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A STUDY OF NIGERIA NATURAL BITUMEN AND EFFECT OF POLYMER MODIFICATION ON THE BINDER PROPERTIES

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ABSTRACT : *This research assessed the performance of natural bitumen binder extracted from tar sand and the effect of polymer addition on the binder properties of the extracted bitumen. The polymers used in this research are WasteWater Sachets (WWS) and shredded Waste PET bottles (SWPB). The natural bitumen was extracted from Tar sand collected at two surface outcrops along the Dahomey Basin in Imeri town along Sagamu Benin Expressway, IjebuImushin, South West, Nigeria (6^0 47' 36.1" N and 3^0 59' 30.1" E).*
The average percentage weight of bitumen extracted from samples from the two locations are 13.38% and 7.1%. The major constituent of Tar Sand is Fine Sand. The extracted bitumen is light, with specific gravity value of 0.57 compared with the British Standard range of 0.97 to 1.02 of conventional bitumen. The bitumen was graded 85/100 pen. There was a trend of decrease in value of Penetration, increase in value of softening point and viscosity as the polymers were incrementally added. The results show that, the natural bitumen can be modified to 60/70 bitumen and with satisfactory softening and flash point at 1.5% addition of SWPB and 0.1% WWS. The natural bitumen can be used as liquid Asphalt.
KEYWORDS *-Marshall Flow, Marshall Stability, Natural Bitumen, Polymer Modification, Tar sand.*

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I INTRODUCTION

Large percentage of bitumen used for road construction is obtained from the refining of crude oil. Crude oil from Nigeria is light and has very low percentage yield of bitumen from fractional distillation [1].

The Nigerian bitumen belt is on the onshore areas of the south-western Nigeria Eastern Dahomey (Benin) Basin. The probable reserve of bitumen and heavy oil in the entire Nigerian belt is approximately 120 x 4km with an estimated 30-40 billion barrels in reserve [2,3]

Modified bituminous materials can bring real benefits to highway maintenance/construction, in terms of better and longer lasting roads, and savings in total road life costing. The choice of what materials to choose, how they perform, what may be achievable by the addition of various modifiers and the broad action of how it is achieved has been a subject of research.

It is well known that asphalt mixture has several temperature weaknesses which are low temperature cracking damage, medium temperature fatigue and high-temperature rutting (see Plates 1 and 2).

Plate 1: Rutting

Plate 2: Fatigue Cracking

Properties of asphalt can be improved by controlling the refining process or selecting the proper starting crude oil but these two are very difficult to achieve [4]. Therefore, the most favoured method to improve the quality of asphalt is its modification, one of which is to improve asphalt quality by the addition of polymers [4]. Rheological properties of asphalt are commonly improved by asphalt modification with a polymer [5].

Improvement of road performance is necessary because nowadays, there are increasing traffic factor, for example, higher traffic volume, higher tyre pressure, and heavier loads. A better performance pavement needs asphalt which has good bonding between aggregate and less exposure to low-temperature cracking and high-temperature rutting. Utilization of waste plastic and virgin plastic such as Polyethylene terephthalate (PET), polypropylene (PP), Low Density Polyethylene (LDPE), Ethylene Vinyl Acetate (EVA), Acrylonitrilebutadienne-styrene (ABS), High Density Polyethylene (HDPE), Polystyrene-butadiene-styrene (SBS), rubber latex, Chloroprene Rubber (CR), Polyolefines, Polyethylene (PE) and Polyvinyl chloride (PVC) in asphalt mixture can improve properties such as:0 softening point, resistance to rutting, durability, viscoelastic property and fatigue life [6-16].

This research therefore aims to utilize Waste Water Sachet (WWS) which is a Low Density Polyethylene (LDPE) material and Shredded Waste PET Bottle (SWPB) in improving the properties of natural bitumen as obtained at Ijebu-Imushin, Nigeria.

II MATERIALS AND METHODS

2.1 Bituminous material

Natural Bitumen as obtained from Ijebu-Imushin was used as the main binder. Some laboratory tests have been carried out to determine the properties of the natural bitumen: solubility, penetration, viscosity, flash point and Softening point.

2.2 Aggregates

The aggregates used for this study were from stockpile in sizes (mm) of 0-4 (fine sand), 0-5 (stone dust), 4-8 (crushed stone), 8-16 (crushed stone) and 16-25 (crushed stone). They were properly dried, cleaned from deleterious materials and sieved.

