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Effect of Coated Aggregates by Plastic Bottles on Bituminous Concrete for Road Pavement

Gaspard Ukwizagira[1], Theogene Ndabamenye[2], Bienvenu Nezerwa[3], Habimana Umukunzi George Bush[4]

[1,4]Assistant lecturer, Department of Civil Engineering, Rwanda polytechnic /IPRC Huye P.O. Box:575 Huye-Rwanda

[2]Lecturer of civil engineering department at Rwanda polytechnic /IPRC Huye P.O. Box:575 Huye-Rwanda, PhD student in Civil Engineering (Structural Option) at Pan Africa university, Institute for Basic Sciences, Technology and Innovation (PAUSTI).

[3]Assistant Lecturer & Head of civil engineering department at Rwanda polytechnic /IPRC Huye P.O. Box:575 Huye-Rwanda,

ABSTRACT: The amount of waste plastics which are released by factories and human activities day to day becomes big problem to human being health as days ahead. The major impact of waste plastics is the environmental pollution, as they do not decompose. This current study, was about to use those waste plastics as Partial replacement of bitumen in bituminous concrete production for road pavement. Different materials like plastics, coarse aggregate, fine aggregate, filler materials and bitumen were used. The plastics used in this research were shredded into small pieces of 5 to 10 mm size and mixed with aggregates in hot state. Tests on aggregates and bitumen for strength and specific gravity were carried out respectively. To examine the behavior of plastics, test specimens were prepared without plastic contents with different bitumen percentage of 4.5%, 5%, 5.5%, 6%, 6.5% for the purpose of finding optimum bitumen binder for normal mix. The optimum bitumen percent for normal bituminous mix is 5.7% and the maximum stability of 9.2875 KN is reported, which is above 8.2 KN as minimum stability accepted. The quantity of bitumen was partially replaced with 3%, 10%, 15% and 20% by plastics. High stability value of 10.89 KN was found at optimum 14.3% plastics. This paper reports that waste plastics produce a good result compare to normal mix.

KEYWORDS: Waste plastics, Bitumen, Aggregates, Stability, Optimum bitumen, Partial replacement

1. INTRODUCTION

1.1. Background

Different waste produced from different industries and from different buildings is a great problem nowadays. These materials pose environmental pollution in the nearby locality because many of them are non-biodegradable. These quantities increase gradually and cost of extracting good quality of nature material is increasing. Traditional soil, stone aggregates, sand, bitumen, cement etc. are used for road construction. Bitumen is mostly used as a binding material for its excellent binding characteristic, waterproofing properties and its low cost as compared to other binders. However, it is widely known to have various types of distresses and does not perform well in aggressive situations. To counter these shortcomings, bitumen is ordinarily assorted with various forms of modifiers such as polymers, crumb rubber (G.Ramesh Kumar, 2017). Alternative materials were expected by scientists for highway construction and one of which is residential waste products. Especially in under developing countries where proper maintenance of road networks is difficult due to lack of funds, heavy control while laying and effective machinery. Better road infrastructure requires less maintenance. Many investigations have found that the strength of paving mixes can be enhanced by using various types of modifiers with bitumen such as crumb rubber, polypropylene, and organic polymers. The aggregate mix is heated and the plastic is effectively coated over the aggregate. This plastic waste coated aggregate is mixed with hot bitumen and the resulted mix is used for road construction. The use of the innovative technology will not only strengthen the road construction but also increase the road life as well as to improve the environment. Plastic roads would be a boon for India's hot and extremely humid climate, where temperatures frequently cross 50°C and torrential rains create havoc, leaving most of the

roads with big potholes (Prince Ghalayan, 2017). Despite the lower quality of coarse recycled concrete aggregates (CRCA) compared to natural aggregates, the physical and mechanical characteristics of CRCA used in the asphalt concrete are improved when the waste material is coated with waste plastic bottles (Alireza Azarhoosh, 2021). The cost of construction has decreased, and there is now a more environmentally responsible way to dispose of the garbage, thanks to the use of plastic wastes to alter the bitumen's characteristics, that will be used to build roads (Bahia, 2001). The term "Optimum Bitumen Content" refers to the value that corresponds to optimum stability, maximum bulk density, and 4% air voids in the Bituminous concrete mix. This number is computed based on the mean bitumen content. The major impact of waste plastic on the environment is that it takes many years to decompose (SavitaDevi, 2016)**.** And also, the current bituminous materials used for road pavement is expensive, so the use of plastic bottles as partially replacement of bituminous will also reduce the cost of paved road. So, this project will come up with solution to the problems stated above, which are environment pollution and high cost of paved road.

