



Reuse of Waste Plastic as an Additive in Asphalt Concrete

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ABSTRACT

Plastics are used extensively by people in their everyday life and thus causes environmental pollution when disposed of improperly. Consequently, there is a rising global concern towards waste plastic (WP) management either through recycling or proper waste disposal. However, this study focusses on utilizing waste plastics as an additive for road construction thereby minimizing the environmental hazards caused by improper waste plastic disposal. An investigation of stability of asphalt pavement was made using polythene as an additive to enhance its stability. In the course of this study, Marshall Stability test was performed on five samples (Samples A-E) with a view to determining the proportion of WP required to achieve a stable bituminous mixture. Each sample was characterized by percentage replacement of bitumen with waste plastic (WP) which varied from 0% to 4%. Results from experimentation revealed that high stability of bituminous mixture was attained at 1% replacement of bitumen with WP (i.e. for Sample B). Also, it was observed that at 1% WP replacement, flow values reduced. Nevertheless, this reduction in flow values was attributed to many voids between the mineral aggregates. More so, it was established that Sample E which was characterized by 1% bitumen and 5% WP showed poor stability. The poor performance of Sample E was ascribed to insufficient binding modifier.

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INTRODUCTION

Pavements have been an essential part of our lives. They are used for several things like roads, driveways and runways etc. (Mallick *et al.* 2008). Road transportation being the most widely used mode of transportation, is an essential part of human activity, which contributes and plays a vital role in the physical and economic growth and development of a town, city, and country (Mallick *et al.* 2008). In the transportation sector, both developed and developing countries face various road failure challenges which usually occur when the load applied on roads exceeds the maximum allowable value. Subsequently, the road surface distress occurs when there is a sign of poor pavement performance or indications of imminent failure (Adlinge and Gupta 2013). Road deterioration is a serious crisis for the transportation sector, owing to the high construction costs of new roads and maintenance of existing roads and routes (Okigbo, 2012). According to Bello *et al.* (2015) also the mostly used method of transportation

Nigeria is by road while flexible pavement is the most rampant type road pavement in the country. Moreover, since the attainment of independence in 1960, Nigeria's transportation system is being faced with the problem of bad roads and other factors (Federal Ministry of Transport, 2011). The demands of roads are increasing rapidly year by year and also the numbers of commercial vehicles with increased axle loads which will continue in the future, as such several research works have been carried out to explore the useful application of certain type of waste materials in pavement construction. The focal point of this study boils around the need for safe and economical disposal of waste materials, plus the need for utilizing cost-effective and reliable construction materials for asphalt pavements.

However, flexible pavements in Nigeria, particularly in the urban areas, deteriorate quickly after construction due to poor quality of pavement material used and lack of proper drainage facilities (Tiza, 2016). Pavement failures in Nigeria is worrisome and



constitutes one of the challenges must be tackled. Consequently, the roads have been placed amongst the poorest and yet the most expensive roads in the world. Pavement failure basically is caused by several factors such as, stresses from heavy vehicles, expansion and contraction from seasonal temperature changes, and sun exposure (Adil, 2017). Adams and Adetoro (2014) highlighted that Nigeria's pavement failure is often characterized by the distress of different kinds like; potholes, cracks, depression, ruts, etc. whose cause are due to various reasons from construction materials to inappropriate designs. In this regard, sorting plastic waste and exploiting it in pavement construction will reduce waste accumulation to a great extent and minimize material construction costs. The performance and longevity of roads constructed with plastic blended bitumen are significantly better compared to the normal bitumen roads.

Nevertheless, this study seeks to show a better way of constructing a flexible pavement by minimizing construction cost and failure of roads during its service life. This study will also contribute to solving drainage problems in Nigeria which is mainly caused by water clogging due to accumulated waste plastics in drainage systems. Therefore, the reuse of waste plastic with bitumen in road construction offers a sustainable solution to drainage problems.

