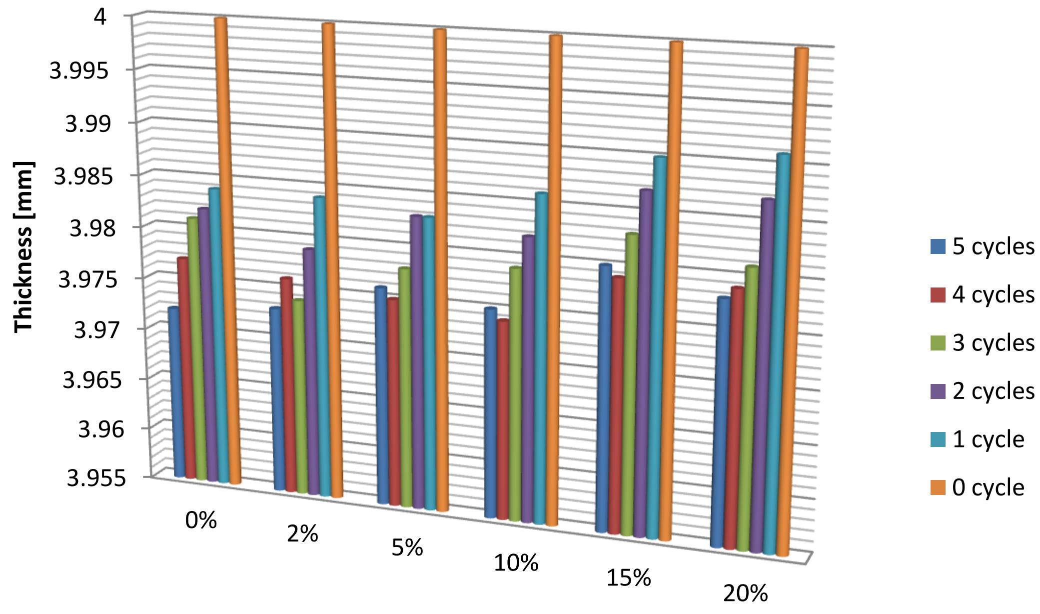



**Fig. 4.7: Pattern of variation of weathering resistances of the bamboo-modified bitumen samples shown in Table**

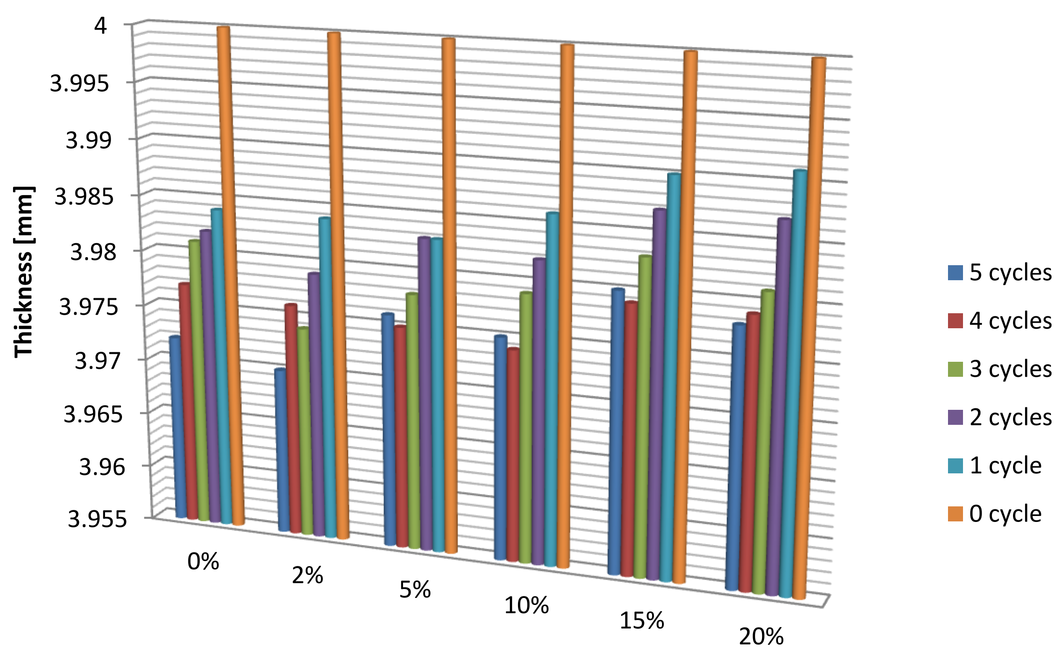



**Fig 4.8; Pattern of variation of weathering resistances of the rosewood-modified bitumen samples shown in Table**

## DISCUSSION

From Fig. 1, it can be seen that increase of 0-20% by weight of bamboo and rosewood in the modified bitumen samples generally had incremental effect on the flash point of the unmodified bitumen from 230$^{O}$C. Increase in flash point however became observable only from the 10% bamboo and rosewood-contained samples. Maximum flash points of 290$^{O}$C can be observed with the 15%-bamboo-contained sample. The flash points of the rosewood modified samples follow more or less similar trend of variation of the bamboo-modified samples with the highest value 270$^{O}$C from the 10-15% rosewood contained samples. According to Volume 3, Division 3-Pavement work Technical specifications [54], minimum flash point requirement for the 40/50, 60/70, 80/100, and 100/200 penetration grade bitumen is 250$^{O}$C in accordance with the Cleveland Open Cup test with the ASTM 10.5 procedure. From this, it is evident that modifications of the bitumen with 15% bamboo and 15% rosewood by weight composition upgraded its below-grade flash point to much better values.

Fig. 2 also shows that increase in weight content of bamboo and rosewood in the modified bitumen samples raised the fire point of the control bitumen in a more or less similar way to the flash point results. The fire points increased from 230$^{O}$C to the highest values of 280$^{O}$C and 170$^{O}$C with the 15%-bamboo and 15% rosewood-contained samples respectively.

Fig. 3 shows that the penetrations of the modified bitumen samples more or less reduced minimally from 67dmm with the control sample with increase in percentage weight of bamboo in the samples and attained the least value of 50dmm with the sample that contained 20% bamboo. On the other hand the penetration value of the control bitumen sample remains more or less constant at 67dmm with increase in percentage weight of rosewood in the modified bitumen samples except the 20% rosewood-contained samples which produced penetration value of 65dmm. The acceptance limits of penetration for the 40/50, 60/70, 80/100, and 130/150 bitumen grades are in the ranges of 37-53, 57-74, 75-105, and 