IOSR Journal of Business and Management (IOSR-JBM)
e-ISSN: 2278-487X, p-ISSN: 2319-7668. Volume 20, Issue 4. Ver. VII (April. 2018), PP 22-31
www.iosrjournals.org

Techno-Economic Analysis Of The Use Of Waste Polyethylene (Pure Water Sachet) As A Modifier For Bituminuous Road Construction In Nigeria

Mojisola A.Bolarinwa*,Paul O. Adeosunand Jennifer U. Egwuatu
Department of Industrial and Production Engineering, University of Ibadan, Nigeria.
Corresponding Author: Mojisola A. Bolarinwa

Abstract: *Recently, there has been an increase in the consumption of satchet water in Nigeria. However, the disposal of pure water satchets poses an environmental problem due to its non-biodegradability under a natural atmosphere. This study seeks to explore the potential prospects of using pure water sachet made of "Low Density Polyethylene" (LDPE) in improving the desirable properties of bitumen binder in asphalt mix in Nigeria. The materials collected were pure water sachets and bitumen. The desired properties of polyethylene modified and unmodified bitumen were investigated through specific gravity, penetration, viscosity, flash point and fire point tests, as well as pH determination. In addition, cost-benefit analysis was used to determine the economic worth of using modified and unmodified bitumen.Results showed the modified bitumen to possess improved desirable properties in stability, load bearing capacity, safety, ability to withstand heavy traffic, and cost effectiveness in road construction than unmodified bitumen. Furthermore, economic analysis showed that using polyethylene-modified bitumen in road construction leads to a saving of $500 and about 50% reduction in road maintenance cost per km, in comparison to using unmodified bitumen in road construction. The use of waste pure water sachet as a modifier in bituminous road construction has been found to economize, enhance road construction and also improve the pure water satchetwaste management in Nigeria.*

Keywords:*Biodegradability,modifiedbitumen, polyethylene, roadconstruction, satchetwater,wastemanagement*

Date of Submission: 12-04-2018 Date of acceptance: 30-04-2018

I Introduction

Polymer modified bitumen have been found to be more advantegeuous than the unmodified one due to its improved breaking point, fatigue life, softening point, aging resistance and increased life of the overlay,resulting in decrease in maintenance cost[1]. Bitumen is a dark sticky blend of hydrocarbons, acquired usually in form of deposits through petroleum distillation[2]. It is utilised as a binding agent when constructing roads and sometimes for roof covering.Typically, when at ambient temperature, bitumen is delicate, having a density value yielding to 1g/cm while at higher temperature it moves just like a sticky fluid[2]. Bitumen is composed primarily of very compacted polycyclic chain-like hydrocarbons; ninety-five percent carbon and hydrogen, approximately three percent sulphur, one percent nitrogen and one percent oxygen[3]. It is the largest fraction of crude oil, with a boiling point of 977ºF[3,26].

Despite the fact that the fraction of the binder is comparatively small, the binder affects the tar performance a lot more than the aggregate[2]. Ecological states, like hot atmospheric conditions, as result of solar energy modifies the physical structure and properties of the binder much more than the aggregate[4]. Hence, if the pavement is exposed to high temperature, as in Nigeria, long-term deformation occurs along the wheel path of the pavement[11]. Nigeria is blessed with bitumen deposits in large quantity, estimated to be at 42.74 billion metric tons, and this value has proven to put Nigeria as the second largest bitumen-rich country on the planet,with the major bitumen-producing states in the country being Lagos, Ogun, Ondo, Edo and Enugu States[5,12,26].

Presently, with technological advancement and the ever growing population, the continuous increase in traffic cannot be over emphasized, particularly in terms of automobiles. Also, global warming problem has left us with no other option than to discover better alternatives that will bring about enhancement of asphalt pavement features by making use of some essential alterations which will fulfill both durability and economical areas. Hence, this has led to the development of modified bitumen, by introducing polymeric substances[18,25](uncustomarily the use of waste pure water sachets, PWSas polyethylene).Pure water is normally packed with low-density polyethylene (LDPE) sachets which are known to be resilient and non-biodegradable[6]. The poor disposal of these wastes, for example, byincinerating/burning has been scientifically and medically proven to be hazardous[7], as this is known to generate air-borne cancerous toxic fumes which commonly cause varieties of human health problems like breast cancer, immune and reproductive system defects and much more. Moreover, these kinds of plastic materials waste products get embodied with water, thereby causing danger to marine existence[8]. Sometimes, they are either thrown over an expanse of land or burnt to ashes[16]. The aftermath of these methods of waste disposal that have been previously mentioned is environmental pollution and health hazards. For these reasons, some other use of this waste (pure water sachet) is required. Furthermore, the cost of constructing bituminous roads in Nigeria is high and methods to improve durability of these roads have been a major concern.Improvement in the bitumen mix using modifiers as binders is one of the possible solutions to the problems of poor road conditions having cracks, potholes and shorter lifespan[25].

Pure water sachets,which are lying virtually all over the place across the country may be found useful if examined as a bitumen property enhancer. Taking into consideration the high maintenance requirement of using bitumen in road construction, the search for ways to improve the durability of bituminous road construction cannot be undermined. More so, improper disposal of pure water sachet which is made up of polymeric substancecan pose harm to the environment, in form of pollution.Therefore, alternative methods that would reduce pure water sachet waste to acquire wealth can be sought after.