THEORIES AND DEFINITIONS

Concepts of Road Pavements

Generally, pavements are subdivided into flexible (asphalt) and rigid (concrete) pavement. According to Mallick et al., (2008), flexible pavement comprises mixtures of bituminous material, aggregates and sometimes additives while rigid pavement consists of Portland cement concrete slab. Flexible pavements are made up of different layers with different materials consisting of aggregates, binder (bitumen), air voids and any other additive. Asphalt pavement materials are extremely subjected to frequent stresses, heavy

loads, heavy traffic, and various climatic and environmental constraints such as temperature. Honarmand *et al.* (2019) also proposed that the load bearing behavior and subsequent failure of asphalt pavements depend on several mechanisms which are directly connected to the transfer of local load between aggregate particles. The most basic purpose of having a good mix and structural design is for the pavement is to withstand traffic loads without deforming or degrading to the point that it is unusable during the design era. To mitigate this cycle, various ways may be effective, such as improving roadway design, securing maintenance funds, improving material quality control, and using more efficient construction methods. Consistent research is required to create better materials, processes and designs to make pavement safer, longer-lasting and more cost-effective.

The performance of flexible pavement is influenced by many factors, such as the component properties (binder, aggregate, and additive) and the components proportion in the mix. Through the use of different types of additives, the efficiency of asphalt mixtures can be improved, including: polymers, latex, fibers and several chemical additives. It has been proven that adding some polymer additive to asphalt mix will enhance asphalt pavements performance. Usually, the application of polymers exhibits improved resilience, greater resistance to permanent deformation in the form of rutting and thermal crack. It also increases stability, and decreases damage to fatigue (Honarmand *et al.* 2019). Various types of polymers have been identified to be effective polymer additives that would improve asphalt pavements life and also address many environmental problems (Nemade and Thorat 2013; Kumar and Khan, 2020). Flexible pavements are constructed structures consisting of a group of layers of different materials placed on an existing (Subgrade) surface. Figure 2.1 demonstrates cross-section of a flexible pavement structure.

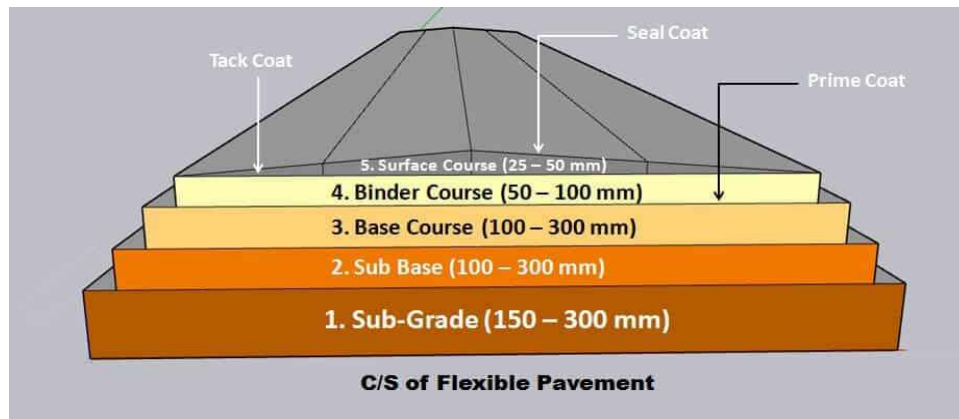


Figure 2.1: Cross-section of a flexible pavement (Mahajan, 2021)

Asphalt Plant Mixing

Asphalt plants are facilities built and constructed to produce asphalt and asphalt concrete, which are primarily used as the starting raw material for road layout and construction. For the asphalt to be formed, carefully measured quantities of the raw material are heated to a standard temperature and then removed from the plant. Only with the production of the right quantity of aggregate, sand and stone dust in the plant at the optimum temperature is guaranteed the right quality of asphalt, which is absolutely necessary for laying quality roads.