121-158dmm respectively [9, 10]. It can therefore be appreciated that the penetration values of 50dmm for the bamboo-modified sample altered the grade of the control bitumen from 60/70 to the harder grade 40/50 so make it better for practical coat-applications. This was however not achieved with the rosewood sample with penetration value of 65dmm due to its minimal increase in hardness.

From Fig. 4, it can be observed that increase of 0 to 20% by weight of bamboo and rosewood in the modified bitumen samples resulted minimal increment of relative density of the control bitumen. Relative densities decrease minimally from 1.023g/cm$^3$ of the control bitumen with increase in the weight contents. Maximum relative densities of 1.093 and 1.082 were attained with the modified bitumen samples that contained 20% by weight bamboo, and rosewood respectively. Relative density is a measure of consistency of bitumen and determines acceptability of bitumen in relation to bitumen of standard grades [9, 10]. Generally, relative densities of penetration grade bitumen range from 0.99 to 1.06g/cm$^3$. The value of relative density for the 60/70 bitumen is in the range of 1.01-1.06. From this, it can also be understood that the unmodified bitumen is of 60/70 penetration grade and the modification did not significantly alter the relative density out of the range. So the modified bitumen samples are also of satisfactory values as per the 60/70 grade bitumen.

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Fig.5 shows that the softening point of the control bitumen sample increased from 40$^{O}$C with 5 to 20% by weight of bamboo and rosewood in the modified bitumen samples. Maximum softening points of 58$^{O}$C, and 55$^{O}$C were attained with the modified bitumen samples that contained 15% bamboo, and 15% rosewood respectively. This made the two samples best in terms of this property. The softening points of the 40/50, 60/70, 80/100, and 100/200 penetration grade bitumen by the ASTM 10.2 test procedures are in the ranges of 52-60, 48-56, 45-52, and 37-43$^{O}$C respectively [9]. By these, it can be appreciated that the 15%-contained bamboo and 15%-contained rosewood bitumen samples which produced the greatest improvements in softening points of the unmodified bitumen, altered the grade of the control bitumen from the softer grade 100/200 to a grade equivalent to those of harder grades 40/50 and 60/70 bitumen respectively.