Several studies have found out that plastic waste could act as a sustaining additive in bitumen mix[13,14,15,22,24]. The results showed that pliable pavement with good reliabity and longevity can be achieved when bitumen is blended with certain percent of frayed polymer.Likewise, modified-asphalt mixture has a higher stability when compared to the non-modified mixtures, and so, positively influences the rutting resistance of these mixtures[19,20].HDPE (high density polyethylene)modified asphalt mixture exhibitedimproved properties far better than the improvements realiseable by utilizing LDPE (low density polyethylene). Studies to determine effective blending technique(s)when using plastic waste with bitumen for road laying have also been reported, for which different polymer-bitumen mixtures of varying compositions were prepared and used for carrying out various tests[21].It was concluded that plastics will increase the melting point of the bitumen[22,25]. The technology not only strengthened road construction, but also increased the road life. However, polymer-bitumen blend is a better binder, compared to plain bitumen[9,18,19,23.25],as the blend has increased softening point and decreased penetration value, in addition to having suitable ductility[17]. Also,any mix prepared with modifiers normally shows higher resistance to permanent deformation at higher temperature[4].

The cost effectiveness of asphalt rubber, polymer-modified and unmodified hot mix of asphalt was examined,by deriving their expected performance and the mixture unit cost[10], wherein ashpalt rubber and polymer-modified asphalt mixtures showed significantly higher cost effectiveness than unmodified mixture. Likewise,theeconomic and financial analyses of both conventional bitumen and polymer-modified bitumenhavebeen determined[1]. Their results showed that the requirements of polymer modified bitumen, even though with higher initial cost, isstill lesser than that of conventional bitumen. However, its maintenance and repair costs are relatively lower than that of conventional mix during service period of road and highway construction.

In essence, numerous people from different parts of the world have worked on various impacts of polymer-reinforced bitumenfor road construction.Unfortunately,in Nigeria, the economic analysis on the use of polyethylene in bituminous road construction have notbeen reported, which thus forms part of the aim of this work:Techno-economic analysis of using polyethylene as a modifierin bitumen-mix for road construction in Nigeria. Thestudy was aimedat technically and economically analysing the performance of polyethylene-modified-bituminous-roads by blending polyethylene in varying proportions intobitumen.Therefore, the objectives of the study are:(1) Blending of polyethylene in different proportions so as to assess the properties of the mixture. (2) Conducting relevant tests that would examine the properties of polyethylene-modified bitumen against that of unmodified bitumenin order toinvestigateits performance and effectiveness in bituminous pavement construction in Nigeria, and (3) Economically assessing the use of raw bitumen binder and polyethylene as modifier in bituminous pavement construction.

II Materialsand Methods

Materials: Pure water sachets (PWS: empty), raw bitumen.

Reagent: Toluene, butane gas.

Apparatus/Equipment: Shredding machine, grinder, rack, rheometer/8-speed viscometer, multi-unit extraction heater, 0.85mm diameter sieve, thermometer, stop watch, digital weight balance, penetrometerset-up, electric multi-mixer, pycnometer/density bottle, flash and fire point apparatus, container, needle, stainless-steel cups, adjustable screw, stirrer, containers, water bath, pH meter.

Method: Pure water sachets, gathered fromthe vicinity of University of Ibadan,Ibadan, Nigeria were washed, stacked,sun-dried, sorted, shredded using 35-40kg capacity shredding machine and grinded to grain size, with the aid of the grinder, and, on the long run,2kg ofthegrain-sized pure water sachet wereprepared.

5kg of 60/70 grade (Nigerian product) bitumen was acquiredthrough the University's maintenance department. The PWS and bitumen wereblendedtogetherby partially replacing the bitumen with grinded pure water sachet(PWS) at 0%, 2%, 4%, 6%, 8% and 10% weight replacements. Each ofthe mixture was stirred manually for 10 minutes and then at a constant rpm on an electric powered multi-mixer (heated on lab-line five plate electric heating mantle at a temperature 100°C for 6 minutes).The samples were thereafter put in different stainless steel cups,and each appropriately affixed a paper to denote the % polyethylenethat was blended into the bitumen sample.

1.) Sieve analysis of pure water sachet grains: Essence was to ensure uniformity in the particle size range of the shredded pure water sachet to be used in carrying out other tests.
Method: The technique utilized was manual dry sieving. 1 kg of the grains of pure water satchetwasshacked for about 5 minutes and sieved through the 850micron sieve (0.85mm). After shacking, the remnant particles left on the sieve was placed in a bowl-like container. For the purpose of further analysis, grains pure water sachet left as remnant on the sieve (i.e. % retained) and the pure water sachet particles that passed through the sieve (i.e % passing) were compared with the weight of the PWS grains before sieving (total weight) using these equations;

% retained = $\frac{Wretained}{Wtotal} x100$ (1)

% passing = $\frac{Wpassing}{Wtotal} x100$ (2)

Where “W”= weight

2.) Specific gravity test: Specific gravity was determined using the ratio of density of bitumen to density of water (1g/ml). Pycnometer/density bottle of 10ml capacity was used in carrying out the test.
Method: The pycnometer bottle, along with the stopper were cleaned, dried and weighed.The bituminous material was heated to its pouring temperature, and thereafter poured into the empty bottle to prevent entry of air bubbles.This was allowed to stand for half an hour at suitable temperature and cooled to 27^0C to permit escape of air bubbles and then weighed again.The bottle containing bituminous material was cleaned from outside and still re-weighed.The process was repeated simultaneously,onadding 2%, 4%, 6%, 8% and 10% polyethylene into the bitumen. Deductions were made with the use of the expressions:

