EFFECT OF POLYTHENE MODIFIED BITUMEN ON PROPERTIES OF HOT MIX ASPHALT

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ABSTRACT

The continuous increase in road traffic couple with an insufficient degree of maintenance due to shortage of funds has caused an accelerated and continuous deterioration of the road network in Nigeria. To alleviate this process, several types of measures are reported to be effective, for instance, securing funds for maintenance, improved roadway design, use of better quality of materials and the use of more effective construction methods. Improving the quality of materials used in road construction had been shown to improve road service performance in the wake of the increase usage. Practical experience over the last four decades have shown that the modification of the bituminous binder with polymer additives offers several benefits in asphalt concrete and has been tested in a number of countries around the World. The use of polythene materials for pure water sachet in the country has received a great boost due to its abundant supply and high resistance to insects, fungi, animals, as well as molds, mildew, rot and many chemicals. However the disposal of the waste polythene materials in large quantities has been a problem all over the country. This study was therefore designed to investigate the effect of polythene as contained in pure water sachet in the asphalt concrete properties. Polythene was added in grinded state as binder modifier. It was introduced to the mixture by melting it in the bitumen used in preparing the asphalt concrete mix. Marshall Mix design method was used, first to determine the optimum bitumen binder content and then further to test the modified mixture properties. In total, 17 samples were prepared (10 samples were used to determine the binder content and the remaining samples were used to investigate the effect of modifying the asphalt mixtures). The optimum asphalt content was 7.0%. Six proportions of polyethylene by weight of the optimum binder content were selected to be tested (2.5, 5.0, 7.5, 10, 12.5 and 15%). The properties tested include bulk density, stability and flow of the concrete mix. The obtained optimum proportion of the modifier is 12.5% by the weight of the optimum bitumen content. It is found to increase the stability, reduce the density and slightly reduce the flow of asphalt concrete specimen. Findings from this study suggest that polythene modifier offers better engineering properties and its usage as bitumen modifier could serve as a means of managing the waste menace.

Keywords: waste polythene, bituminous binder, asphalt mixture, optimum binder content, bulk density, stability, flow.

1. INTRODUCTION

The use of polyethylene materials for pure water sachet in the country has received a great boost due to its abundant supply and high resistance to insects, fungi, animals, as well as molds, mildew, rot and many chemicals. However the disposal of the waste polythene materials in large quantities has been a problem all over the country. These polythene break down in fire and form hazardous smoke, and toxic fumes or ash, typically containing hydrogen cyanide. Incinerating polythene to recover the high energy used to create them is usually expensive, so most of this polythene reaches the garbage dumps, decaying very slowly. Some recycling is done on them, usually creating pellets for reuse in the industry, but this is done at a much lower scale. The mixing up of these waste pure water sachets with other bio-degradable organic waste materials in the garbage of the urban areas is another problem of great concern. As a result, more research need to be focused towards a better way of managing these waste materials, so as to eliminate the problems usually encountered in the present disposal method.

In case it is possible to find useful application for the waste polythene materials, there will be substantial scrap value for this waste product and therefore they will be collected and sold by interested persons, instead of being littered or thrown out in the waste bins or into the road side drains. Asphalt concrete is a composite material commonly used in construction projects such as road surfaces, airports and parking lots. It consists of bitumen, used as a binder and mineral aggregate mixed together, then lay down in layers and compacted [1].

The amount of aggregate in asphalt concrete mixtures is generally 90 to 95 percent by weight and 75 to 85 percent by volume and they are primarily responsible for the load supporting capacity of a pavement. The binder, usually penetration grade bitumen is a viscoelastic material with suitable mechanical and rheological properties for waterproofing and protective coverings for roofs and roads, because of its good adhesion properties to aggregates [2, 3, 4, 5].

Ordinarily, the binder constitutes 5 to 10 percent by weight of the concrete mixture and different grades like 30/40, 60/70 and 80/ 100 are available on the basis of their penetration values.

The performance of the road pavement is strongly influenced by the properties of the bituminous binder as bitumen is the continuous phase and the only deformable component [6]. However, Roads produced with bitumen binders are subjected to many harsh environmental

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conditions such as heavy traffic loading, ingress of water, chemical attack and widely fluctuating temperatures. Conventional bitumen often cannot provide the desired resistance to these conditions so modification of the bitumen properties becomes necessary. Though, some improvements in asphalt properties have been achieved by selecting the proper starting crude to make asphalt. Unfortunately, there are only a few crudes that can produce very good asphalts suitable for paving applications [6, 7].