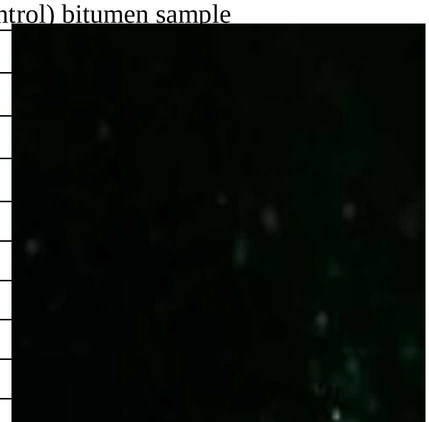
From Fig. 6, it can be observed that the kinematic viscosity of the control bitumen sample increased appreciably from 3041 Poise within 0-20% increase in weight content of bamboo and rosewood in its modified samples. The highest kinematic viscosities of 8734, and 6064 were achieved with the modified samples that contained 20% bamboo, and 20% rosewood respectively. Viscosity of bituminous materials generally decreases with increase in temperature. At room ambient temperature of 25$^{O}$C, the viscosity of most bitumen range from 1000 to 50000. At 60$^{O}$C, the viscosity of any bitumen is thus expected to be less than 50000. Therefore, the viscosities obtained here are indicative of bitumen of satisfactory quality with appreciable improvement by 15-20% by weight of the bamboo and rosewood additives to it [7, 8, 11].

Figs. 7 and 8 show that the control and modified bitumen samples weathered minimally with environmental conditions. The results also indicates that the modified bitumen sample that contained 15% by weight bamboo, and another that also contained 15% by weight weathered least by coating thickness reduction from 4mm to so produced the best weathering resistances among all the samples.

From the foregoing analyses it is apparent that the modified bitumen samples exhibited more meaningful improvement in the physicochemical properties of the test refinery bitumen with the 10-20% by weight of bamboo and rosewood additions. In totality, the modified bitumen sample that contained 15% by weight bamboo and the other that contained 15% rosewood produced the best physicochemical properties of the bitumen. The bamboo modified sample however had an edge over the rosewood modified sample with regard to improvement of the properties. To understand some implicit character responsible for the performances of the two samples, their X-ray fluorescence (XRF) were conducted to know their distinct chemical compositions and scanning electron micro-structural (SEM) analyses carried out on the to understand compatibilities of the fiber additives with the bitumen all wit facilities at the National Steel Raw Material Research and Development Council, Malali, Kaduna. The obtained XRF results were as shown in Tables 1, 2, and 3 while the SEM results were as shown in Plates XI, XII, and XIII..

From Table 1, it can be seen that the control bitumen samples contained 15 different chemical species of different percentage compositions. Modification of this sample by blending it with 15% by weight bamboo altered the percentage compositions of these chemical species and increased their number by 2 to 17 as can be seen in Table 2. Modification of the control sample by blending it with 15% by weight rosewood content also altered the percentage chemical composition of the bitumen to different levels but did not increase the number of chemical species as can be observed in Table 3. From these it is understandable that the improvements achieved in the physicochemical properties of the modified bitumen samples can be due rearrangements and or increment in the number of chemical species in their structures resulting in a different material with better properties. Furthermore, it can be seen from Plate XI that, micro-structurally the control bitumen sample has more or less granular or cross link regular structure. With blend of this sample with 15% bamboo by weight, the pattern of the structural regularity is maintained but the grains become pale and smoother as can be observed in Plate XII. This indicated that the bamboo had good compatibility with the bitumen. It can nevertheless be observed in Plate XIII , that blend of 15% by weight of rosewood with the bitumen altered the pattern of microstructure of the control bitumen sample into a much smoother appearance that is more or less uniform but different. This also indicates fair compatibility of the blended materials in the sample.