$density = {}^{mass}/_{volume}$ (g/ml) (3)

Mass (g) = wet weight (g) - dry weight (g) (4)

Specific Gravity = $\frac{qbitumensample}{qofwater}$(5)

Where: q= density; Density of water = 1g/ml

3a.) Dynamic viscosity (DV) test: This test was used to determine the degree of opposition to flow at reduced temperature, in units of Poise, in accordance with ASTM 2171[27].
Method: The following procedural steps were carried out in the course of the test.

1. Using the digital weight balance, 200g of raw bitumen sample was weighed in six (6) places, and thereafter mixed with PWS grains at 0%, 2%, 4%, 6%, 8% and 10% weight replacements respectively.
2. The prepared samples were heated to 130°C fluid form.
3. The rheometer/8-speed viscometer was set to 200 revolutions per minute (rpm), 100rpm, 60 rpm, 30 rpm & 6rpm respectively to determine the dynamic viscosity value of each sample.

3b.) Plastic and Apparentviscosity tests: The viscosity test was used to measure the consistency of the 6 bitumen samples (0% - 10% polyethylene modified bitumen) at some specified temperatures (60°C and 135°C). The lower the viscosity of bitumen, the faster the flow of bitumen under the same stress.

Plastic viscosity: 200rpm-100rpm (6)

Apparent viscosity: $\frac{200rpm}{2}$(7)

4.) Flash and fire point tests: The tests were used to qualify theparticular temperature at which the bitumen grade (60/70) will become volatile, and possibly become hazardous by catching fire. The flash point was taken as the temperature read on the thermometer at the time of the flame application that causes a distinct flashin the interior of the cup. The fire point was taken as the lowest temperature under specified test conditions at which bituminous material gets ignited and burns. Butane gas was used as fuel for combustion.
Method: The following procedural steps were carried out in the course of the test:

1. The flash and fire point apparatus were calibrated to 25°C room temperature.
2. 2g of each of the 6 prepared samples(0% - 10% polyethylene modified bitumen) was measured and placed in the interior cup of the apparatus.
3. Application of test flame at regular intervals of at least 5 seconds till flash was observed.
4. The flash point was observed at the time of the flame application that caused a distinct flash in the interior of the cup, the temperature at this point read on the thermometer was recorded.

5. The fire point was deduced when ignition and burning of the material was observed for at least 5 seconds, the thermometer reading at this point was also recorded.

5.) Penetration test: It was used to measure the consistency of the bituminous material by determining the distance in millimeters that a standard needle vertically penetrates the bitumen under known conditions of loading, time and temperature. It is a means of classification, rather than a measure of quality.

Method: The following procedural steps were carried out in the course of the test:

1. The 6 samples (0% - 10% polyethylene modified bitumen) were simultaneously stirred exhaustively to ensure that each mix is homogenous and air bubbles are absent.
2. The sample vessels were then cooled at room temperature.
3. A weight of 100g was attached to the needle and the needle afterwards mounted on each sample, such that it touched the surface.
4. While the stop watch was started, the penetration needle was allowed to penetrate freely for five seconds.
5. After five seconds the penetration was stopped.
6. With the aid of the adjustable screw, the needle assembly was descended until the edge point of the needle came in contact with the topmost surface layer of the sample.
7. The initial reading of the penetrometer dial was noted.Readingswere recorded for the various samples.

6.)pHdetermination: To determine the pH values of the 6 samples(0% - 10% polyethylene modified bitumen).

Method: The pHmeter was calibrated using buffer solution (mixture of weak acid and conjugate base).

III Results

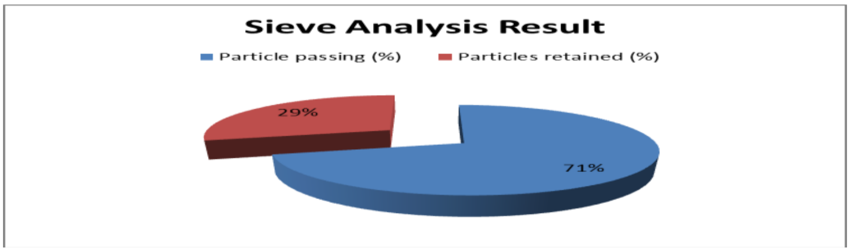
Having gathered and processed the pure water satchets as earlier described in section II, and respectively blending and heating itsdifferent percentages (0% – 10% polyethylene)with the Nigerian bitumen, six different cups, out of which one (1), containing raw bitumen and five (5) others, containing hot mix blend of PWS and bitumen wererealised.

1.) Sieve analysis of pure water satchet grains

Table no 1:Shows that having sieved1Kg of the grains of polyethylene (PWS),while a total of 290g was retained (29%),710g (71%) of the grains of shredded pure water sachet passed through the sieve and was used in obtaining further results from other tests carried out.