However, practical experience over the last four decades has shown that the modification of the asphalt binder with polymer additives, offers several benefits. These include improved adhesion and cohesion properties, enhanced fatigue resistance, improved thermal stress cracking, decrease in temperature susceptibility and reduction of rutting [8, 9, 10]. As a result, bitumen modified with polymers is a common means of providing optimally performing pavement. This work aims to determine the effect of polythene modified bitumen on the properties of hot mix asphalt.

2. MATERIALS AND METHODS

The materials used for the purpose of this research were Waste Polythene nylons, Bitumen (80/100), and Aggregates. Waste polythene nylons were collected from the canteens of residential hostels within the University of Ibadan (namely Awo hall canteen, Zik hall canteen and Independence hall canteen). The collected wastes were sorted, de-dusted, washed when necessary and sun-dried for few days until all the samples were dry. The dried samples of the waste polythene were shredded into sizes between 0.6mm to 2.36mm in the shredding machine to increase its surface area of contact with the bitumen during blending. Generally, polymer utilization in asphalt concrete could be in form of aggregate or binder modifier. For the purpose of this research, polythene material was used as binder modifier. The modified bitumen was prepared by heating bitumen with shredded polythene of sizes between 0.6mm to 2.36mm. Six proportion of polythene content (2.5, 5, 7.5, 10, 12.5 and 15%) by weight of bitumen were considered. The mixture was continuously steered until a uniform blend was achieved at 265^{o}C.

Traditionally, graduation requirements are so broad that they permit the use of paving mixtures ranging from coarse to fine and to either low or high stability. To further complicate matters, different combinations of sieve sizes are specified to control specific grading ranges.

The coarse and fine aggregates used were crushed granite and sand materials respectively, stone dust were used as filler materials, all collected from the yard of Lagos State Public Works Department.

Sieve analysis was performed using mechanical shaker. The sieve sizes range between 0.075mm to 19mm. The weight retained on each sieve was measured and recorded. Percentage passing each size was calculated. Graph of percentage weight passing against sieve size was plotted to see if the selected aggregates fall within the specified envelop. Trial mixes were made to combine the coarse and fine aggregates to obtain an all-in combined grading satisfying the specification.

In order to determine the effect of modified binder on the properties of asphalt concrete, it is necessary to carry out mix design to determine the optimum bitumen content for the mix using unmodified bitumen as the binder. Marshall Mix design method for designing hot asphalt concrete mixtures, designated as (ASTM Designation: D 6927-06) using manual compaction was used.

The performance of an asphalt mixture is based on the determination of the correct proportion of aggregate and bitumen. To determine the optimum bituminous content that would produce asphalt concrete mixtures with strength and durability properties that meet the standard specifications. 10 samples each of 1200 gram in weight were prepared according to the proposed mix design. Two samples were used to prepare asphalt mixtures with one-bitumen content. The average values of two samples for the Unit Weight, Bulk Specific Gravity, Marshall Stability and Flow properties for each binder content was determined. Five binder contents were considered (4, 5, 6, 7 and 8%). All examined asphalt concrete mixtures were prepared in accordance with the standard 50-blows.

Density and Bulk Specific Gravity of specimens of compacted asphalt mixtures were determined in accordance with AASHTO T 166.

The Marshall Stability and Flow test was done to determine the Marshall stability and Flow values of bituminous mixture as per ASTM D 6927-06. The principle of this test is that Marshall Stability is the resistance to plastic flow of cylindrical specimens of a bituminous mixture loaded on the lateral surface. It is the load carrying capacity of the mix at 60^{o}C and is measured in Newton.

The Optimum Asphalt Binder content was finally selected based on the combined results of Marshall Stability, Flow and density analysis. Optimum asphalt binder content was arrived at in the following procedures:

a) The following graphs were plotted:

- Bulk density content vs. Asphalt binder content
- Marshall Stability vs. Asphalt binder content.
- Flow vs. Asphalt binder content.

b) Optimum asphalt binder content satisfying the maximum stability and bulk density, as well as the required minimum air void was selected from the graphs.

c) The modified binders (2.5, 5, 7.5, 10, 12.5 and 15% replacement by weight of the bitumen) were used to prepare six samples of asphalt concrete according to the mix design following the standard procedures explained above. The modified binders were applied at optimum bitumen content for all the specimens and the samples were tested for Marshall Stability, Flow and Density to

VOL. 8, NO. 4, APRIL 2013 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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observe the effect of polythene modified binder on the properties of the specimen.