Table 1: XRF-analyzed chemical composition of the unmodified (control) bitumen sample

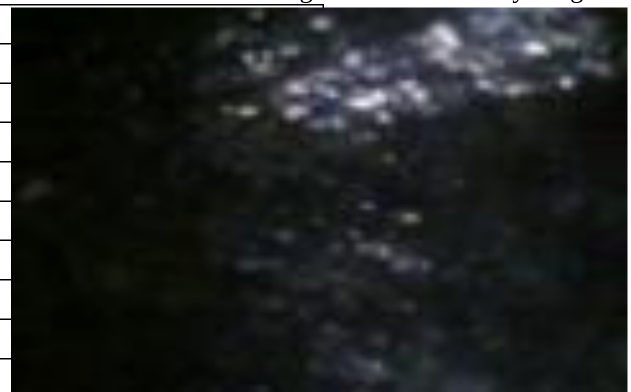


| | | | |
|---|---|---|---|
| Sample Name | BITUMEN CONTROl | | |
| Supplier | ABDULLAHI | | |
| Operator | | | |
| Date | 2018-07-13 11:24 | | |
| GPS | | | |
| Testing time | 30m | | |
| Volt | 45kV | | |
| Curr | 50uA | | |
| Mode | Mineral Mode | | |
| Specification | | | |
| Element | Content | Detection limit | Error |
| MgO(%) | 8.8146 | 0.0000 | 0.3472 |
| Al2O3(%) | 7.4703 | 0.0000 | 0.2667 |
| SiO2(%) | 5.5466 | 0.0000 | 0.0764 |
| P2O3(%) | 0.6572 | 0.0000 | 0.0073 |
| SO2(%) | 41.8170 | 0.0000 | 0.0815 |
| K2O(%) | 0.0239 | 0.0000 | 0.0062 |
| V2O3(%) | 0.0060 | 0.0000 | 0.0003 |
| Fe2O3(%) | 0.1719 | 0.0000 | 0.0032 |
| Ni2O3(%) | 0.1330 | 0.0000 | 0.0035 |
| CuO(%) | 0.0030 | 0.0000 | 0.0001 |
| SrO2(%) | 0.0451 | 0.0000 | 0.0005 |
| NbO(%) | 0.0460 | 0.0000 | 0.0003 |
| MoO(%) | 0.1480 | 0.0000 | 0.0009 |
| Ag2O3(%) | 0.0156 | 0.0000 | 0.0003 |
| CdO(%) | 0.0754 | 0.0000 | 0.0017 |
| HfO(%) | 0.0006 | 0.0000 | 0.0000 |

Table 2: XRF-analyzed chemical composition of the modified bitumen containing 15% bamboo by weight

| Sample Name | BITUMEN+BAMBOO DUST | | |
|---|---|---|---|
| Supplier | ABDULLAHI | | |
| Operator | | | |
| Date | 2018-07-13 12:57 | | |
| GPS | | | |
| Testing time | 30m | | |
| Volt | 45kV | | |
| Curr | 50uA | | |
| Mode | Mineral Mode | | |
| Specification | | | |
| Element | Content | Detection limit | Error |
| MgO(%) | 0.0545 | 0.0000 | 0.0030 |
| SiO2(%) | 1.9415 | 0.0000 | 0.0341 |
| P2O3(%) | 0.4267 | 0.0000 | 0.0059 |
| SO2(%) | 26.4221 | 0.0000 | 0.0684 |
| K2O(%) | 0.0223 | 0.0000 | 0.0060 |
| MnO(%) | 0.0001 | 0.0000 | 0.0000 |
| Fe2O3(%) | 0.1655 | 0.0000 | 0.0031 |
| Ni2O3(%) | 0.1919 | 0.0000 | 0.0044 |
| SrO2(%) | 0.0489 | 0.0000 | 0.0006 |
| Y2O3(%) | 0.0283 | 0.0000 | 0.0003 |
| ZrO2(%) | 0.0218 | 0.0000 | 0.0002 |
| NbO(%) | 0.0971 | 0.0000 | 0.0005 |
| MoO(%) | 0.4344 | 0.0000 | 0.0021 |
| PdO(%) | 0.0136 | 0.0000 | 0.0007 |
| Ag2O3(%) | 0.0211 | 0.0000 | 0.0003 |
| CdO(%) | 0.2863 | 0.0000 | 0.0046 |
| HfO(%) | 0.0010 | 0.0000 | 0.0001 |