2.3 Waste Water Sachets (WWS)

Pure water sachets are low density polyethylene found littering everywhere, they were collected in huge quantity from streets, market place, dumpsite and washed with detergent to remove microbes and other dirty substances. It was then shredded into small pieces of about 2 mm to 4.75mm sizes.

2.4 Shredded Waste PET Bottles (SWPB)

PET is a polymer which is easy to handle and also durable and sturdy, has low gas permeability, thermally stable and chemically [16]. For this research, waste PET bottles were collected, and also shred into small pieces of about 2 mm to 4.75mm sizes.

Plate 3: Waste Water Sachet

Plate 4: Waste PET Bottles

Plate 5: Shredded Waste PET Bottles

The polymers (WWS and SWPB)were added into the extracted bitumen at an elevated temperature of 110^{o}c and mixed thoroughly to achieve a uniform blend. The SWPB was added in percentages of 1.5%, 2.5%, 5%, 7.5% and 10%. while the WWS was added in percentages of 0.1%, 0.2%, 0.3%, 0.4%, 0.5%, 1%, 1.5%, 2% and 2.5% to producePolymer-bitumen mixtures of different compositions and they were used to evaluate the properties of modified binder.

III RESULTS AND ANALYSIS

3.1 Analysis of Tar Sand

The analyses conducted on the Tar Sand samples collected include:

i. Natural Bitumen Saturation in Tar Sand
ii. Particle-Size Distribution (Sieve Analysis) of the sand residue after extracting the bitumen
iii. Textural Classification of the sand residue.
iv. Specific Gravity of the Tar Sand and Extracted Bitumen.
v. Marshall Test Properties on Direct Application of Tar Sand as Bituminous Mix.

3.1.1 Natural Bitumen Saturation in Tar Sand

The Natural Bitumen Saturation in Tar Sand denotes the percentage weight bitumen occupied in the tar sand collected. The results of natural bitumen extraction from the surface sample of the tar sand collected are shown in Table 1.

TABLE 1: Natural Bitumen Saturation in Tar Sand

	Sample A	Sample B
Weight of Tar sand (g)	600.24	201.16
Weight of Sand(g)	496.52	163.15
Weight of Fillers(g)	28.53	9.38
Weight of Bitumen(g)	75.19	28.63
% Weight of Bitumen	12.53	14.23
Average % Weight of Bitumen	13.38	

3.1.2 Particle-Size Distribution (Sieve Analysis) of Extracted Sand

The grading of aggregates shows the distribution of sizes from coarse to fillers. TheParticle-Size Distribution Curveof the sieve analysis done on the sand after extraction of the bitumen from the tar sand is shown in Fig. 2.

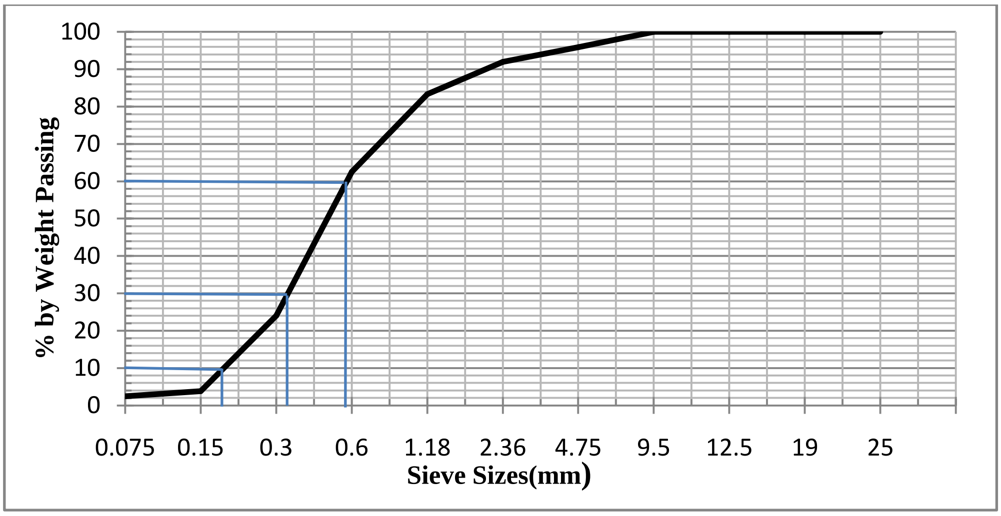


Fig. 1: Particle-Size Distribution Curveof the Sand Residue

The distribution curve of the extracted sand shown in Fig. 1 represents a type of soil in which most of the soil grains are the same size. The extracted sand is a Poorly Graded Soil [18}. The following parameters were determined from the particle distribution curve as shown in Fig. 1.