Table no 1: Sieve Analysis Result

Initial weight before sieving (g)	Weight of particle passing (g)	Weight of particles retained (g)
1,000	710	290



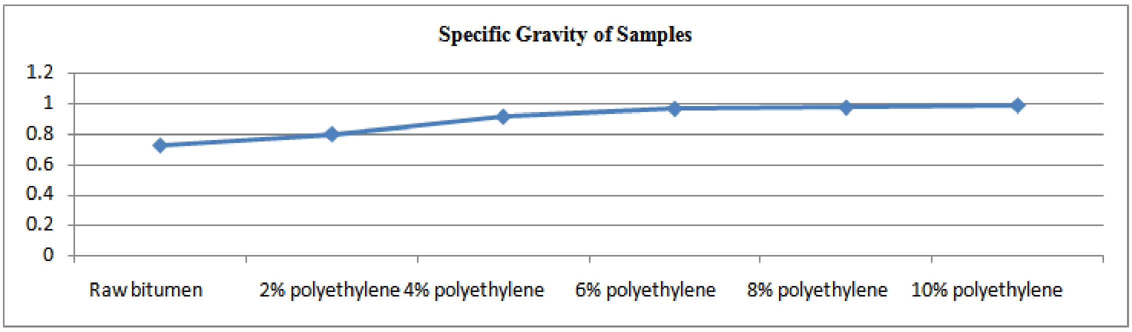
2.) Specific gravity test

Table no 2:Shows that as the percentage of polyethylene added was being increased (from 0% - 10%), the corresponding specific gravity value obtained also increased, indicating increases in aromatic-type impurities present therein, that is, more cyclic- chained molecules were being formed. In terms of ranking, partially replacing bitumen with 10% polyethylene produced the best result and assumed the first position.

Table no 2: Specific Gravity Result of Samples

Polyethylene-Bitumen mix	Dry weight (g)	Wet weight (g)	Mass (g)	Density (g/ml)	Specific Gravity	Ranking
Raw bitumen	9.340	16.640	7.300	0.730	0.730	6th
2% polyethylene	8.950	17.000	8.050	0.805	0.805	5th
4% polyethylene	10.220	19.420	9.200	0.920	0.920	4th
6% polyethylene	8.750	18.480	9.730	0.973	0.973	3rd
8% polyethylene	8.720	18.530	9.810	0.981	0.981	2nd

10% polyethylene	8.940	18.890	9.950	0.995	0.995	1st

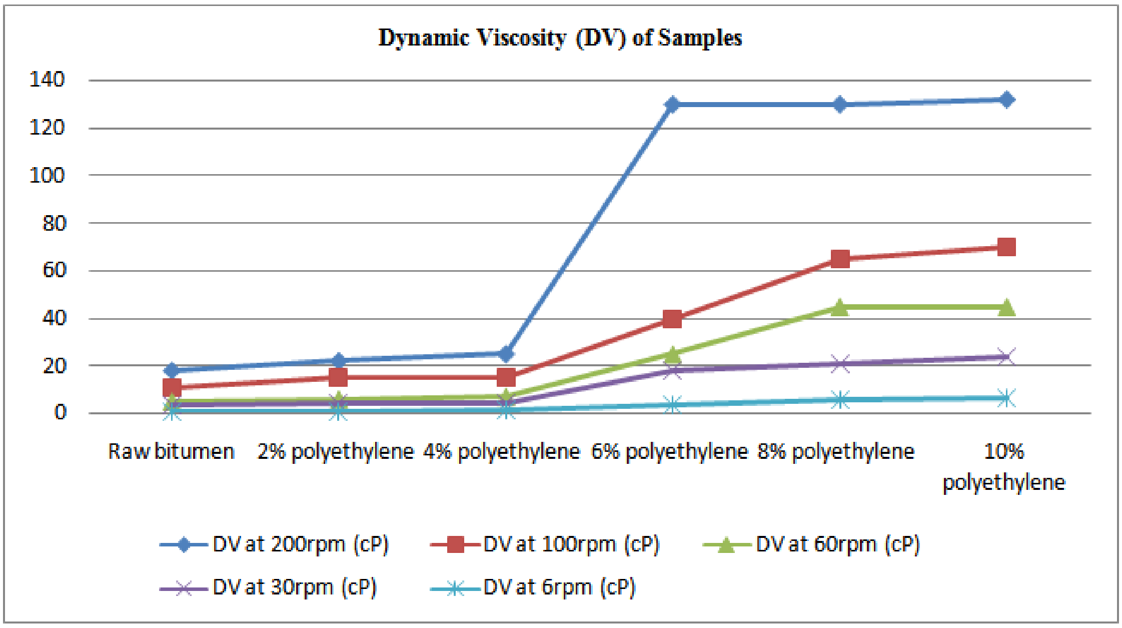


3a.) Dynamic viscosity (DV) test

Table no 3:Shows that even with the same polyethylene content (all through 0% - 10%), the viscosity kept increasing as the rpm increased, meaning that the higher the rpm, the higher the viscosity and vice-versa. Also, increasingthe polyethylene content(from 0% - 10%)blended into the bitumen showed an increasing order in the viscosity values at 200rpm,100rpm, 60rpm, 30rpm, 6rpm,havingmaintained a temperature of 105^{o}C.