The Asphalt Plant is made of high-quality steel & reliable design to deliver long-term high performance without compromising the quality of the high-fuel efficiency product / mix, enhancing customer profit. The asphalt plant consists mainly of cold aggregate supply system, drum dryer, coal burner, coal feeder, dust collector, hot aggregate elevator, vibrating screen. All of these components has properties that have an impact not only on the asphalt overall quality but also the effect on the environment.

Hot Mix Asphalt

Standard type of asphalt is the Hot Mix Asphalt (HMA). The binding material and aggregate materials are heated to a temperature of between 275 and 300 degrees Fahrenheit and laid out while still intensely hot. Hot-mix asphalt (HMA) is mostly laid in a warm period, because cold temperatures will cause the base to cool quickly (Atuboyedia, 2019).

For asphalt pavements, the asphalt binder is combined with aggregates to create

hot mix asphalt (HMA). The Hot-Mix Asphalt (HMA) is the most commonly used paving substance worldwide. Many common names like: Hot-Mix Asphalt (HMA), plant mix, asphaltic concrete, bituminous mixture, bituminous concrete etc. The aggregates used in the mixture comprise coarse and fine materials, usually a blend of rock and sand of varying thickness (Mallick *et al.* 2008).

Asphalt pavement primarily consists of aggregate binders and asphalt binder. Usually, the aggregate accounts for about 95% of the HMA mixture by weight, while the asphalt binder accounts for the remaining 5%. By volume a typical HMA mix is around 85% composite, 10% asphalt binder, and 5% air voids. Hot-mix asphalt (HMA) is manufactured at temperatures between 140 ° C and 160 ° C, and some mixtures, including asphalt rubber and polymer-modified asphalt (PMA) mixtures can require even higher mixing temperatures. Such temperatures ensure that the aggregate is dry, that the asphalt coats the aggregate, and that the mixture has the appropriate workability.

Polymer Modified Asphalt Mix

Many polymeric substances have been introduced into the asphalt mix as an additive in different forms to enhance the efficiency of asphalt pavements. The alteration of bitumen and asphalt mix in polymer has many benefits. These benefits include; improved thermal cracking resistances, enhanced fatigue resistance, improve rutting resistance, and decrease in temperature susceptibility (Mallick *et al.* 2008). Polymers are mainly incorporated as a binding agent (bitumen) modifier in an asphalt mix. Polymers can be added to form an



aggregates coating material. In addition, in an asphalt mix, Polymers may be used as a partial replacement for certain amount of aggregates.

The qualities of a modified asphalt mix vary depending on several factors such as: polymer characteristics, mixing conditions, and polymer compatibility with content of asphalt mix. Polymers are of many types and classifications. Plastics are one the most widely used polymers nowadays. Extensive research has also been conducted to assess the suitability of plastic waste to be used in asphalt mix.

Additives, which are used to modify or improve the quality of virgin materials is simply called the modifier of it. Modifiers are blended directly with the binder or added to the asphalt concrete mix during production to enhance the properties, and the performance of the pavement. It should be mentioned here that a huge quantity of bituminous binder is required every year for pavement construction.

Waste Plastic Utilization in an Asphalt Mixture

Different types of plastic become waste after use and require huge quantities of land for storage, which is also inconvenient for recycling. Hazardous plastic struggles to fill land due to its poor biodegradability and is not a dominant disposal technique. Because of the stronger binding properties of plastics in their molten state, innovative waste disposal methods are investigated by using them in the construction of flexible paving. As a consequence, waste plastic was one of the plastomer polymers that can be used by three different processes in asphalt concrete mixing: dry process, wet process, and the third process requires the use of waste plastic as a partial replacement for some aggregate sizes (Yeole *et al*, 2017).