Effective size (D_{10})

Thisis the diameter corresponding to 10% finer on the Particle-Size Distribution Curve. It is a good measure to estimate the hydraulic conductivity and drainage through soil.The effective size of the extracted sand from its Particle-Size Distribution Curve is 0.19 (That is, D_{10} = 0.19).

Uniformity coefficient (C_u)

This parameter is expressed as the ratio of the diameter in the particle-size distribution curve corresponding to 60% finer (D_{60}) to the Effective size (D_{10}):

$$C_u = \frac{D60}{D10} = C_u = \frac{0.58}{0.19} = C_u = 3.05 \qquad (1)$$

Coefficient of gradation (C_c)

This parameter is expressed as:

$C_c = \frac{D30^{\ 2}}{D60 \times D10} = C_c = 0.66.$ (2)

3.1.3 Textural Classification of the Extracted Sand

Texture of soil means its surface appearance. It is influenced by the size of the individual particles present in the soil. On the basis of particle sizes, a soil can be classified as gravel, sand, silt, and clay [18]. The Textural Analysis of the Extracted tar from the sieve analysis conducted is shown in Table 2.

TABLE 2: Textural Analysis of the Extracted Sand (Asphalt Institute Classification System)

Sieve Sizes	%Passing	Analysis of Extracted Sand	
		Remarks	Impacts
1" (25mm)	100	No Coarse Aggregates in the tar sand	Low value % passing indicates: • No Presence of oversize particle • No Compaction difficulties • No segregation Tolerance of 2% - 3% less than 100% allowed
No. 8 (2.36mm)	91.9	Major Constituent of Tar Sand is Fine Aggregates (Sand)	High value % passing will result in: • Reduction of stripping in pavement • longevity of roadway • No inherent permeable mix
No. 200 (0.075)	2.45	Low Fine Particles	Low value % passing will result in: • High Air Void • High Permeability • Low Asphalt Demands • High VMA

3.1.4 Specific Gravity of the Tar Sand and Extracted Bitumen

The result of Specific Gravity of the tar sand and extracted Natural Bitumen is summarized in Table 3.

TABLE 3: Specific Gravity of Extracted Natural Bitumen

	Tar Sand	Extracted Bitumen
Specific Gravity	2.50	0.57

3.1.5 Marshall Test Properties on Direct Application of Tar Sand as Bituminous Mix.

This test is aimed at determining the resistance of the tar sand to deformation when applied directly as bituminous mix. This will help verify if tar sand can withstand wheel load when applied directly in its raw form. The results obtained are summarized in Table 4.

TABLE 4: Summary of The Marshall Test On Direct Application of Tar Sand as Bituminous Mix

Properties	Values	Specification	Remarks
Stability (KN)	2.08	Not less than 3.5	Not Satisfactory
Flow (mm)	34.5	2 – 6	High Flow
Void (%)	19.59	3 – 5	High Void
VFA (%)	70.78	65 – 78	Satisfactory
VMA (%)	66.78	Min. of 13%	Satisfactory

The results show that the stability (KN) of the direct application of Tar Sand in its raw form as Bituminous Mix is low and not satisfactory for road pavement construction. However, with appropriate selection and blending of aggregates, bituminous mixes produced with Natural Bitumen binder present in the tar sand will be suitable for preventive road maintenance works, construction of footways, recreational trails, walkways, bikeways, golf cart paths, tennis court overlay and running track surfacing. The values of the Flow and Void are too high. However, the results of the VFA and VMA are within the ranges for Light Traffic ($< 10^4$ESALS) [19].

