The Use of Polymer for Road Surfacing as a Strategy for Waste Recycling in Maiduguri

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***Abstract*— The road network in Maiduguri, Borno State in Nigeria has been continuously deteriorating due to the ongoing rise in traffic combined with insufficient maintenance due to a lack of funding. Various actions, such as securing finances for maintenance, improving roadway design, using better quality materials, and using more efficient construction techniques are reported to be useful in reducing this process. The purpose of this study was to investigate the effect of polythene on the characteristics of asphalt and concrete for road surfacing as well as strategy for waste recycling. Hot bitumen and waste polymer were combined at 160°C using a strong mechanical stirrer; plastic was added to the bituminous mix using wet process techniques to create polymer-modified bitumen. Base bitumen with a penetration grade of 60/70 was used for the laboratory tests. To achieve consistency in the mixture, all the polymers were heated and chopped into pieces. 2%, 4% and 6% volume of polymer were used with a control volume of 0%. Different tests such as the Viscosity test, Flash and fire point test, Penetration test, Marshall Test, and Ductility test were all conducted using standard procedures. The test results for penetration, ductility, viscosity, flash and fire points, indicate that the material is becoming less consistent and more resistant to temperature variations. The marshal test findings showed that the modified combination had higher stability and a lower % of VMA (Voids in mineral aggregates) than the traditional plain mixtures. This would significantly increase these mixes' resistance to rutting.**

Keywords*— *Polymer, polyethylene, road surfacing, Marshal test, bitumen, plastic.

I. Introduction

The country has seen a major increase in the usage of polymer materials because of their plentiful supply and high resistance to animals, fungi, insects, mold, mildew, rot, and numerous chemicals. However, it has been difficult to dispose of the waste polymer components in huge amounts across the nation. These polymers burn away and produce toxic fumes, ash, and dangerous smoke that frequently contains hydrogen cyanide. The majority of this polythene ends up in landfills where it slowly degrades because it is typically expensive to incinerate polymers to recoup the considerable energy they require to be created. Although it is done on a much smaller scale, certain recycling is processed on them, typically producing pellets for industrial re- use [1].

Another issue of significant concern is the blending of these wastes is mixed with other organic biodegradable wastes in the garbage of urban regions. More study is therefore required to find a better technique to handle these wastes in order to solve the issues that the current disposal method frequently causes. A typical composite material utilized in building projects including parking lots, airports, and road surfaces is asphalt concrete. It is made out of bitumen, which serves as a binder, mixed with mineral aggregate, put out in layers, and compacted. Aggregate typically makes up 90 to 95 percent of the weight and 75 to 85 percent of the volume of asphalt concrete mixtures, and they primarily support the load supporting capacity of a pavement. Because of its excellent adhesion properties to aggregate, the binder, is typically a visco-elastic substance with sufficient which mechanical and rheological qualities for waterproofing and protective coverings for roads and roofs is penetration grade bitumen. The binder typically makes up 5 to 10% of the weight of the concrete mixture, and based on their penetration characteristics, numerous grades are available, including 30/40, 60/70, and 80/100. Given that bitumen is the nonstop period and the only deformable element, the qualities of the bituminous binder have a significant impact on the performance of the road pavement. However, roads built with bitumen binders are subject to a variety of adverse environmental factors, including heavy traffic loads, water intrusion, chemical attack, and drastically different temperatures. Frequently, conventional bitumen is unable to provide the requisite resistance under these circumstances. Modification of the bitumen's characteristics is therefore necessary. However, by choosing the ideal starting material to produce asphalt, some enhancements in its qualities have been made. Sadly, only a small number of crudes can create excellent asphalts appropriate for paving purposes [1-3].

However, practical experience over the past 40 years has demonstrated that adding polymer additives to the asphalt binder offers a number of advantages. Improved anti-fatigue resistance, lowered susceptibility to thermal stress cracking, lowered temperature susceptibility, and less rutting are a few of them. They also include improved adhesion and cohesion qualities. As a result, bitumen treated with polymers is a popular way to create pavement that performs at its best. Frequently, conventional bitumen is unable to provide the requisite resistance under these circumstances. Modification of the bitumen's characteristics is therefore necessary. However, by choosing the ideal starting material to produce asphalt, some enhancements in its qualities have been made. Sadly, only a small number of crudes can create excellent asphalts appropriate for paving purposes [1].