3. RESULTS AND DISCUSSIONS

3.1. Sieve analysis result

From Figure-1 below, it can be observed that the selected aggregates gradation fall within the standard specified envelope for hot asphalt mix design.

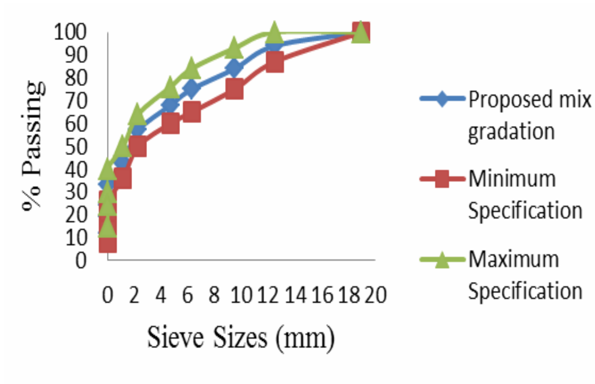

Figure-1 Gradation curve for the aggregates

3.2. Marshall Mix design result

The result of bulk density test carried out on the specimens prior to marshal stability test is presented graphically on Figure-2 below. The graph of bulk density against percentage bitumen content is plotted to obtain the maximum bulk density and the corresponding bitumen content. The maximum bulk density is 1.830 gm/cm^3 which correspond to bitumen content of 7.0%.

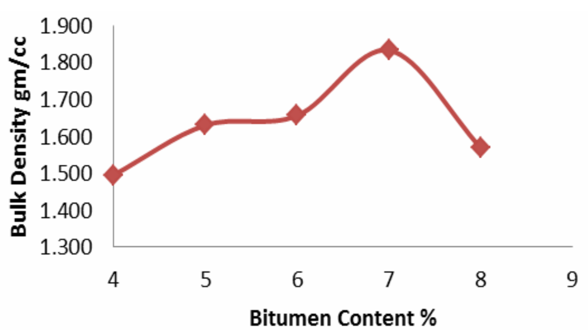

Figure-2 Bulk density against percentage bitumen content

The values of Marshall Stability and flow for the specimens were read directly from Marshall Apparatus. The gauge readings were multiplied by the machine constant to obtain the stability in Newton and the results were corrected based on the specimens' thickness using the values given in Table-1 of ASTM D 6927-06 (Standard Test Method for Marshall Stability and Flow of Bituminous Mixtures). The results are summarized graphically below; from the graphs below, the Maximum Marshall Stability is 4440 N at 7% bitumen content and the corresponding flow value is 3.5mm.

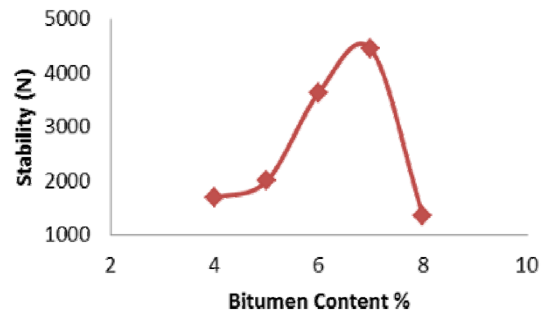

Figure-3 Marshall Stability against bitumen content

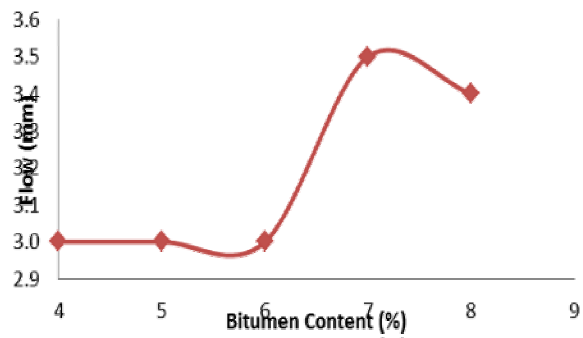

Figure-4 Flow against bitumen content

The summary of Marshall Test results is given in Table-1 below. The optimum bitumen content for the mix should give maximum stability and bulk density with flow value within the specified values. The optimum bitumen content is 7% by weight of the aggregates.