The primary mixture of shredded plastic polymer waste over hot aggregates is involved in the dry process to create an aggregate coating layer usually by melting plastic over a hot aggregate surface. In addition to cement filler and crush sand, coated aggregates after coating are added to hot bitumen to obtain a homogeneous bituminous mix for versatile pavement course wearing. Depending on plastic properties and mixing conditions, this coating layer will enhance aggregate bonding and engineering properties,

contributing to improved durability of asphalt mixtures. Dry process only applies to plastics polymers (Gawande *et al*, 2012).

The wet process requires the simultaneous combining of bitumen and plastic waste. This method starts with the initial mixing of shredded plastic polymer waste into hot bitumen with continuous stirring. At around the same time, hot aggregates are inserted into modified bitumen along with crushed sand and cement filler to obtain a homogeneous bituminous mix for wearing flexible pavement (Gawande *et al*, 2012).

The modification of bitumen by adding polymer offers many improvements to asphalt mixtures that may include improvements in thermal cracking, resistance to rutting and stripping, and sensitivity to fatigue damage and temperature. In many paving and maintenance applications, improving asphalt mixtures has resulted in polymer modified bitumen becoming a substitute for ordinary bitumen. The consistency of the modified bitumen depends on various factors, such as the properties of the polymer-bitumen, the mixing conditions and the compatibility of the plastic polymer with the bitumen. To blend plastic polymers into bitumen, two methods are used the first method is to apply latex polymer to bitumen, which allows reasonably fast dispersal of polymer. The second solution is to apply solid polymers to the bitumen, which typically requires a high shear mixer to achieve an evenly distributed mixture (Yeole *et al*, 2017).

Another way to incorporate plastics into the asphalt mixture is to substitute a portion of plastic polymer mineral aggregates of the same size that is mainly used to blend waste plastic and absorbs a greater proportion of plastic in the asphalt mix (Gawande *et al*, 2012). More so, a firm pavement surface is often characterized by high resistance under heavy traffic loadings (Nuhu *et al.*, 2019). Consequently, many researchers have participated in studies that investigated how the use of additives in bituminous mixtures can help enhance the performance of pavements (Modarres *et al.*, 2014; Khan *et al.*, 2016; Nuha *et al.*, 2021)

MATERIALS AND METHODS

As the primary technique for achieving the research objectives, this study is based on laboratory testing. All work is carried



out using the equipment and instruments available at the Federal University of Technology Minna Laboratory. The laboratory tests are divided into several steps, starting with the assessment of the properties of aggregates, bitumen, and plastics as the materials. In order to obtain the grading of aggregate sizes followed by aggregate mixing, sieve analysis is carried out for each aggregate form. After that, asphalt mixes are formulated with various bitumen contents and the marshal test is carried out to achieve the optimum bitumen material. Typically, many research works have recommended the range of 6% to 7% Bitumen (Binder) content for an open-graded surface mixes (Institute, 2014). For preparing asphalt mixes modified with different percentages of waste plastic bags, the value of the optimum bitumen is used. The properties of these modified mixes were subsequently tested using the Marshal Test. Also, the findings of laboratory experiments are collected and analyzed.

Materials Selection

The components of hot mix asphalt and waste plastic bags are materials required for this research. Basically, the materials used for the asphalt mix design were sieved aggregates of 2.36mm size distribution, heated bitumen of grade 60/70 (which is in compliance with ASTM standards), and waste plastic modifiers. Modifiers are generally used to enhance the properties of bituminous concrete mixes by reducing the air void present between the aggregates and to bind them together so that no bleeding of bitumen will occur. For the present study, Plastic waste such as carry bags and hard polythene bags PETE (water bottle) are used as a plastic modifier.

Preparation of Waste Plastic

- 1) Plastic waste collection: The used plastic collected from roads, garbage trucks, dumps or composting plants, or from school collection programs, or from the purchase of waste pickers or buyers for N30 per kg.
- 2) Cleaning and crushing of waste plastics: Waste plastic was in the form of thin film bags, disposable cups, PET bottles, etc. The collected waste plastics are classified, de-dusted, and washed, if necessary. After that Plastic

waste (cups, bags) made out of PE, PP and PS are cut into a size between 2.36mm and 4.75mm manually due to unavailability of the shredding machine.