The use of PMB for asphalt paving has been very restricted in many countries despite strong performance, primarily due to higher initial costs. A test road was constructed in Sweden between 2003 and 2006 to evaluate the cost-effectiveness of using PMB and its sustainable benefits on heavily traveled roads in the Nordic condition. Building such a test road has the additional purpose of confirming whether binder testing can accurately measure the functional characteristics of asphalt pavements. The test road was created as a section of route E6 north of Uddevalla and is situated in Geddeknippel - Kalss. Ten portions headed south and five sections headed north made up the entire project. Different PMBs and bitumen were chosen for the wearing course, binder course, and base course in the south-bound sections, however only the wearing course was tested in the north-bound sections. The test road has been regularly monitored, and since 2010, the Swedish National Road and Transport study Institute (SNRTRI) and Nynas have been conducting a follow-up study project with funding from the Swedish Transport Administration. Field measurements, asphalt core testing, binder testing and evaluation, degradation modeling, and life cycle cost analysis (LCCA) are all included in the project [4] .

II. METHODOLOGY

A. Area of the Study

First, confirm that you have the correct template for your paper size. This template has been tailored for output on the A4 paper size. If you are using US letter-sized paper, please close this file and download the Microsoft Word, Letter file.

B. Material and equipment

The following materials and equipment were used to conduct this research:

Heating oven, Weighing balance, Equipment for material mixing, Container for heating aggregate, Sets of specimen mold, Marshall test apparatus, Water bath, Cup-cleaving and opening tools , Square shield, Thermometer , Lighter, Barometer, Standardized penetrometer , Stop watch, Penetration tins, Calibrated thermometer, Rings and balls (3.5g) , Ring holder and a thermometer, Softening point thermometer , forceps , glass container , glycerol, Standardizes brass mold, Water bath, Testing machine for pulling the machine, Thermometer, Straight edge knife and Glycerol

The tests conducted are as follows:

- Viscosity test

The viscosity of bituminous material is a fluid characteristic that measures flow resistance. This characteristic significantly affects the finished paving mixtures' strength at the application temperature.

- Flash and fire point test

Flash and fire point of bitumen is the temperature at which, its vapor will ignite temporarily during heating, when a small flame is brought into contact with the vapor. The plash point tells the critical temperature at and above which suitable precautions are required to be taken to climate the danger fire during heating process.

- Penetration test

Penetration test is used to measure consistency of bituminous materials. It is expressed as the distance in millimeter a standard needle vertically penetrates a sample under known condition of loading, time and temperature. Grades of straight-run bitumen are designated by two penetration values. The actual sample of the bitumen in any grade should fall between the lower and the upper value given.

- Ductility test

The Ductility test is used to describe how the bitumen behaves under tensile and ductile loads. The test also evaluates the homogeneity and flow ability of bituminous binder.

- Marshall Test

The Marshall test was once applied to bituminous material-containing asphalt mixes with aggregate sizes no larger than 25.4 mm. A marshal loading head is used to load asphalt specimens onto their cylindrical side edges at a predetermined loading rate and temperature. It measures the resistance to elastic flow.

III. DISCUSSION OF RESULTS

The use of leftover polymer has advanced bituminous road construction significantly in recent years[5-6]. Bituminous courses like Base course and Binder course employ waste polymers. This study aims to assess the effects of incorporating used plastic bottles into bituminous concrete (BC), which uses a course mix of aggregate grade I and plain 60/70 bitumen. Table 1 shows the penetration values obtained in laboratory test conducted.

TABLE 1. PENETRATION VALUE

Actual test temperature			25°C	
Bitumen type	Plain	2% polymer	4% polymer	6% polymer
Early reading	200	264	324	362
Last reading	264	324	362	397

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Penetration value	64	60	38	35

Figure 1 displays the penetration value in relation to the added polymer fraction. And this indicates that the permeation value of the sample reduces as the amount of waste polymer increases.

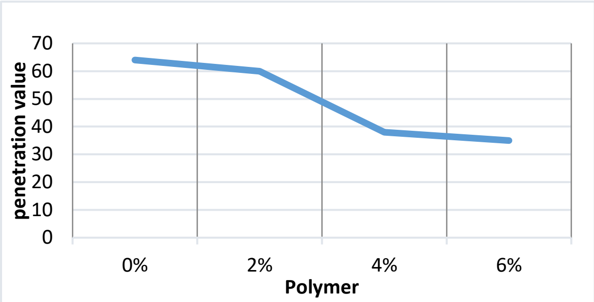

Fig. 1: Effect of Polymer on Penetration Value

Table 2 Shows the influence of polymer on the viscosity of plain bitumen and the various percentages of polymer added to the bitumen.