Table 3: XRF-analyzed chemical composition of the modified bitumen containing 15% rosewood by weight



| Sample Name | BITUMEN+SAWDUST | | |
|---|---|---|---|
| Supplier | ABDULLAHI | | |
| Operator | | | |
| Date | 2018-07-1312:11 | | |
| GPS | | | |
| Testing time | 30m | | |
| Volt | 45kV | | |
| Curr | 50uA | | |
| Mode | Mineral Mode | | |
| Specification | | | |
| Element | Content | Detection limit | Error |
| MgO(%) | 8.3580 | 0.0000 | 0.3333 |
| Al2O3(%) | 6.7833 | 0.0000 | 0.2495 |
| SiO2(%) | 6.7839 | 0.0000 | 0.0879 |
| P2O3(%) | 0.5758 | 0.0000 | 0.0068 |
| SO2(%) | 37.7414 | 0.0000 | 0.0796 |
| K2O(%) | 0.0271 | 0.0000 | 0.0066 |
| CaO(%) | 0.3767 | 0.0000 | 0.0310 |
| Fe2O3(%) | 1.8818 | 0.0000 | 0.0126 |
| Ni2O3(%) | 0.1194 | 0.0000 | 0.0033 |
| SrO2(%) | 0.0194 | 0.0000 | 0.0003 |
| NbO(%) | 0.0356 | 0.0000 | 0.0003 |
| MoO(%) | 0.0802 | 0.0000 | 0.0006 |
| Ag2O3(%) | 0.0062 | 0.0000 | 0.0002 |
| CdO(%) | 0.0368 | 0.0000 | 0.0010 |
| SbO(%) | 0.0002 | 0.0000 | 0.0001 |

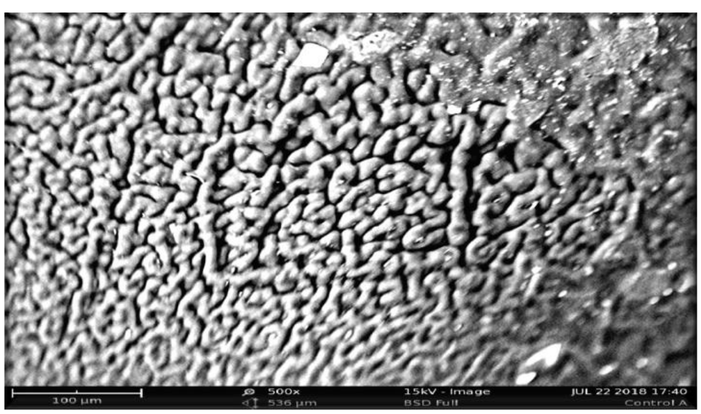



Plate XI: SEM microstructure of the unmodified (control) bitumen sample

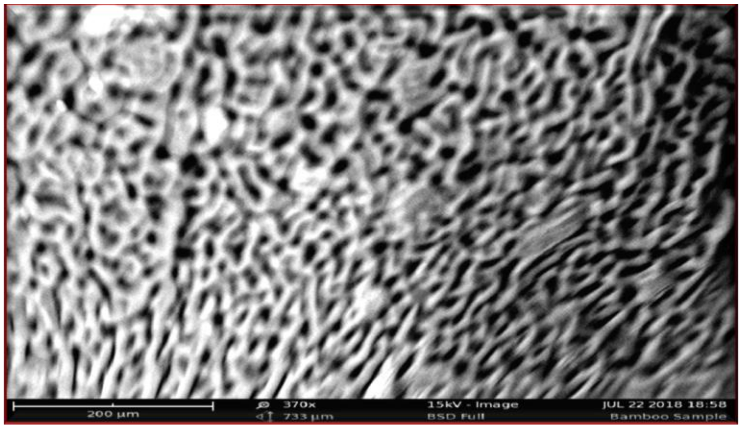


Plate XII: SEM microstructure of the modified bitumen containing 15% bamboo by weight

