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# Influence of Shredded Waste Water Sachet on Engineering Properties of Asphalt

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**Abstract**

The search for any improvement has always brings about some sort of modification especially if a new discovery has not been made. This research work focused on the potential utilization of waste water sachets in the modification of the engineering properties of asphalt cement (Bitumen) used in the production of Asphaltic concrete.

In achieving this, the samples of waste water sachets were collected from four sachet water producing companies in Ilorin. They were sun dried and later shredded. The bitumen was replaced by shredded waste water sachets by weight at 1 to 10%. Some conventional Laboratory tests were carried out on the unmodified and modified bitumen specimens.

The property of bitumen was strongly affected by the addition of shredded water sachet. The specifications of American Society for Testing and Materials {ASTM} and Government of Federal Republic of Nigeria General Specifications for Roads and Bridges were employed as guides. A modification of 1 – 3 % could be allowed as almost all requirements are met except the Softening Point of 3 % modification that seems to be on the high side. The modification enhances the resistance to permanent deformation, fatigue cracking and cohesion. Further study of the research is encouraged and could involve asphalt concrete production from the modified asphalt cement to investigate the effects.

**Keywords:** Waste water sachets, Bitumen, Modification, Engineering properties.

## 1. Introduction

The current level of urbanization and industrialization across the globe has increased the rate at which wastes are being generated. It has been reported by Hoornweg and Bhada-Tata (2012) that the current global municipal solid waste generation is approximately 1.3 billion tonnes per year and it is projected to almost double by year 2025. The waste generated had been influenced by economic development, degree of industrialization, public habits and local climate. However, the alarming thing is that most countries of the world do not have efficient means of managing the waste. Therefore, there is the need to explore the possibility of recycling the wastes to something useful and not harmful to both human and the environment.

The municipal solid wastes are in different categories: food waste, garden and park waste, paper and cardboard, wood, textiles, nappies, rubber and leather, plastics, metals, glass and others. Some of these wastes are biodegradable and some are not. The plastic and rubber fall into the non biodegradable. They are equally classified as polymers. Polymers of various types had been used successfully in modification of bitumen (Hinishoglu and Agar, 2003, Awwad and Shbeeb, 2007 and Yero and Hainin, 2012). The polymers are classified as plastomers and elastomers. The plastomers include the following: ethylene, vinyl acetate, polyethylene, and so on. They increase the viscosity and stiffness of bitumen at normal service temperatures, however, they do not perform satisfactory when heated and they poor elastic property when used in modifying bitumen. The elastomers include the following: natural rubber, polybutadiene, polyisoprene, and so on (Awwad and Shbeeb, 2007). The elastomers have the ability to return to their original shape when load is removed. They also increase the bitumen viscosity.

According to British Standards; bitumen is defined as a naturally occurring hydrocarbon and the residues obtained from the distillation of petroleum. It is given the same definition in American Standards, with an addition that it must be soluble in Carbon Disulphide ($CS_2$). When the bitumen contains some inert materials or minerals, it is called asphalt.

Airey et al, 2003 investigated the effectiveness of Recycled Low Density Polyethylene (LDPE) Modified Bitumen on Road Pavement. It was discovered that the modified bitumen could resist road failure such as permanent deformation, fatigue cracking and temperature susceptibility. It was also reported that the performance and service life of road are improved. The modified bitumen was obtained from recycled LDPE pellet. The plastomer modified bitumen would be concentrated between 3 to 7% of bitumen (by weight) into two kind of bitumen: soft (160/220) and hard (40/60) penetration grade. The modified bitumen were with a high speed mixer at temperature ranging from $140^0$C to $180^0$C since melting point of the pellet is $111^0$C. The study concluded that the application of recycled LDPE modified bitumen is different in behavior from that of unmodified bitumen and the former has some advantages and could be considered as a suitable material from environmental and economical points of view.