TABLE 2. THE INFLUENCE OF POLYMER ON THE VISCOSITY OF PLAIN BITUMEN

	Observations			
Bitumen type	Plain	2%	4%	6%
Test temperature	100 ºC	100 ºC	100 ºC	100 ºC
Time taken to flow	4.26	6.12	8.22	9.26
Viscosity	266	372	502	566

The American Association for Testing and Material (ASTM) has established 100 seconds as the norm for bituminous material viscosity tests. The viscosity of polymer modified bitumen, however, rises as the polymer content does, as shown in Figure 2. When the value was measured against the reference value, it was determined that it was sufficient.

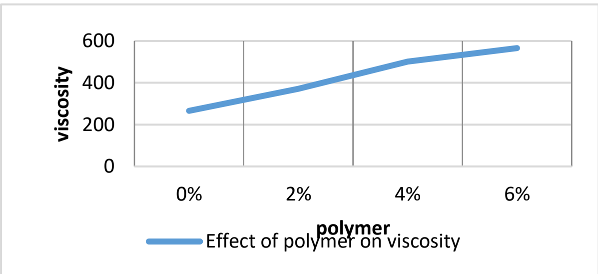

Fig. 2: Effect of Polymer on Viscosity

Table 3 - shows the laboratory test result obtained in the laboratory for the varied percentages.

TABLE 3. LABORATORY TEST RESULT

Sample	plain bitumen	2% polymer	4% polymer	6% polymer
Ductility value (cm)	76.4	60.2	24.1	12.3

Fig. 3 presents ductility against polymer content. The ductility test (ASTM D113) determines the maximum stretchable length of asphalt under standard testing conditions (5 cm/min at 25 °C). Before testing, the briquette must have a minimum cross section of 1 square cm. The results revealed that when the amount of ground waste polymer in the bitumen increased up to around 6% by weight, ductility tended to decrease. When the amount of waste polymer was raised, the high ductility that existed at 0% by weight gradually decreased. Because waste polymer is less ductile while it's molten, adding it to bitumen reduces the ductility of the modified mix, which is why the ductility value of waste polymer modified bitumen has decreased. The (ASTM) precision value must be met by the ductility results. The test is abnormal because the value after adding the polymer does not fall within the usual range.

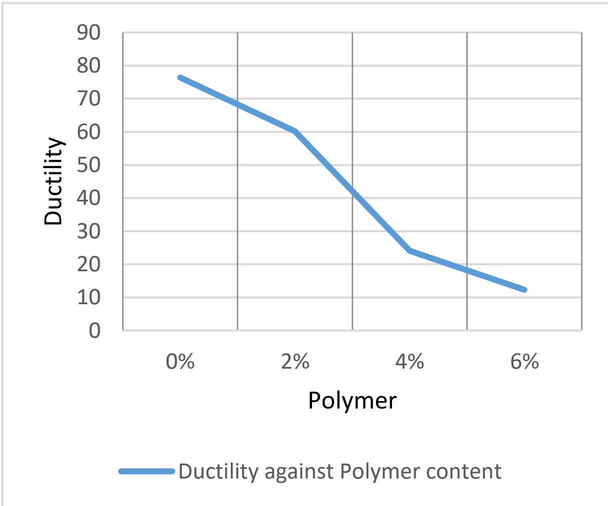

Figure 3: Ductility against Polymer Content

The ductility test (ASTMD113) result is presented on the Table 4 and fig. 4 for the different samples. The temperature at which a bitumen sample can no longer withstand the weight of a 3.5g steel ball is what is being measured. The softening point of waste polymer modified bitumen is depicted in Figure 5. The softening points measured for the bituminous materials added with 2%, 4%, 6%, and waste polymer content are 46°C, 54°C, 68°C, and 78°C, respectively. The values do increase with the quantity of waste polymer content added, although a linear trend was seen for the addition of 4% to 6% waste polymer. The trend in the waste polymer modified bitumen's softening point suggests that adding ground waste polymer will raise the material's softening point value.