Table-1 Summary of Marshall Mix design result

Measured property	Marshall test result	Standard specification	
		Minimum	Maximum
Stability (N)	4440	3336	---
Flow (mm)	3.5	2	4
Bulk density (gm/cm^3)	1.83	---	---

3.3. Effect of polythene modified bitumen on the properties of asphalt concrete

Seven samples of asphalt concrete mixtures at the designed mix were prepared to test the effect of adding waste polythene material on the mix. Polythene was added, as binder modifier, to six samples by considering the six proportions of polythene (2.5, 5, 7.5, 10, 12.5 and 15%) replacement by weight of the optimum bitumen content. The samples were tested for bulk density, Stability and flow. The results are presented in the following section.

The bulk densities of the sample were calculated as follows:

$$Gmb = (A/(C - B)) \tag{1}$$

Where
G_{mb} = Bulk Density of the specimen
A = Weight of sample in the air, gms.
B = Weight of sample in water, gms.
C = Weight of specimen surface dried, gms

The bulk densities of the asphalt concrete containing polythene were lower than that of the control concrete mixture (1.87 gm/cm^3) for all polythene percentages (Figure-5). This is due to lower specific gravity of polythene. This observation was confirmed [11] in his study of the effect of high density polyethylene on permanent deformation of Asphalt concrete. [12] Also agreed with the result.

The maximum bulk density is found when the polythene content is around 10% and the trend shows that the bulk density increased as the modifier content increases until it reaches the highest bulk density of 1.85 gm/cm^3 and started to decline significantly afterwards.

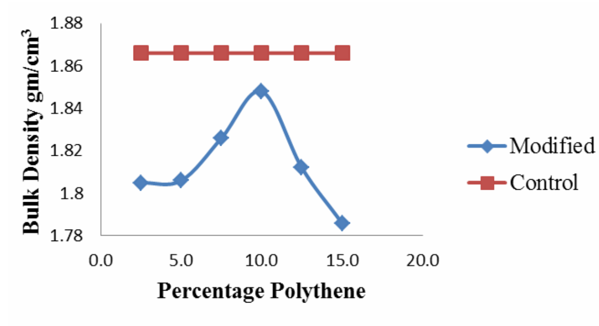

Figure-5 Bulk density against polythene percentage

Table-2 Bulk density of polythene modified asphalt concrete specimen

Sample description	% Polythene						
	0.0	**2.5**	**5.0**	**7.5**	**10.0**	**12.5**	**15.0**
Thickness (mm)	64	66	73	62	71	67	70
Wt of sample in air (gms), A	1257.3	1162.1	1288.5	1136.2	1214.6	1216.0	1240.0
Wt of sample in water (gms), B	584.9	519.0	576.6	515.5	560.2	548.0	552.1
Wt of sample surface dried (gms), C	1258.8	1162.7	1290.0	1137.8	1217.5	1219.0	1246.3
C - B	673.9	643.7	713.4	622.3	657.3	671.0	694.2
Bulk density, G_{mb} (gm/cc)	1.866	1.805	1.806	1.826	1.848	1.812	1.786

Table-3 Marshall Stability and flow properties of polythene modified asphalt concrete

Polythene %	**Thickness** (mm)	**Gauge reading** (load)	**Proving ring constant 24** (N)	**Stability loads** (N)	**Correction ratio**	**Corrected stability** (N)	**Flow** (mm)
0	64	185	24	4440	1.00	4440	3.50
2.5	66	271	24	6505	0.93	6050	3.30
5	73	354	24	8494	0.81	6880	3.1
7.5	62	294	24	7048	1.04	7330	3.00
10	71	459	24	11024	0.83	9150	3.10
12.5	67	411	24	9871	0.93	9180	2.90
15	70	431	24	10349	0.86	8900	2.80

For all polythene percentages, the stabilities of the modified asphalt concrete mixtures were higher than the conventional asphalt concrete mixture - no modifier (4440 N). Since cohesion increases with viscosity, the high stabilities may be attributed to higher cohesion of the binder and improved internal friction. The highest stability (9180 N) was reported for modifier content of 12.5% and started declining afterwards. The trend supports the observations of [11, 12]

The improvement in stability of polythene modified asphalt due to increase adhesion and cohesion properties of the binder will enhance higher fatigue resistance, improved thermal stress cracking, decrease in temperature susceptibility and reduction of rutting as observed by [8, 9, 10]