Marshall Mix Design

From Marshall Mix design, we can identify the following desirable properties of the asphalt concrete mix design. These are;

1. Sufficient stability: The ability to withstand traffic loads without distortion or deflection, especially in higher temperatures.
2. Sufficient Workability: The ability to be placed and compacted with reasonable effort and without segregation of the coarse aggregates.
3. Sufficient Durability: The ability to resist aggregate breakdown due to wetting, drying, freezing or excessive inter-particle forces.
4. Sufficient skid resistance: Proper traction in wet and dry conditions.
5. Sufficient Flexibility.
6. Sufficient Air voids.

Mainly, Marshall Mix design is done to find the optimum bitumen Content of asphalt concrete mixture. From the test, we measure two parameters they are stability and flow of mix design. Meanwhile, stability refers to the maximum load that the specimen can carry at 60°C temperature; flow means deformation in the sample during application of load in units or 0.25mm.

Marshall Stability Test

Marshall stability test, the resistance to plastic deformation of cylindrical specimen of bituminous mixture measured when the same is loaded at the periphery at a rate of 5 cm per minute. This test procedure used in design and evaluation of bituminous paving mixes.

Apparatus

- 1) Specimen Mold Assembly – Mold cylinders 4 in. (101.6 mm) in diameter by 3 in. (76.2 mm) in height, base plates, and extension collars.
- 2) Specimen Extractor steel, in the form of a disk with a diameter not less than 3.95 in. (100.33 mm) and ½ in. thick for extracting the compacted

specimen from the specimen mold with the employment of the mold collar.

- 3) Compaction machine with 4.54 kg hammer drop from 45.7cm height.
- 4) Breaking Head: The breaking head shall consist of upper and lower cylindrical segments.
- 5) Loading Jack: The loading jack shall consist of a screw jack mounted in a testing frame and shall produce a uniform vertical movement of 5mm / min.
- 6) Ovens or Hot Plates.
- 7) Mixing Apparatus: Mechanical mixing recommended.
- 8) Water Bath: The water bath shall be at least 15cm deep and shall be thermostatically control as to maintain the bath at $60 \pm 1.0^{\circ}\text{C}$.
- 9) Containers, Mixing Tool, Thermometers, Balance, Gloves, Rubber Gloves, Marking Crayons and Scoop.

Laboratory Procedure Using Marshall Method

Preparation of Test Specimens

- 1) Number of Specimens - Prepare at least three specimens for each combination of aggregates and bitumen content.
- 2) Preparation of Aggregates - Dry aggregates to constant weight at temperature of 150°C to 110°C and separate the aggregates by sieving into the desired size fractions. These size fractions are recommended:
 - I. 25.0 to 19.0 mm (1 to $\frac{3}{4}$ in.)
 - II. 19.0 to 9.5 mm ($\frac{3}{4}$ to $\frac{3}{8}$ in.)
 - III. 9.5 to 4.75 mm ($\frac{3}{8}$ in. to No. 4)
 - IV. 4.75 to 2.36 mm (No. 4 to No. 8)
 - V. Passing 2.36 mm (No. 8)
- 3) Determination of Mixing and Compacting Temperatures. The temperatures to which the bituminous binder must heated to produce a viscosity of 170 ± 200 Centistokes shall be the mixing temperature.
- 4) Preparation of Mixtures: Weight the aggregates into separate pans for each test specimen the amount of

each size fraction required to produce a batch that will result in a compacted specimen about 1200g. Place the pans in the oven and heat to a temperature not exceeding the mixing temperature $175^{\circ}\text{C} - 190^{\circ}\text{C}$.