Table no 3: Dynamic Viscosity Test Result at 105°C

Polyethylene-Bitumen mix	DV at 200rpm(cP)	DV at 100rpm(cP)	DV at 60rpm(cP)	DV at 30rpm(cP)	DV at 6rpm(cP)
Raw bitumen	18	11	5	4	1
2% polyethylene	22	15	6	5	1
4% polyethylene	25	15	7	5	2
6% polyethylene	130	40	25	18	4
8% polyethylene	130	65	45	21	6
10% polyethylene	132	70	45	24	7

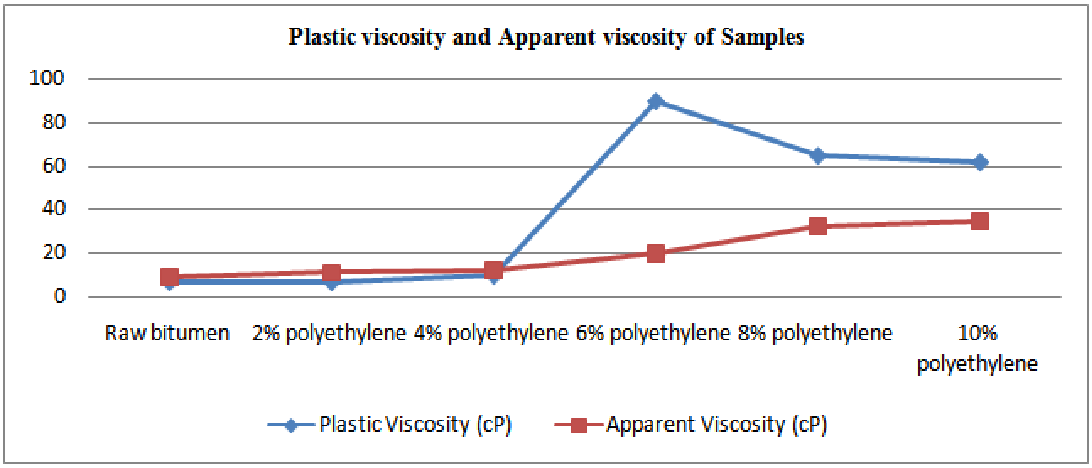


3b.) Plastic and Apparent viscosity tests

Table no 4: Shows the ranking of results for the plastic and apparent porosity tests to have been based on the values obtained from the apparent porosity, which tend to be more reliable, as plastic viscosity normally exhibits initial resistance without movement, and the condition which the bitumen will be subjected to in service involves constant movement of persons and automobiles on it. Therefore, in terms of ranking, partially replacing bitumen with 10% polyethylene produced the best result and assumedthe first position.

Table no 4: Plastic and Apparent Viscosity Results

Polyethylene-Bitumen mix	Plastic Viscosity (cP)	Apparent Viscosity (cP)	Ranking
Raw bitumen	7.0	9.0	6th
2% polyethylene	7.0	11.0	5th
4% polyethylene	10.0	12.5	4th
6% polyethylene	90.0	20.0	3rd
8% polyethylene	65.0	32.5	2nd
10% polyethylene	62.0	35.0	1st

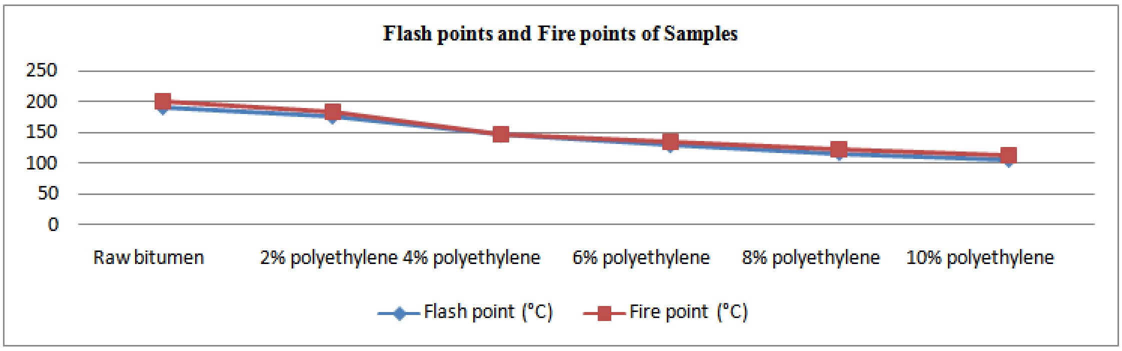


4.) Flash and Fire point tests

Table no 5: Shows that the inflammability of the bitumen samples decreased as the percentage of polyethylene was gradually increased from 0% - 10%.Since the higher the temperature, the higher the tendency for the bituminous material (depending on the grade) to leave out fire-causing volatiles, a very hazardous situation. At lower temperature, flash lasts only for about one second but fire burns for a longer period when it occurs at high temperature because of the volatiles that are constantly left behind. Then, the lower the temperature, the safer it is to operate and work with bituminous materials. In terms of ranking, partially replacing bitumen with 10% polyethylene produced the best result(recorded lowest temperatures at its flash and fire points) and assumed the first position. From the experimental results, it can be inferred that polyethylene modified bitumen develops better resistance to burning. Hence, pure water sachet modified bitumen for road surfaces will be less affected by fire hazards.