3.2 Grading Analyses of Extracted and Modified Natural Bitumen

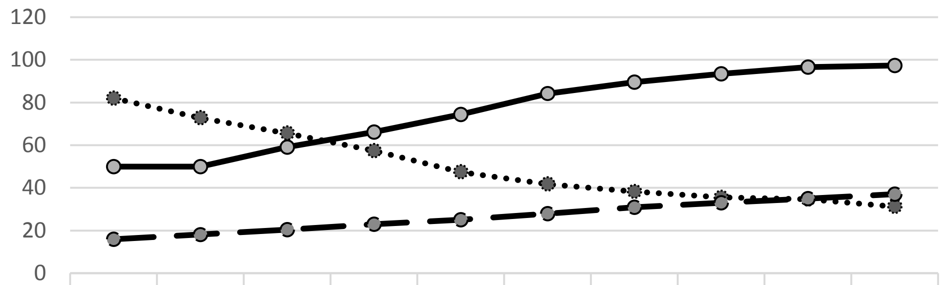
The preliminary and grading analyses conducted on the extracted and modified natural bitumen are summarized in Table 5 and the trend expressed in Fig 2 and 3 for Waste Water Sachets (WWS) and Shredded Waste PET Bottles (SWPB) respectively.

TABLE 5: Grading Analyses of Extracted and Modified Natural Bitumen

Properties	% Modification	Values	Standard Specification (ASTM)		Remarks
			Min.	Max.	
Solubility in Trichloroethylene (%)	0% Additives	**100**	99	-	Satisfactory
	0.1% WWS	**100**	99	-	Satisfactory
	0.2% WWS	**100**	99	-	Satisfactory

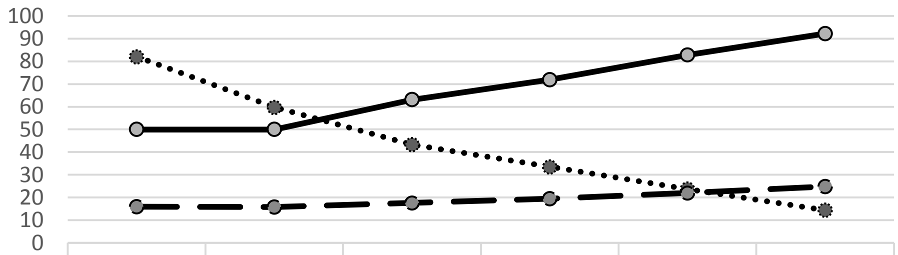
	0.3% WWS	**100**	99	-	Satisfactory
	0.4% WWS	**100**	99	-	Satisfactory
	0.5% WWS	**100**	99	-	Satisfactory
	1.0% WWS	**100**	99	-	Satisfactory
	1.5% WWS	**100**	99	-	Satisfactory
	2.0% WWS	**100**	99	-	Satisfactory
	2.5% WWS	**100**	99	-	Satisfactory
	I.5% SWPB	**100**	99	-	Satisfactory
	2.5% SWPB	**100**	99	-	Satisfactory
	5.0% SWPB	**100**	99	-	Satisfactory
	7.5% SWPB	**100**	99	-	Satisfactory
	I0.0% SWPB	**100**	99	-	Satisfactory
Penetration at 25 °C, 100g, 5s (pen)	0% Additives	**82**	85	100	Bitumen 85/100
	0.1% WWS	**72.8**	85	100	Bitumen 60/70
	0.2% WWS	**65.6**	85	100	Bitumen 60/70
	0.3% WWS	**57.4**	85	100	Bitumen 60/70
	0.4% WWS	**47.5**	85	100	Bitumen 40/50
	0.5% WWS	**41.8**	85	100	Bitumen 40/50
	1.0% WWS	**38.3**	85	100	Hard Grade
	1.5% WWS	**35.6**	85	100	Hard Grade
	2.0% WWS	**34.8**	85	100	Hard Grade
	2.5% WWS	**31.3**	85	100	Bitumen 85/100
	I.5% SWPB	**59.7**	60	70	Bitumen 60/70
	2.5% SWPB	**43.3**	40	50	Bitumen 40/50
	5.0% SWPB	**33.5**	-	-	Hard Grade
	7.5% SWPB	**23.7**	-	-	Hard Grade
	I0.0% SWPB	**14.4**	-	-	Very Hard Grade
Softening Point (^{0}C)	0% Additives	**50**	45	52	Satisfactory
	0.1% WWS	**50**	45	52	Satisfactory
	0.2% WWS	**59.1**	45	52	High
	0.3% WWS	**66.2**	45	52	High
	0.4% WWS	**74.4**	45	52	High
	0.5% WWS	**84.2**	45	52	High
	1.0% WWS	**89.5**	45	52	High
	1.5% WWS	**93.4**	45	52	High
	2.0% WWS	**96.5**	45	52	High
	2.5% WWS	**97.3**	45	52	High
	I.5% SWPB	**50**	45	52	Satisfactory
	2.5% SWPB	**63.1**	45	52	High
	5.0% SWPB	**71.9**	45	52	High
	7.5% SWPB	**82.8**	45	52	High
	I0.0% SWPB	**92.2**	45	52	High
Flash Point (^{0}C)	0% Additives	**> 350**	230	-	Satisfactory
	0.1% WWS	**> 230**	230	-	Satisfactory
	0.2% WWS	**> 230**	230	-	Satisfactory
	0.3% WWS	**> 230**	230	-	Satisfactory
	0.4% WWS	**> 230**	230	-	Satisfactory
	0.5% WWS	**> 230**	230	-	Satisfactory
	1.0% WWS	**> 230**	230	-	Satisfactory
	1.5% WWS	**> 230**	230	-	Satisfactory
	2.0% WWS	**> 230**	230	-	Satisfactory
	2.5% WWS	**> 230**	230	-	Satisfactory
	I.5% SWPB	**> 350**	230	-	Satisfactory
	2.5% SWPB	**> 350**	230	-	Satisfactory
	5.0% SWPB	**> 350**	230	-	Satisfactory
	7.5% SWPB	**> 350**	230	-	Satisfactory
	I0.0% SWPB	**> 350**	230	-	Satisfactory
Viscosity (Secs)	0% Additives	**16**	-	-	-
	0.1% WWS	**18.2**	-	-	-
	0.2% WWS	**20.5**	-	-	-
	0.3% WWS	**23.0**	-	-	-
	0.4% WWS	**25.12**	-	-	-
	0.5% WWS	**28.0**	-	-	-
	1.0% WWS	**31.0**	-	-	-
	1.5% WWS	**33.0**	-	-	-
	2.0% WWS	**35.0**	-	-	-
	2.5% WWS	**37.11**	-	-	-
	I.5% SWPB	**15.8**	-	-	-
	2.5% SWPB	**17.6**	-	-	-
	5.0% SWPB	**19.5**	-	-	-