1.2. Objectives

1. To evaluate the properties of aggregates to be used in bituminous concrete for road pavement.
2. To assess the stability value and flow value of bituminous concrete mix specimen
3. To compare the experimented results of normal mix with the conventional mix coated aggregates by plastic bottles

2. REVIEW OF RELATED LITERATURE

Recycling and reusing plastic trash are essential for sustainable development. The need of the hour is to utilize waste polythene for various supporting reasons since it is not biodegradable. These materials are made of polymers like polyethylene, polypropylene, and polystyrene. Due to the enhanced performance and elimination of the environmental issue, adding plastic waste to flexible pavement has emerged as a desirable choice. A composite material known as bituminous concrete (BC) is often utilized in construction projects such as road paving, airport terminals, stopover areas, etc. It includes mineral aggregate and black top or bitumen, which are combined, laid down in layers, and then compacted. Plastics fall under the category of lightweight materials; furthermore, they are employed in a range of applications and are mass-produced due to their strength, affordability, and flexibility. According to Gawande, 8310 million metric tons of new plastic have indeed been produced as of 2017. If the plastic waste system does not improve, 12 billion million tons of plastic will be released into the environment by 2050. The author proposed to find the right technique to discard plastic garbage as a serious challenge in today's world since many plastic materials are abandoned after about a year of use and end up in municipal refuse (Gawande, 2012). Plastic debris is also thrown into waterways as a means of disposal, and cause pollution of the atmosphere of seas and rivers, obliterates life of marine, and that creates ocean garbage patches. Along with ocean dumping, drainage from the land, damaged fishing equipment, and plastic debris from ships are also to blame for the presence of plastic in the seas. The 60-80% of trash in the water is made up of plastic garbage (Habib, 2010) . The increase of waste plastic in bitumen increases the properties of aggregate and bitumen. And use of waste plastic in flexible pavements shows good result when compared with conventional flexible pavements. According to Prince Ghalayan research, the stability value of bitumen content with different proportion of waste plastic coating reported an increase of waste plastic in bitumen with an increase of aggregate and bitumen properties.The optimum use of plastic can be 12 % of bitumen based on Marshal Stability test (Prince Ghalayan, 2017). The modified binder mixture containing rubber and/or plastic wastes is more stable than regular bituminous mix. Almost all changed mixtures have higher stability ratings than unmodified mixtures (Hodhod, 2010).

Bitumen is mostly used as a binding material for its excellent binding characteristics, waterproofing properties and low cost as compared to other binders (G.Ramesh Kumar, 2017). However, it is widely known to have various types of distresses that does not perform well in aggressive situations. The addition of 5% and 7 % Polypropylene raises the Marshall stability of control mix by 73% and 85% respectively. This was attributed to the specific gravity of additive (less than 1) which is less than that of bitumen. This serves to penetrate between particles and enhanced the interlock of aggregates, which increases the stability and decreases the flow value. Beyond this percentage of additive content, the stability value decreases (G.Ramesh Kumar, 2017). The use of the innovative technology not only strengthened the road construction but also increased the road life as well as to improve the environment and also creating a source of income. In the research done by Kumar in 2017, aggregates were coated by plastic wastes and the stability has been increased by adding 7% of Waste Plastic and 5% of polypropylene. The flow of mix got decreased by adding 7% of Waste Plastic and 5% of Polypropylene when compared to conventional mix. It is found that the Marshall Quotient almost doubled with respect to the control mixture at 5% Polypropylene content and 7% Waste Plastic content and is found that it is slightly higher with waste plastics additive (G.Ramesh Kumar, 2017). The plastic waste when mixed with bitumen improves desired mechanical properties in particular road mix (K.Sandhiya, 2018). The concept of utilization of waste plastic in the construction of pavement has shown better resistance to water which reduces the stripping of bitumen from aggregate and