Table no 5: Flash Point and Fire Point Values

Polyethylene-Bitumen mix	Flash point (°C)	Fire point (°C)	Ranking
Raw bitumen	192.5	202.5	6th
2% polyethylene	177.5	185.5	5th
4% polyethylene	147.5	149.5	4th
6% polyethylene	130.5	136.5	3rd
8% polyethylene	117.5	124.5	2nd
10% polyethylene	106.5	114.5	1st

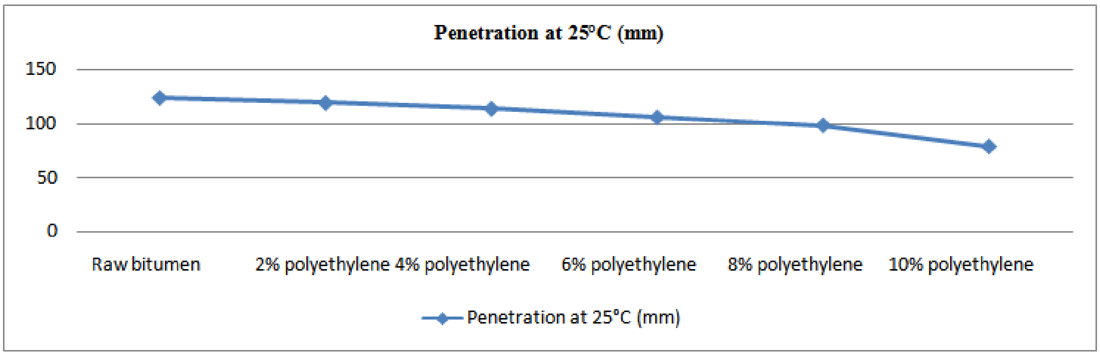


5.) Penetration test

Table no 6: Shows that increasing the polyethylene percentage (from 0% - 10%)added into the bitumenresulted todecrease in the corresponding penetration value obtained. In terms of ranking, partially replacing bitumen with 10% polyethylene produced the best result and assumed the first position. This establishes that increase in polymer content improves the toughness of bitumen. However, the decrease in the penetration value may be as a result of the interlinks between the polyethylene lattice within bitumen.

Table no 6: Penetration Results of Samples

Polyethylene-Bitumen mix	Penetration at 25°C (mm)	Ranking
Raw bitumen	124.0	6th
2% polyethylene	119.3	5th
4% polyethylene	114.1	4th
6% polyethylene	106.2	3rd
8% polyethylene	98.9	2nd
10% polyethylene	79.6	1st

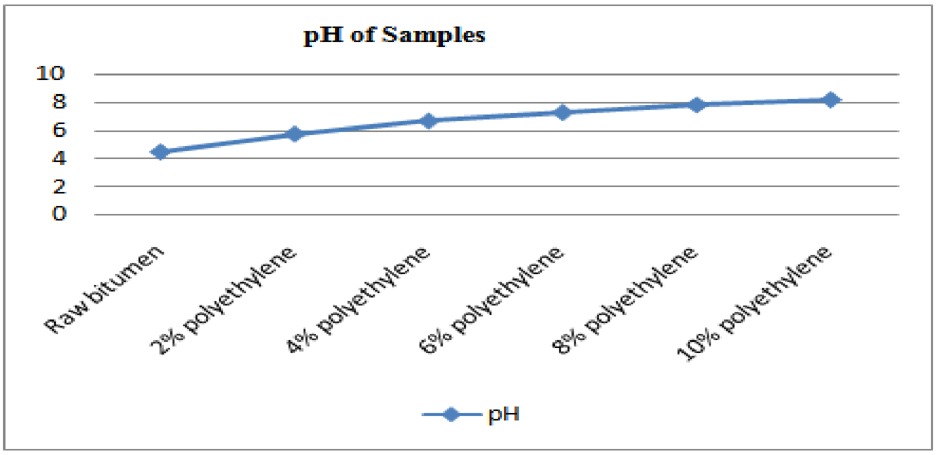


6.) pHdetermination

Table no 7:Showsthat as the percentage of polyethylene introduced into the bitumen samples increased, the corresponding pH value also increased.In terms of ranking, partially replacing bitumen with 10% polyethylene produced the best result and assumed the first position. Increase in pH value indicates increase in the stability of the bitumen samples, that is, the higher the pH, the more stable becomes the bitumen mix in question.

Table no 7: pH values of Samples

Polyethylene-Bitumen mix	pH	Ranking
Raw bitumen	4.50	6th
2% polyethylene	5.78	5th
4% polyethylene	6.71	4th
6% polyethylene	7.32	3rd
8% polyethylene	7.86	2nd
10% polyethylene	8.22	1st



IV Economic Analysis

Based on findings and the research, the associated costs in order to carry out cost-benefit analysis, are:

Direct costs: Cost of labour, cost of raw materials, cost of tools, cost of equipment, cost of recycling polyethylene.

Indirect costs: Wages of supervisory staff, maintenance cost, and administrative overheads, as well as the benefits derived from use of bituminous roads which include ease of transportation and durability.