	7.5% SWPB	**22**	-	-	-
	I0.0% SWPB	**24.9**	-	-	-



	0% Additives	0.1% WWS	0.2% WWS	0.3% WWS	0.4% WWS	0.5% WWS	1.0% WWS	1.5% WWS	2.0% WWS	2.5% WWS
Penetration	82	72.8	65.6	57.4	47.5	41.8	38.3	35.6	34.8	31.3
Softening Point	50	50	59.1	66.2	74.4	84.2	89.5	93.4	96.5	97.3
Viscosity	16	18.2	20.5	23	25.12	28	31	33	35	37.11

Fig 2: Grading Analyses of Extracted and WWS-Modified Natural Bitumen



	0% Additives	I.5% SWPB	2.5% SWPB	5.0% SWPB	7.5% SWPB	I0.0% SWPB
Penetration	82	59.7	43.3	33.5	23.7	14.4
Softening Point	50	50	63.1	71.9	82.8	92.2
Viscosity	16	15.8	17.6	19.5	22	24.9

Fig 3: Grading Analyses of Extracted and SWPB-Modified Natural Bitumen

IV. CONCLUSION AND RECOMMENDATION

4.1 CONCLUSION

From the research work results, there is significant quantity of natural bitumen for exploration in the surface impregnated sedimentary Tar Sand. The percentage saturation of bitumen in the Tar Sand increases with depth of exploration. The bitumen is a light binder; the results show that, it can be modified to 60/70 bitumen and at satisfactory softening and flash point at 1.5% SWPB and 0.1% WWS.

The raw form of the tar sand can be used directly for preventive road maintenance works, construction of footways, recreational trails, walkways, bikeways, golf cart paths, tennis court overlay and running track surfacing. The natural bitumen extracted from the tar sand can be used as liquid Asphalt.

4.2 RECOMMENDATION

The results obtained from the research test show that, the use of natural bitumen is viable. This study was carried on only one surface outcrop of Tar Sand. I recommend that further studies be conducted on other surface outcrops of Tar Sand in Nigeria with extensive research on sub-surface Tar Sand. The possibility of using modified natural bitumen for asphalt concrete should be researched.

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