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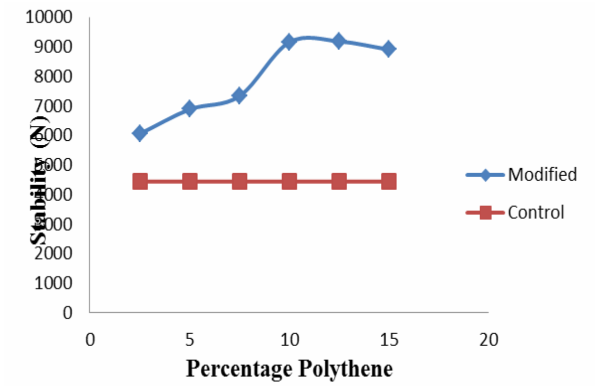

Figure-6 Stability against polythene percentage

For all polythene percentages, the flows of the modified asphalt concrete mixtures were lower than that of the control - no modifier (3.5mm). This may be attributed to the reduction in viscosity of the binder with increasing polythene content as observed during the experiment. This agrees with the result of [11]. [11] Noted that the reduction in flow suggested that the polythene content has increased effect on the internal friction of the concrete. The general trend (Figure-7) shows that flow decreases with increasing polythene content.

However, the above result does not agree with the observation of [12]. [12] Observed that the flows of asphalt concrete containing polythene were higher than that of the control.

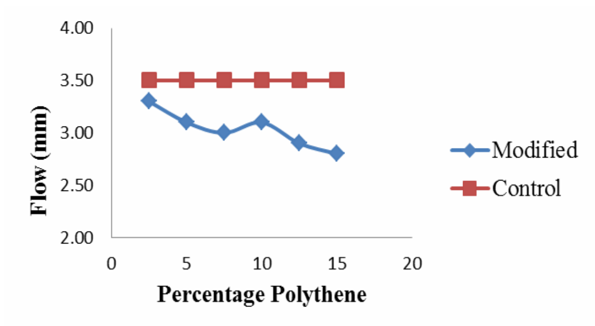

Figure-7 Flow against polythene percentage

CONCLUSIONS

To investigate the effect of polythene modified bitumen on the properties of hot mix asphalt concrete, a study was conducted at the University of Ibadan, Ibadan. The tests proceeded in two stages. Firstly, Asphalt concrete mix design was done to determine the optimum bitumen content for the mix. Secondly, modified binder prepared by blending bitumen with waste polythene at different percentages, was used to prepare asphalt concrete specimen. The specimens were tested to observe the effects of the modified binder.

Testing and observation of the asphalt concrete prepared from polythene modified binder concluded that:

- The bulk density of modified asphalt is lower than that of the control due to low density of the polythene.
- The bulk density of polythene modified specimen increases with increasing polythene percentages reaching peak value at 10% polythene content and drops afterward.
- The flow for modified asphalt concrete decreases with increasing polythene content and the values are lower than that of the control for all polythene percentages.
- The Marshall Stability of the modified asphalt is generally higher than that of the control reaching maximum value at about 12.5% polythene content. This shows about 100% increase in stability compared to that of the control.
- The optimum proportion of the binder is 12.5% by weight of the bitumen.
- The improvement in stability of the polythene modified asphalt due to increase adhesion and cohesion properties of the binder will enhance higher fatigue resistance, reduce thermal stress cracking, and decrease temperature susceptibility and reduction of rutting.

RECOMMENDATIONS

The benefits derivable from the use of waste polythene in asphalt concrete cannot be over emphasized. It will not only improve the strength and durability of the pavement but also reduce the problems associated with the disposal of waste polythene both in the country and other parts of the world, as a result, the followings are recommended:

- More research is needed to verify the results and conclusions of this work. First and foremost, other properties of asphalt concrete such as air voids and void filled aggregates should be tested and compared to standard values.
- The effects of aggregate gradation on polythene modified mixtures should be examined. The limited results of this study did not adequately determine whether aggregate gradation plays a major role in the behaviour of mixtures containing polythene material.
- The effects of different binder grades also need to be addressed. Binder grades determine what type of pavement an asphalt binder can be used in. The optimum percentage of polythene in different grades should be determined.
- The Federal and State Governments should encourage and provide incentives for demonstration projects on the use of waste polythene in asphalt concrete in various locales and under differing conditions. This would stimulate further research work on the subject matter. Furthermore, demonstration projects are needed to derive reliable estimates of the benefits and impacts of the polythene modified asphalt.

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