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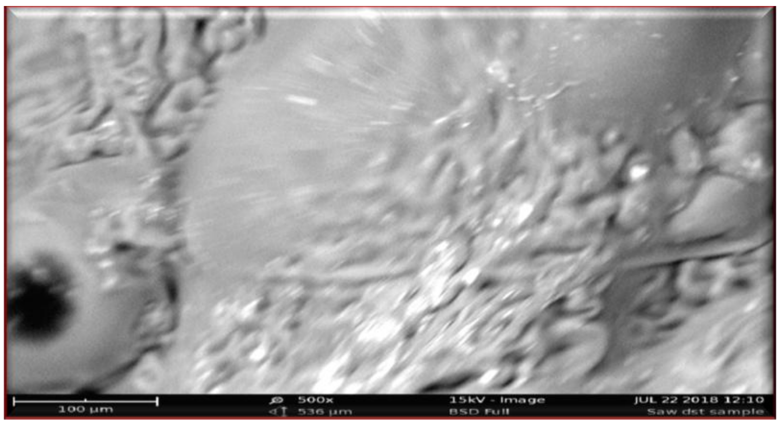

Plate XII: SEM microstructure of the modified bitumen containing 15% rosewood powder by weight

## CONCLUSIONS

Physicochemical properties of individually sequentially modified ungraded synthetic bitumen from Kaduna refinery with bamboo and rosewood additives 0-20% weight contents have been procedurally investigated. Test results with prepared samples indicated marked improvement in the basic physicochemical properties of the bitumen with 10-20% bamboo and rosewood additions. The 15%-bamboo-contained sample however exhibited the best practicable properties among all others prepared samples followed by the 15%-rosewood-contained sample. X-ray fluorescence (XRF) and scanning electron microscopy (SEM) analyses of the two samples were conducted to understand the underlying characters for their outstanding properties. The XRF results showed that the additives altered the percentage compositions and number of 15 listed chemical species in the unmodified bitumen to more or less 17. The SEM analysis showed that the bamboo and rosewood additives altered the microstructure of the unmodified bitumen from more or less regular structures of bigger grains into smoother grains of different regular patterns that are indicative of good compatibilities of the additives with the bitumen.

**REFERENCES**

[1]. Arafat, S.Y and Mohammad, R. H. (2012), *Evaluation of bitumen properties modified with additive.* International journal of research and reviews in applied sciences IJRRAS. Vol.1, No.1, pp. 93.
[2]. Robert N. H., Andy S., John R. (2015). The Shell Bitumen Handbook, 6th Edition. ICE Publishing, Westminster, London, pp 4,150.
[3]. `Asphalt Institute and Eurobitume (2015). The Bitumen Industry-A Global Perspective: Production, Chemistry, Use, Specification and Occupational Exposure, 3rd Edition, Asphalt Institute, Lexington, Kentucky, USA; Eurobitume Brussel, Belgium.
[4]. Chubuike, O.M., Ebele, C. C., Ifeanyi, I. F. *Study on chemical treatments of jute fiber for application in natural fiber reinforced composites (NFRPC).* International Journal of Advanced Engineering Research and Science (IJAERS), Vol. 4, Issue 2, Feb. 2017.
[5]. Müssig, J. (2010).Industrial applications of natural fibres: structure, properties and technical applications. John Wiley & Sons, Ltd., United Kingdom.
[6]. Srivastava A. and Roijen R.V. (2000), Bitumen Performance in Hot and Arid Climates. A Paper Prepared for Pavement Seminar for Middle East and North Africa Region on Innovative Road Rehabilitation and Recycling Technologies, New Policies and Practices in Pavement Design and Education, 22nd October, Amman. Jordan.
[7]. Thomas Ndyar Guma (2015), Effects of Some Bitumen Coating Treatments on the Corrosion and Mechanical Behaviour of Low Carbon Steel. A Dissertation Submitted to the Postgraduate School, Ahmadu Bello University, Zaria, Nigeria, for PhD Degree in Mechanical Engineering
[8]. T.N. Guma, P.B Madakson, D.S. Yawas, and S.Y. Aku. *Assessment of physicochemical properties of some bitumen from Nigerian resources*. Nigerian Journal of Basic and Applied Sciences, 20 (1 & 2), 2012. UsmanuDanfodio University, Sokoto.
[9]. Volume 3. Technical Specifications. Division 3-Pavement Works. May 2001 www.rhd.gov.bd/Documents/.../TechnicalSpecification/Bituminous%20Materials.pdf
[10]. NZTransport Agency WAKA KOTAHI Technical Memorandum
[11]. Ravindra, N. Jackson and K.D. (1997). Civil Engineering Material, 5th Edition, London : Palgrave, pp. 53-64.