- 5) Charge the mixing bowl with the heated aggregate and dry mix thoroughly.
- 6) Form a crater in the dry blended aggregate and weigh the preheated required amount of bituminous material into the mixture. Mix the aggregate and bituminous material rapidly until thoroughly coated.

Compaction of Specimens

- 1) Thoroughly clean the specimen mold assembly and heat them in boiling water or place it in the oven at a temperature $93.3^{\circ}\text{C} - 148.9^{\circ}\text{C}$.
- 2) Place a piece of filter paper or paper toweling cut to size in the bottom of the mold before the mixture introduced.
- 3) Place the batch in the mold by layers for three layers, spade the mixture vigorously with a heated spatula or trowel 15 times around the perimeter and 10 times over the interior per each layer.
- 4) Remove the collar and smooth the surface of the mix with a trowel to a slightly rounded shape.
- 5) Replace the collar, place the mold assembly on the compaction machine in the mold holder, and apply 75 blows with the compaction hammer with a free fall in 45.7 cm.
- 6) Remove the base plate and collar, and reverse and reassemble the mold. Apply the same number of compaction blows to the face of the reversed specimen.
- 7) After compaction, remove the base plate carefully transfer the specimen to a smooth, flat surface and allow it to stand overnight at room temperature.
- 8) Place the mold in sample extractor on that end of the specimen. Place the assembly with the extension collar up in the testing machine; apply pressure to the collar by means by means of



the load transfer bar. Lift the collar from the specimen.

The above procedure was used first for the control (i.e. 6% Bitumen + 0% Polythene) which after, the same procedure was used for the different samples, keeping other constituents constant and varying the percentage composition of bitumen by replacing it with melted Polythene as an additive. The following samples are the percentages replaced with Polythene;

- I. 5% bitumen + 1% Polythene as an additive.
- II. 4% bitumen + 2% Polythene as an additive.
- III. 3% bitumen + 3% Polythene as an additive.
- IV. 2% bitumen + 4% Polythene as an additive.
- V. 1% bitumen + 5% Polythene as an additive.

Testing of the Specimen

- 1) Take the specimen for testing; attach the proving ring of 30kN capacity on marshal machine before conduction the test.
- 2) Place the sample in water bath maintained at 60°C for 30min – 40 min; thereafter take off the sample from water bath.
- 3) Then place the sample on lower segment of breaking head assembly and insert the upper segment of breaking head assembly and place the whole assembly with the sample on the Marshal Stability test apparatus.
- 4) Place the steel ball on breaking head assembly and lower the proving ring until it touch the steel ball also position dial gauge on breaking head assembly to measure flow value.
- 5) Set the value of proving ring to read zero, also set the value of dial gauge to zero.
- 6) Then start the loading unit is started and the load is applied at a constant rate of 51 mm/min.

- 7) The load on proving ring and flow value on dial gauge was closely observed at a time as soon as the sample fails the pointer of the proving ring rotate opposite direction, exactly at in this location note down reading of the proving ring for load and dial gauge value for flow value.

RESULTS AND DISCUSSION

From the result analysis obtained from all the samples, it is observed that the values obtained from bitumen volume, aggregate volume, aggregate volume, total mixture voids, bitumen filled voids and stability average decrease from sample 'A to sample 'E' because of the initiation of a plastic material. As percentages of bitumen were replaced with percentages of polythene, the average flow values observed varied from sample 'A to sample 'E' (i.e. an increment and decrement was observed as per when various percentage of waste plastic was incorporated with the asphalt mixes) as such the resistance deformation under heavy wheel loads increases.