effective way to utilize the plastic waste (K.Sandhiya, 2018). Experiments were conducted on cylindrical mold that was prepared by partial replacement of bitumen by plastic waste passing through 4.75mm sieve and retaining at 2.36mm sieve. So, various proportions and hot mix bitumen concrete design was prepared. Bitumen is taken 4.5% of total weight aggregate, and the results shows that with increase of waste plastic in bitumen increases the properties of aggregate and bitumen. Using of waste plastic in flexible pavements shows good result when compared with conventional flexible pavements. The optimum use of plastic can be 10% and 15% of bitumen based on Marshal Stability test (K.Sandhiya, 2018). Performance of roads depends highly on the quality of its components, especially the type and quality of the bitumen and aggregate properties since it determines the most important properties of the asphalt mix (Toth, 2015) **.** Methods used to attain a higher performance road are duly by improving the quality of bitumen which is done by modifying the rheological properties of bitumen by blending it with various products such as plastics and rubber (Vasudevan, 2006). The Marshall stability test shows that the maximum use of 12- 16 % of plastic in the bitumen gives the good and effective results than using of plastic more than 20 % (Vasudevan, 2006). The use of waste plastic in construction of roads gives suitable strength. they give better compaction and reduce air voids because of better binding between bitumen and plastic (Shivani Madhavrao Murshetwad, 2021) . Recycled plastic along with aggregates is used for the better performance of roads. The polymer coating also reduces the voids. This prevents the moisture absorption and oxidation of bitumen by entrapped air. This has resulted in reducing rutting travelling and there is no pothole formation. The roads can withstand heavy traffic and show better durability. The Marshall Stability value of plastic-coated bitumen is 1.1 times greater than the one which is coated normal bitumen mix (U.Sathishi, 2020). After assessing the previous studies it seems like with introduction of plastic there is a great change in stability value of asphalt concrete so we are going to carry out a study for checking the stability value of asphalt concrete by using local materials we have in Rwanda with replacement of bitumen by plastics for 5%,10%,15%,20% in total mix.

3. METHODOLOGY

3.1. Introduction

Normally the materials used for highway construction are bitumen, coarse aggregate fine aggregate and filler materials. This study was to examine the effect of aggregates coated by plastic in bituminous concrete mix with a reduce in bitumen content by that amount of plastic coating aggregates.

3.2. Materials and methods

3.2.1 Plastics

Plastics especially plastic bottles were taken as waste in society and are good binding materials than other binding materials means that they have advanced binding property. They were used as partial replacement of bitumen, quantities of bitumen are replaced at 5%, 10%, 15% and 20% of plastics for reducing quantities of bitumen. Plastics used were collected from private organization, public's zones, nearby garbage, dumping sites, and industrial waste, as well as food containers, etc.

Figure 1: Shredded plastic and aggregates prepared

Figure 2: Aggregates coated by plastics

Plastic used during this research was shredded at small pieces by using scissors, at which its size is ranged from 5mm to 10mm. The shredded plastic was mixed with aggregate heated between 165°C and 180°C for 10 to 15 minutes.

3.2.2 Aggregates

Aggregates is important ingredient in bituminous concrete mix, it is composed with coarse aggregates and fine aggregate**.** They play an important role in pavement construction. In addition, they also influence to a great extent, the load transfer capability of pavements. Hence it is essential that they should be thoroughly tested before using for construction. Not only that aggregates should be strong and durable, but also, they should possess proper shape and size to make the pavement act monolithically (Barksdale, 1991) .

3.2.3. Filler materials

Mineral filler shall consist of finely divided mineral matter such as rock dust including limestone dust, slag dust, hydrated lime, hydraulic cement, or other suitable mineral matter. At the time of use it shall be sufficiently dry to flow freely and essentially free from agglomerations. Filler materials is the aggregate pass in sieve size of 0.075. Therefore, sieve analysis test is to be carried out to find or to identify the percentage (%) of course aggregate, fine aggregate and filler materials.

3.2.4. Bitumen

Bituminous materials or asphalts are extensively used for roadway construction, primarily because of their excellent binding characteristics, water proofing properties and relatively low cost. Bituminous materials consist of bitumen which is either a black or dark colored solid. They are also viscous cementitious substances consisting of chiefly high molecular weight hydrocarbons derived from not only the distillation of petroleum but also the natural asphalt, has adhesive properties, and is soluble in carbon disulphide.

3.2.5 Overall process

Summary of overall process

Waste plastic coated aggregates

Aggregates → Hot aggregates at 170^0c

↓

Waste plastics in form of shredded Poly.Coated aggregate

↓

Hot bitumen at 160^0c

Polymer, Bitumen and aggregate mixture

4. RESULTS AND DISCUSSION

4.1. Material testing

4.1.1. Sieve analysis

Aggregates from GASINGA quarry in NYARUGURU District, RUSENGE Sector were used. The test was carried out in IPRC Huye Civil Engineering Laboratory. Sieves of 4.75 mm and 2.26 mm were used. The required percentage by specifications to pass 4.75 mm and 2.26 mm sieves are ranged from 16 to 36 and from 4 to 19 respectively. The tested aggregates had 34.74% and 17.34% passing 4.75 mm and 2.26mm respectively. It is clear that the obtained values are falling within the specifications.

4.1.2. Aggregates impact value test

The specification for impact value must be less than 30 percent, as per BS 812: Part 103.1: 1985.) so, the impact value found is 17.62% which is less than 30%. Therefore, the sample is good to be used in bituminous mix.