Savings calculation is given as:

Savings = $UBcost - PMBcost$ (8)

Also to choose the preferable option, the percentage cost savings on material need to be calculated:

$$= \frac{UBcost - PMBcost}{UBcost} x100\% \quad (9)$$

Where: $UBcost$ = Cost of unmodified bitumen; PMB$cost$ = Cost of polyethylene modified bitumen

Derivation of cost incurred in bituminous road construction

The followings are the cost derivations for the road construction of 1km single lane, 3.5m wide for both modified and unmodified bitumen.

i) Direct costs

Cost of pure water waste (this encompasses cost of collection, segregation, shredding, drying, stacking and processing) = $0.28 per kilo

Cost of bitumen per drum (200kg) = $155.56

Cost of bitumen per Kg =$0.78

Cost of bitumen per ton = $777.78

Cost of labor (assume 1machine operator and 2bitumen spreaders) = $39.00/drum

Cost of labor per ton = $194.45

Cost of equipment and tools (assuming equipment are hired) = $72.22 per ton

ii) Indirect cost

Maintenance cost of equipment and fuelling (assuming it is an ideal periodic maintenance and arithmetically quantified): $111.11 per ton

Wages paid to supervisory team (5 persons): $27.80 per ton

(Costs and expenses are estimated from the records of a construction company in Western Nigeria).

Table nos 8 and 9: Show the costs involved in using raw bitumen and modified bitumen for the construction of 1km road. To lay 1km of road, 10 tons of bitumen are required.However, in using polyethylene as modifier together with the bitumen (with an optimum polyethylene percentage content of 10%), 9 tons of bitumen and 1 ton of polyethylene are required, as shown in Table nos8and9.

Table no 8: Associated Cost Using Unmodified Bitumen

Category	Cost ($)
Bitumen (10 tons)	7777.778
Labour	1944.444
Machine & equipment	722.2222
Maintenance cost	1111.111
Wages paid to supervisory team	277.7778
Total	**11,833.333**

Table no 9: Associated Cost Using Polyethylene Modified Bitumen

Category	Cost ($)
Bitumen (9 tons)	7000
Polyethylene (1 ton)	277.7778
Labour (10 tons)	1944.444
Machine & equipment (10 tons)	722.2222
Maintenance cost	1111.111
Wages paid to supervisory team	277.7778
Total	**11,333.333**

Derivation of maintenance cost of the roads

The lifespan of the unmodified bitumen road is estimated to be 20 years. During the period of 3-5 years of its construction, the road shows signs of cracking, while within 5-7 years of its usage, there may be need for patching. It is expected that during 15-20 years of the bituminous road, there will be need for frequent preventive maintenance to be performed on it. The maintenance costs are derived as:

$$F = A\left[\frac{(1+i)^N - 1}{i}\right] \qquad (10)$$

Where F= future cost of road maintenance, A= annual maintenance cost, i= interests rate, and N=lifespan of the road (years).
Average annual cost of maintaining unmodified bitumen road = $277,
With an interest rate of 10% for a 20 year period, the total expected cost of mainteneace is:
F= $277 (21.3843)
=$5,923.45
For the modified bitumen, due to its unique properties such as durability, less frequent maintenance activities are required.Hence,for an estimated average annual maintenance cost of $138 for the same period of 20 years and at 10% interest rate, the total expected cost of maintenance is:
F= $138 (21.3843)
=$2,970.04

Table no 10: Total Cost and Savings of using Modified and Unmodified Bitumen

	Unmodified bitumen	modified bitumen	Savings ($)
Total cost of road construction ($)	11,833.3	11333.3	500
Total cost of maintenance ($)	5923.45	2,970.04	2953.41

The percentage savings of using modified bitumen for road construction is derived as:

$$\%\, constructionsavings = \frac{500}{11{,}333.3} x\ 100$$

=4.4% savings.
While the percentage savings of the future expected maintenance cost of the road for the 20 year period is derived as:

$$\%\, roadmaintenancesavings = \frac{2{,}953.41}{5{,}923.45} x\ 100$$

= 49.86% savings
Table no 10:Shows the economic analysis,wherein the use of pure watersatchet (modifier)reduces the amount spent on resources (savings) used for road construction by $500 (4.4%) for every 1km single lane of 3.5m wide road constructed and a 49.86% reduction in the cost of maintaining the road over its lifespan of about 20 years.

V Conclusion

From this research work, the following conclusions could be drawn:
Addition of pure water sachet (polyethylene) as a modifier to bitumen binder gave a homogenous mixture on heating, improved its rheological properties, increased its viscosity values which improved the solidifying properties of bitumen as well as increased its pH values which enhanced the stability of bituminous roads. Also,

reduced penetration values implies that there would be an increase in the load bearing capacity of modified bitumen and decreased fire point and flash point values imply that polyethylene modified bitumen can withstand higher temperature when used for road construction. Sound pollution due to heavy traffic is lessened as plastic is a good sound absorptive material. The economic analysis has shown that the use of pure water sachet as a modifier will save millions of dollars in future and reduce the amount spent on resources used for road construction by 4.4% and reduction in the cost of maintenance by about 50%.
Hence, polyethylene modified roads provide means of increasing the durability of our Nigerian roads.