Awwad and Shbeeb (2007) investigation revealed that a modified asphalt mix has a higher stability and void of mineral aggregate percentage, a situation that positively influence the rutting resistance of the asphalt mixture. The air void content gave almost same percentage which was concluded satisfactory to give room for the expansion of asphalt binder to prevent bleeding that would reduce the skid resistance of the pavement and increase rutting susceptibility. The study used the polyethylene as aggregate coating agent rather than modifying bituminous properties of the asphalt binder. Bitumen 60/70 was employed with two types of polyethylene grades: Low Density Polyethylene (LDPE) and High Density Polyethylene (HDPE) in grinded and not grinded forms. The research finally concluded that the use of the polyethylene in asphalt mixture reduces permanent deformation, increase fatigue resistance and provides a better adhesion between the bitumen (asphalt binder) and aggregate.

Airey (2004); investigated the Modification of Road Bitumen using Styrene Butadiene Styrene polymer and found out that the degree of Styrene Butadiene Styrene modification is a function of bitumen source, bitumen-polymer compatibility and polymer concentration. When the polymer concentration and bitumen-polymer compatibility allow a continuous polymer network to be established, modification is provided by a highly elastic network which increases the viscosity, stiffness and elastic response of Polymer Modified Bitumen, particularly at high service temperatures. He concluded however, aging of the Styrene Butadiene Styrene Polymer Modified Bitumen tends to result in a reduction of the molecular size of Styrene Butadiene Styrene copolymer with a decrease in the elastic response of the modified road bitumen.

In Nigeria and most countries of the world, there is high demand for mobility and most of the roads are constructed using Asphaltic concrete whose major cementing material is bitumen and most of the roads are failing before the end of their life span. Therefore, there is high demand for bitumen for production of Asphaltic concrete and need to improve the quality of bitumen that is used in production of Asphaltic concrete. This research therefore focused on the potential utilization of waste water sachets in order to reduce the quantity of the non biodegradable materials in the environment and equally improve the performance of bitumen used in highway construction.

## 2. Materials and Methods

### *2.1 Materials*

Used water sachets were collected from four different sources in Ilorin, Nigeria. The water sachets are HDPE. The sachets were shredded in order to reduce their sizes for easy of melting. The waste water sachets are shown in Figure 1. The bitumen used are 60/70 and 85/100 grades.

### *2.2 Methods*

The basic properties of the waste water sachets were determined in the laboratory. They are density, specific gravity, water absorption and melting point. The bitumen was modified with 1 to 10 percent of the shredded waste water sachets. The modification of the bitumen was done by introducing shredded waste water sachets into hot bitumen at a temperature higher than melting point of the sachets. The modification was done at varied percentages as shown in Table 1 below for both the 60/70 and 85/100 grades bitumen.

The following laboratory tests were carried out on the unmodified bitumen and the modified bitumen. The laboratory tests are penetration, ductility, ring and ball softening point, viscosity, specific gravity, flash and fire points and solubility tests. The tests were carried out in accordance with American society for testing and material (ASTM) standards.

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## 3. Results and Discussion

The results of the properties of the shredded water sachet, the unmodified bitumen (control) and the modified bitumen are presented in Tables below.

### *3.1 Density and Specific gravity of waste water sachet*

The average density of the waste water sachet from three trials is 0.911 g/cm$^3$. The detail is presented in Table 2 below. The average specific gravity is 0.91. These results show that the water sachet is less dense than the two grades of bitumen used for this research but when added at higher temperature, the specific gravity increases with increase in quantity of the water sachet.

### *3.2 Melting temperature and Water absorption of water sachet*

The observed melting point of shredded waste water sachet is 120 $^o$C. This melting is above the softening point of the two grades of bitumen used. This property will enhance the performance of the Asphaltic concrete produced from bitumen modified with the waste water sachets. This will increase the resistance of the Asphaltic concrete to temperature changes especially in the tropical countries. The shredded waste water sachet has water absorption of zero. The mass remain the same when immersed in water for 24 hours. This is an excellent property because the Asphaltic concrete produced is expected to produce an impervious layer for water. This is necessary because the subgrade, subbase and base course layers if constructed with Laterite may be susceptible to swelling when in contact with water.