4.1.3. Los Angeles abrasion test results

The specification for Los Angeles abrasion test must be less than 35 percent, so the Los Angeles abrasion test found is 34.6% which is less than 35%. Therefore, the sample is good to be used in bituminous mix.

4.1.4. Specific gravity test on aggregates and bitumen

The specific gravity of 2.85 and 0.993 was found for coarse aggregates and bitumen respectively compare to the specific gravity provided by specifications of 2.5-3 and 0.95-1.05 for coarse aggregates and bitumen respectively. The value of 1.37 specific specific gravity for fine aggregates was found. Therefore, the above materials are good to be used in modified bituminous mix.

4.1.5. Marshall stability test on bituminous concrete

1. Normal Mix

Marshall Test was conducted on five normal mix specimens prepared with bitumen contents of 4.5 percent, 5 percent, 5.5 percent, 6 percent and 6.5 percent respectively. Various Marshall Parameters computed are shown below.

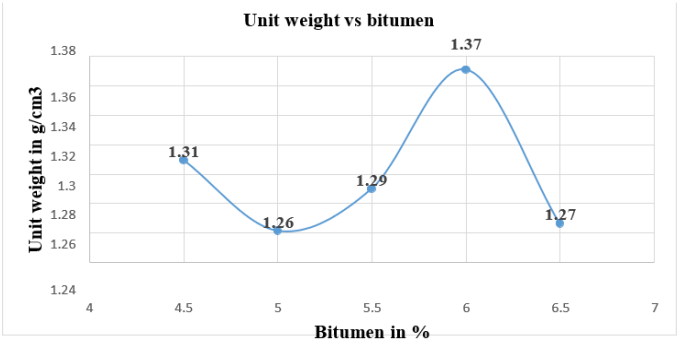

Figure 3: Variation of Unit Weight with Bitumen Content

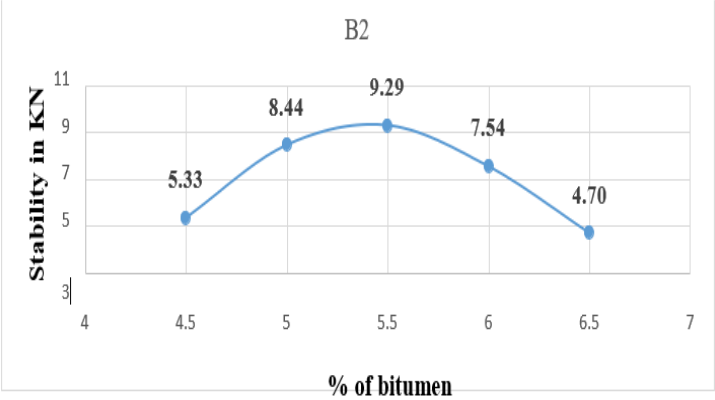

Figure 4: Variation of Stability with Bitumen Content

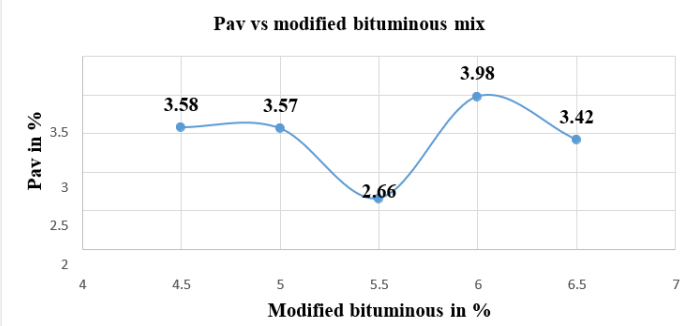

Figure 5: Variation of Percent air voids with Bitumen Content

Optimum binder content (OPC) is selected as the average binder content for maximum density, maximum stability and specified percent air voids in the total mix from figure 4-6.

$$B0 = \frac{B_1 + B_2 + B_3}{3}$$

Thus

B1=5.9 B2=5.1 B3=6.2

Where:

B0 = optimum Bitumen content.

B1 = % asphalt content at maximum unit weight.

B2 = % asphalt content at maximum stability.

B3 = % asphalt content at specified percent air voids in the total mix.

Therefore,

$B0 = \frac{5.9+5.1+6.2}{3}$ and the optimum binder content is 5.7%

The maximum stability found in figure 5 is **9.2875 KN** at **5.5 %** of bitumen already above **8.2 KN** which is minimum stability accepted to the total mix and flow found during this test all is ranged between 2 to 4 which is allowed where high value of flow found is 3.5 mm which found at 5% of bitumen to the total mix.