References

[1]. Bagui SK, Ghosh A. Economicand financial analysis for polymer modified bitumen. Malaysian Journal of Civil Engineering. 2012; 24(1): p. 96-106.
[2]. Arafat SY, Mohd RH. ARPA Press. [Online].; 2012 [cited 2016 October 17. Available from: www.arpapress.com.
[3]. Chetan MK, Sowmya NJ. IJRASET: Utilization of Copper Slag in Bituminous Concrete with a Stone Dust and Flyash as a Filler Material. [Online].; 2015 [cited 2016 October 12. Available from: www.ijraset.com.
[4]. Hussain U, Bahia A, Fahim KN. Prediction of Compaction Temperatures using Binder Rheology. [Online].; 2006 [cited 2016 November 19. Available from: www.onlinepubs.trb.org/./circulars/ec/05.pdf.
[5]. Fagbote EO, Olanipekun EO. Levels of Polycyclic Aromatic Hydrocarbons and Polychlorinated Biphenyls in Sediment of Bitumen Deposit Impacted Area. [Online].; 2010 [cited 2016 November 3. Available from: www.bioonline.org.br/pdf?st1055.
[6]. Flomo KM. Ripository: The Mechanical Property of Cement Mortar. [Online].; 2013 [cited 2016 November 6. Available from: www.repository.aust.edu.ng.
[7]. Women in Europe for Common Future. Dangerous Health Effects of Home Burning of Plastics and Wastes. [Online].; 2005 [cited 2016 November 16. Available from: www.wecf.eu.com.
[8]. Mohanty M. A Study On Use Of Waste Polyethylene In Bituminous Paving Mixes. [Online].; 2013 [cited 2016 October 20. Available from: www.ethesis.nitrkl.ac.in.
[9]. Yojanna S. Cement Concrete Roads Vs. Bituminous Roads – A Cost Analysis. [Online].; 2006 [cited 2016 November 18. Available from: www.pmgsy.nic.in.com.
[10]. Souliman IM, Mamlouk M, Eifert A. Cost effectivenessof rubber and polymer modified asphalt mixtures as related to sustainable fatigue performance. Procedia Engineering: International Conference on Sustainable Design, Engineering and Construction. 2015;: p. 1-8.
[11]. Abdulkareem YA. Road Maintenance and National Development. [Online].; 2005 [cited 2017 April 27. Available from: https:/ilorin.info.ng.
[12]. Adebayo FF, Jimoh YA. Nigeria Production and Cost of Cold Patch Road Mats with Bitumen Extracted from Nigerian Tar Sand. [Online].; 2015 [cited 2016 Ooctober 12. Available from: https://uniilorin.edu.ng.
[13]. Amit G, Zamare V, Renge C, Saurabh T, Bharsakale G. An Overview on Waste Plastic Utilization in Asphalting Of Roads. [Online].; 2012 [cited 2016 October 18. Available from: www.technicaljounalsonline.com.
[14]. Anurag VT, Amravati MS, Rao YRM, Pauls M, Villupuram TN. India Plastic Waste Modified Bitumen for Road Construction. [Online].; 2015 [cited 2016 October 9. Available from: www.ipheindia.org.
[15]. Avula V. Use of Waste Plastic in Construction Of Bituminous Road. [Online].; 2013 [cited 2016 October 19. Available from: www.worldsciencepublisher.org.
[16]. Babatunde M, Biala MI. Externality Effects of Sachet Water Consumption. [Online].; 2010 [cited 2016 November 19. Available from: www.onlinepubs.trb.org/./circulars/.
[17]. Bamidele IO, Dahunsi OS, Awogboro MA, Oladipupo SO. Investigation of the Properties of "Pure Water" Sachet Modified Bitumen. [Online]. [cited 2016 October 6. Available from: www.theijes.com.
[18]. Jiqing Z, Bjorn B, Niki K. Polymer Modification of Bitumen: Advances and Challenges. [Online].; 2014 [cited 2016 November 4. Available from: www.diva-portal.org.
[19]. Muhammad BK, Sarfaz A, Muhammad I, Sajid M. Comparative Analysis of Conventional and Waste Polyethylene Modified Bituminous Mixes. [Online].; 2013 [cited 2016 October 20. Available from: www.journals.2223-9553-SAVAP.
[20]. Nobinur R, Mohammad A, Sobhan MA, Ahmed TU. Performance Evaluation of Waste Polyethylene and PVC on Hot Asphalt Mixtures. [Online].; 2013 [cited 2016 November 2. Available from: www.researchgate.net/./265725.
[21]. Noor ZH, Ibrahim KN, Isa M. Effect of Mixing Process on Polypropylene Modified Bituminous Concrete Mix Properties. [Online].; 2011 [cited 2016 October 6. Available from: www.waset.org.
[22]. Rokdey N, Naktode PL, Nikhar , R. M. Use of Plastic Waste in Road Construction. [Online].; 2015 [cited 2016 October 6. Available from: www.researchijaconline.org/…/icquest28.
[23]. Shirish NN, Prashant VT. Utilization of Polymer Waste for Modification of Bitumen in Road Construction. [Online].; 2013 [cited 2016 October 27. Available from: www.sadgurupublications.com.
[24]. Tom VM, Krishna KV. Bituminous Mix Design. [Online].; 2007 [cited 2016 December 16. Available from: www.nptel.ac.in/courses/./Lec-26.
[25]. Bansal S, Bajpai P. Evaluation of Modified Bituminous Concrete Mix Developed Using Rubber and Plastic Waste Materials. International Journal of Sustainable Buitlt Environment. 2017;: p. 442-448.
[26]. Guma TN, Madakson PB, Yawas DS, Aku SY. Assessment of Physicochemical Properties of some Bitumens from Nigerian Resources.
[27]. American Standard for Testing Materials. [ASTM]. Standard test method for viscosity of asphalts by vacuum capillary viscometer, ASTM D2171/D2171M-10. ASTM International, West Conshohocken, PA. [Online].;2010[cited 2016October 27. Available from: www.astm.org.