Due to the fact that the compaction machine could not hammer and compress the aggregates in the mold, sample 'E' that was 1 percent of Bitumen + 5 percent of polythene failed during the process. Because of the low percentage of bitumen applied to the mixture and because the voids in the mixtures were so visible after test compaction, it failed because the sample lacked a binding modifier. The average stabilities of the samples are given below;

1. Sample A (Control as an additive, i.e. 6% bitumen + 0% polythene).
2. Sample B (5% bitumen + 1% polythene as an additive).
3. Sample C (4% bitumen + 2% polythene as an additive).
4. Sample D (3% bitumen + 3% polythene as an additive).
5. Sample E (2% bitumen + 4% polythene as an additive).

Invariably, results of test analysis performed for Samples A-E are presented in Appendix A.

% of W,P	Stability
0	9.49
1	13.385
2	9.67
3	7.335
4	4.675

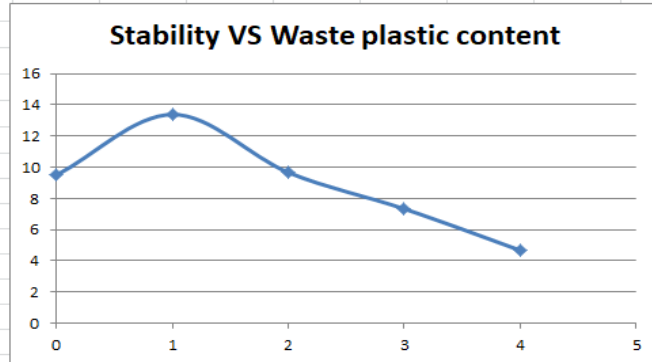


Figure 4.1: A Graph of all samples Stability VS Waste plastic content

Figure 4.1 shows a graph of all samples, consisting of sample 'A' (control i.e. 6 percent bitumen + 0 percent polythene as an additive) which is a sample of 100% bitumen and aggregates without using waste plastic as an additive. It was recorded that there was an improvement in flow stability, which is the natural method of acquiring asphalt pavement strength and stability. The most economical and satisfactory result was observed to be sample 'B' – thus, demonstrating that the strength and stability of asphaltic concrete is higher than the strength of the control (i.e. sample A). Sample 'C' also demonstrate that the strength and stability of asphaltic concrete is higher than the

strength of the control sample A, While Sample 'D' shows a decrease in the strength and stability of the specimen due to the amount or percentage of the waste plastic which in that case is not so favorable. The decrease in the stability of the asphaltic concrete from sample 'D' to sample 'E' is indicated in Figure 4.1. From the chart, Sample "B" (1% polythene replacement) has the highest asphalt stability, while Sample "E" (4% polythene replacement) has the lowest asphalt concrete stability. After testing for all five plastic contents, it was obtained that the optimum bitumen content for the mix design is at 1% waste plastic content.

% of W,P	Flow
0	28.2
1	22.7
2	15.75
3	17.65
4	17.4

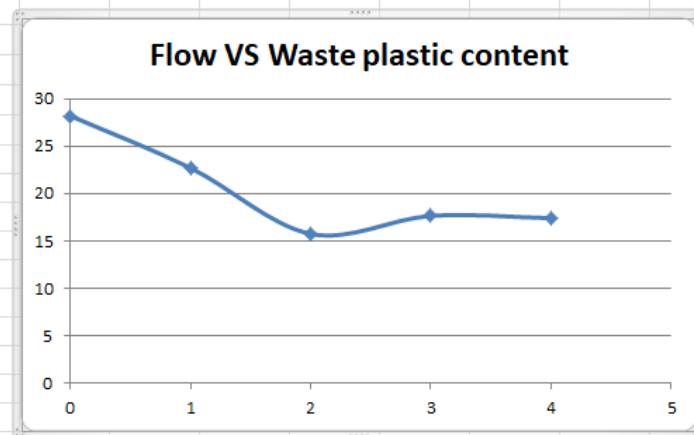


Figure 4.2: A Graph of all samples Flow VS Waste plastic content

According to figure 4.2, when the waste plastic content is 1 % the stability values are high but all the flow values are less than the normal design. This is because when there are

so many voids in between the mineral aggregates, the melted waste plastic can increase the strength of the mixture. But this may increase the plastic properties of bitumen



mixture, it could be a reason to reduce the durability of the mix design. Therefore, the most economical and effective waste plastic content can be considered as 1%.