TABLE 4. DUCTILITY TEST (ASTMD113)

Sample	Plain	2%	4%	6%
Softening point	46	54	68	78

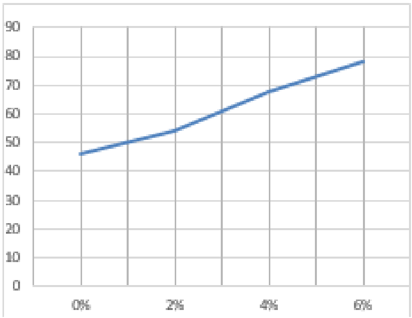

Figure 4: Ductility Test (ASTMD113)

Waste polymer modified bitumen's flash and fire point are depicted in table 5 and Figure 5. As is evident, the flash and fire point increase in addition with waste polymer content. The flash point of the bitumen grows beyond the value of 170oC specified by ASTM standard as various ratios of waste polymer are added to it. The bituminous binder that had been treated with waste polymer had a higher flash point. When 2% waste polymer by weight of bitumen was added, the bitumen's flash point rose from 170 to 181. Similar increases were seen when the bitumen's waste polymer percentage increased from 40% to 6%, with 6% being the highest value. The modified bitumen's Fire point increases from 2% to 6%, reaching a maximum value of 276 at 6%.

TABLE 5. WASTE POLYMER MODIFIED BITUMEN

Polymer content	0%	2%	4%	6%
Measured flash point	172	181	192	197
Measured fire point	240	251	261	276

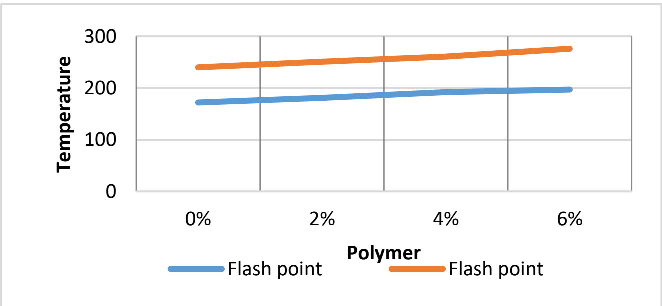

Figure 5: Flash and the Fire point of Waste Polymer Modified Bitumen

The aggregate used in the present study are presented in Table 6.

TABLE 6. PROPERTIES OF AGGREGATE

Aggregate test	Result obtained
Crushing value	24.8
Impact value	11.2
Los Angeles abrasion value	14.87
Water absorption 20mm 10mm Fine aggregate	 0.12 0.23 0.49
Specific gravity 20mm 10mm Fine aggr. Filler	 2.98 2.95 2.90 2.43

TABLE 7. MARSHALL TEST RESULT AT DIFFERENT POLYMER CONTENT

	Marshall test result at different polymer content							
Waste polymer%	Gt	Gb	VMA %	Vv	VFB %	Vb	Stability value (kg)	Flow value
0	2.58	2.27	19.48	7.70	60.47	11.77	1231	5.7
2	2.57	2.29	19.32	7.56	60.87	11.76	1272	6
4	2.54	2.28	17.20	5.34	68.93	11.86	1291	6
6	2.52	2.36	17.27	5.56	67.82	11.72	1300	6

IV. CONCLUSION

Test results for penetration, ductility, viscosity, flash and fire points, and softening points indicate that the material is becoming less consistent and more resistant to temperature variations. Because modified bitumen has a higher softening point than regular conventional bitumen, it will therefore offer superior resistance to pavement deformation and rutting. The marshal test investigation's findings showed that the modified combination had higher stability and a lower VMA % than the traditional plain mixtures. This would significantly increase these mixes' resistance to rutting. The changed combination's air void content is very similar to that of the unmodified mixture. The amount of air voids found is sufficient to allow room for asphalt binder expansion to avoid striping or bleeding of the mineral aggregate, which would weaken the pavement's ability to resist rutting and lower its skid resistance. In addition to improving anti- fatigue and improving bond between the asphalt and the aggregate, adding polymers to asphalt mixtures minimizes pavement deflection overall.

The use of cutting-edge technology not only improved the quality of road building but also prolonged the life of the roads. It will also assist to address the environmental issues

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that face our communities and generate cash. The creation of modified bituminous mix from waste polymer will effectively raise the scrap value of this otherwise "undesirable waste material" that is currently strewn over urban area. Due to the valuable scrap value, these waste polymers will instead be collected and sold by customers or other organizations rather than being thrown out with the trash. It is recommended that more research be conducted to determine how the chemical makeup of the various polymer waste kinds affects the performance of hot mix asphalt.

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