### *3.3 Properties of Unmodified and Modified Bitumen*

The results of the properties of the unmodified and modified bitumen are presented in Table 3 below. The results of the penetration test shows that only 2 percent by weight of the bitumen can be replaced with the shredded water sachet for the 60/70 grade bitumen. The 80/100 grade bitumen cannot be modified because the values for the penetration tests for all the various modification are below the ASTM and Federal Ministry of Works (FMW) specifications for roads and bridges. It could be observed that the bitumen hardness is being enhanced by the addition of the polymer in increasing order. The more the percentage replacement of the polymer in a specimen, the harder (lesser penetration) it becomes for the two grades of the asphalt cement. This attribute will make the Asphaltic concrete produce from the asphalt cement to have resistance to rutting; permanent deformation by stiffening the asphalt cement rather than making it more elastic. Therefore 1 – 2 % modification could be recommended base on the penetration test

The ductility test results show that addition of the shredded water sachet reduces the ductility property of the asphalt cement. The more the percentage replacement of the shredded water sachet in a specimen, the lesser ductility. However, addition of 1 – 3 percent modification falls above the minimum limit of 100cm at the pull rate of 5 cm/minute for both the 60/70 and 80/100 asphalt grade.

The result in Table 4 showed that the Softening Point increases with increase in percentage modification of asphalt cement. With the minimum requirements of $46^0$C and $42^0$C; and $48^0$C and $45^0$C for 60/70 and 80/100 grades respectively in ASTM and Nigeria specifications respectively, both requirements are satisfied. However Nigeria specification limits the Softening Point to $56^0$C and $52^0$C for the 60/70 and 80/100 grades respectively. This means only 1% modification satisfied the requirement and could be allowed.

The specific gravity results show that the addition of shredded water sachet increases the specific gravity of the modified bitumen in increasing order. The more the percentage replacement of the polymer in a specimen, the higher the specific gravity for the two grades of the asphalt cement. And all with exception of 8-10 % modifications in 60/70 grade satisfied the requirement as given in Nigeria Specification.

The result showed that the viscosity of the modified asphalt cement increases with percentage increase in shredded water sachet. With water bath maintained at $60^0$C, the specimen with 3% and above; and **4%** and above modifications for 60/70 and 80/100 grades respectively could not sink for more than 90 minutes. Comparing this result with Softening Point result, it was noticed that unless the water bath temperature is increased, water might not be able to pass through the plug. Therefore, 1 - 3 percent modification of 80/100 grade with $64^0$C Softening Point that sunk in the water bath is recommended.

The result of the Flash Point reduces with increase in percentage modification. ASTM specification allows a minimum limit of $230^0$C for grades while Nigeria specification requires a minimum of $250^0$C and $225^0$C for 60/70 and 80/100 respectively. Thus, while considering Nigeria specification, 1 – 5 % modification in case of 60/70 grade and 1 - 7% modifications in case of 80/100 grade could be recommended.

A minimum of 99.0% (by weight) solubility in Carbon disulfide is specified in both specifications, though ASTM uses Trichloroethylene as substitute due to extreme flammability of Carbon disulfide. The result showed that 1-5 % modifications could meet this requirement.

## 4. Conclusion

The properties of bitumen were strongly affected by the addition of shredded water sachet as shown in the results of the tests. It has been established that the modification has enhanced the resistance to rutting, cracking and cohesion of the resulting asphalt cement. The asphalt cement can be modified with about 1 to 3 % used shredded water sachet. This will help in a great way in reducing non biodegradable waste in the environment and equally reduce the cost of road construction.

## 5. Recommendation

Further study could also involve asphalt concrete production from the modified bitumen to investigate the effectiveness of the modified bitumen during service.