The selected mix design is typically one of the most economical and sufficient meetings ever established. Mixes with exceptionally high values obtained from the Marshall Stability and abnormally low flow values obtained are often less suitable because under heavy load traffic, pavements of such mixes appear to be rigid and could crack.

Conventionally, the stability for heavy load traffic should (from the Marshall Design requirements) range from 816.38Kg for minimum and above for maximum, and the flow should also range from 8mm for minimum and 14mm for maximum (Dude, 2014). It could therefore be seen in Table 4.2 and it could be seen from the outcome analysis that the entire outcome of the three samples is within the defined limit.

Table 4.2: Typical Marshall Design Criteria (Dude, 2014)

Mix Criteria	Light Traffic Surface & Base		Medium Traffic Surface & Base		Heavy Traffic Surface & Base	
	Min.	Max.	Min.	Max.	Min.	Max.
Compaction (number of blows on each end of the sample)	35		50		75	
Stability (minimum) N	3336 lbs.)	(750)	5338 lbs.)	N (1200)	8006 lbs.)	N (1500)
Flow (0.25 mm (0.01 inch))	8	18	8	16	8	14
Percent Air Voids	3	5	3	5	3	5

CONCLUSION

This study was carried out to investigate the effects of polythene modified bitumen on the properties of hot mix asphalt concrete while providing a robust and cost effective alternative to conventional highway pavement. In the course of the experiment, optimum bitumen content for the asphalt mix was selected based on Asphalt Institute standard. Subsequently, different percentages of modified binder prepared by mixing bitumen with waste polythene were used to prepare asphalt concrete samples. In order to assess stability and flow, the Marshall method of testing was employed and used for five samples (namely Sample A-E).

More so, to observe the effects of the adjusted binder, the samples were evaluated based on flow and stability. Results emanating from asphalt concrete prepared from polythene adjusted binder showed that, properties like bitumen volume, aggregate volume, total aggregate volume, bitumen filled voids and average stability decreases from sample 'A to sample 'E.' As percentages of bitumen were replaced with percentages of polythene, the average flow values observed varied from sample 'A to sample 'E' (i.e. it was observed

that, there was an increment and decrement in the flow values due to the varying percentage of waste plastic added, as such the resistance deformation under heavy wheel loads increases as the flow value decreases and decreases as the flow value increases).

The most economical and satisfactory result was yielded by sample 'B' – as it showed an improvement in the bituminous content when one percentage of polythene is applied. Meanwhile, Sample "E" (which is 1% of Bitumen + 5% of polythene) failed during the experiment because of the low percentage of bitumen applied to the mixture. The failure however, can also be attributed to insufficient binding modifier –bitumen.

It is critical that alternative methods of asphaltic concrete production such as the one mentioned in this paper be used as quickly as possible when considering the national expenditure on both new and rehabilitated pavements, especially when considering the current zero residual life of most of our highways. Therefore, in the interests of expediency, we do not settle for anything simplistic. The moment has arrived when science can be translated to practice and we will step into a new age of long-lasting and cost-



effective pavement. This test method would really help to reduce the demand for bitumen, as polythene can be used to substitute the percentage of bitumen with a defined percentage. As polythene is shown to be a strong binding modifier, the consistency and efficiency of asphalt roads will be increased. Both polythene and bitumen are thermoplastics and are compliant as such.

The polythene additives do not change the chemical structure and nature of the modified bitumen, but instead modify the polythene and alter the bitumen's physical nature. It has been established polythene complements the modified asphalt's adhesive, cohesive and long resistance, which in turn improves the physical characteristics of the aggregate mixture in which the modified bitumen is used.

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