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Figure 1. Waste water sachet

Figure 2. Sample of Bitumen

**Table 1. Percentage modification of Bitumen with shredded waste water sachet**

| S/N | Sample Index Number | Percentage Modification (%) | Weight of Bitumen (g) | Weight of Shredded water sachet (g) | Total Weight of Specimen (g) |
|---|---|---|---|---|---|
| 1 | 001 | 0 | 100 | 0 | 100 |
| 2 | 002 | 1 | 99 | 1 | 100 |
| 3 | 003 | 2 | 98 | 2 | 100 |
| 4 | 004 | 3 | 97 | 3 | 100 |
| 5 | 005 | 4 | 96 | 4 | 100 |
| 6 | 006 | 5 | 95 | 5 | 100 |
| 7 | 007 | 6 | 94 | 6 | 100 |
| 8 | 008 | 7 | 93 | 7 | 100 |
| 9 | 009 | 8 | 92 | 8 | 100 |
| 10 | 010 | 9 | 01 | 9 | 100 |
| 11 | 011 | 10 | 90 | 10 | 100 |

**Table 2. Density of waste water sachet**

| Parameter | Trial 1 | Trial 1 | Trial 1 |
|---|---|---|---|
| Mass of Water sachet and Container (g) | 10.85 | 10.88 | 6.95 |
| Mass of Container (g) | 5.6 | 5.6 | 5.6 |
| Volume of water after immersed ($cm^3$) | 45.5 | 57 | 58.5 |
| Volume of water before immersed ($cm^3$) | 40 | 51 | 57 |
| Mass of Water sachet (g) | 5.25 | 5.28 | 1.35 |
| Volume water sachet ($cm^3$) | 5.5 | 6.0 | 1.5 |
| Density of Water sachet ($g/cm^3$) | 0.954 | 0.88 | 090 |
| **Average Density ($g/cm^3$)** | **0.911** | | |

**Table 3. Properties of Unmodified and Modified Bitumen**

| Sample Index number | Percentage Modification (%) | Penetration (mm) | | Ductility (cm) | | Softening Temperature (°C) | | Specific gravity | | Viscosity (seconds) | | Flash Point Temperature (°C) | | Solubility in $CS_2$ (% by weight) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 60/70 | 80/100 | 60/70 | 80/100 | 60/70 | 80/100 | 60/70 | 80/100 | 60/70 | 80/100 | 60/70 | 80/100 | 60/70 | 80/100 |
| 001 | 0 | 68 | 87 | 165 | 150 | 50 | 51 | 1.025 | 0.984 | 620 | 619 | 298 | 296 | 100 | 100 |
| 002 | 1 | 64 | 71 | 143 | 141 | 56 | 54 | 1.022 | 0.992 | 1510 | 899 | 290 | 292 | 99.9 | 99.9 |
| 003 | 2 | 62 | 64 | 122 | 109 | 61 | 58 | 1.031 | 0.997 | 2185 | 1112 | 290 | 289 | 99.8 | 99.5 |
| 004 | 3 | 58 | 59 | 107 | 104 | 70 | 64 | 1.039 | 1.012 | >5400 | 1528 | 285 | 284 | 99.6 | 99.4 |
| 005 | 4 | 47 | 51 | 94 | 90 | 72 | 68 | 1.045 | 1,015 | >5400 | >5400 | 280 | 277 | 99.5 | 99.1 |
| 006 | 5 | 30 | 42 | 81 | 78 | 85 | 69 | 1.049 | 1.013 | >5400 | >5400 | 270 | 269 | 99.3 | 99.1 |
| 007 | 6 | 26 | 33 | 73 | 79 | 88 | 74 | 1.053 | 1.024 | >5400 | >5400 | 245 | 241 | 98.9 | 98.7 |
| 008 | 7 | 24 | 22 | 66 | 62 | 92 | 78 | 1.057 | 1.024 | >5400 | >5400 | 222 | 226 | 98.5 | 98.2 |
| 009 | 8 | 21 | 20 | 54 | 53 | 98 | 94 | 1.168 | 1.029 | >5400 | >5400 | 210 | 211 | 98.1 | 98.0 |
| 010 | 9 | 20 | 16 | 48 | 40 | >100 | >100 | 1.067 | 1.034 | >5400 | >5400 | 208 | 198 | 97.8 | 97.3 |
| 011 | 10 | 17 | 14 | 39 | 31 | >100 | >100 | 1.066 | 1.038 | >5400 | >5400 | 195 | 187 | 97.3 | 96.7 |

 

**Figure 3. Pictures Showing the Observation while Cooling.**