2. Plastic modified mix

Marshall Test was conducted on four plastic modified mix specimens prepared with varying plastic contents of 5 percent, 10 percent, 15 percent and 20 percent respectively. Various Marshall Parameters computed for plastic modified mix are shown below. Tables and figure below show more results found during laboratory test for modified mix.

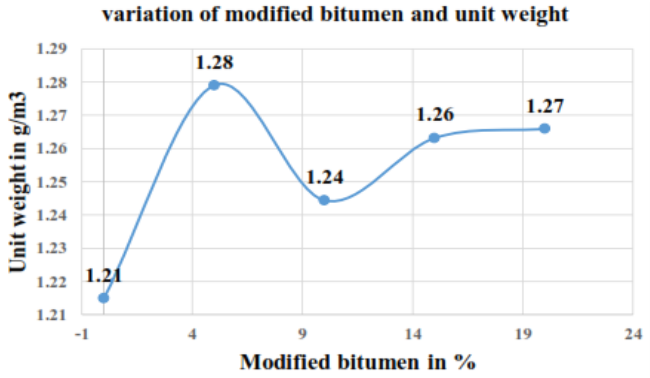

Figure 6:Variation of Unit Weight with modified Bitumen Content

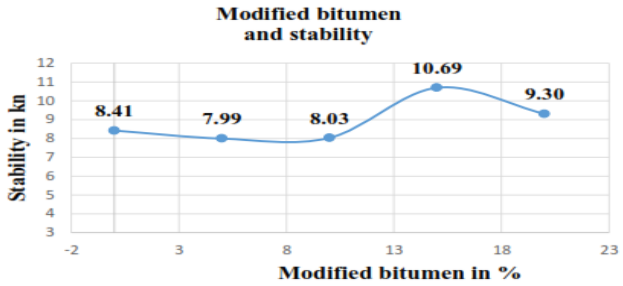

Figure 7:Variation of stability with modified bitumen

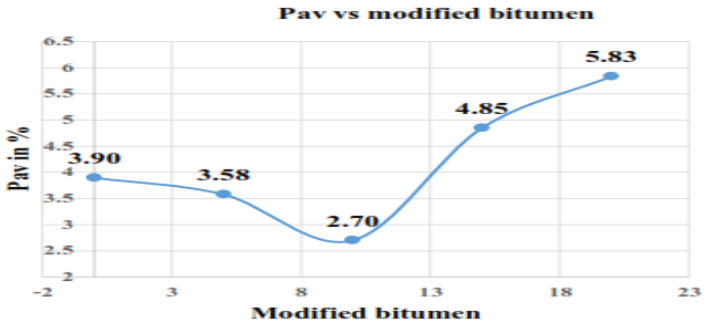

Figure 8:variation of air void with modified Bitumen Content

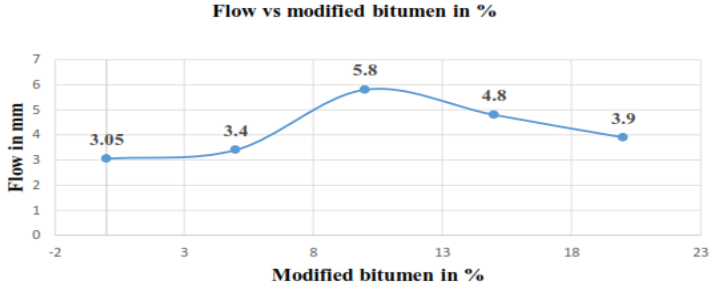

Figure 9: Variation of flow with modified bitumen content

After carrying out laboratory tests and analysis of results **Optimum modified bituminous binder content (OPMBC)** is produced as the average binder content for maximum density, maximum stability and specified percent air voids in the total mix with plastics. Thus, refer to figure 7,8,9 The following modified bitumen content is obtained. These values are used for calculating OPMBC

B1=7 B2=16 B3=20

$$B_0 = \frac{7+16+20}{3} = 14.3\ \%$$

The process of examining the behavior of modified specimen according to 5.7 % as the optimum bitumen percent for normal mix, this quantity of bitumen is replaced partially with (5%,10%,15% and 20%) of plastics. After the stability value are increasing from 9.2875 KN to 10.69 KN a t optimum percent of plastics equal to 14.3%. So, waste plastics produce a good result compare to normal mix.

4. CONCLUSION

After comparing result found on modified mix and normal mix by focusing on its behavior and property, plastic bottles can replace bitumen in bituminous mix for highway construction at 10 % to 15 %. The plastic combined with bitumen and gravel improves the road's performance. The aggregates are coated with a polymer that decreases voids and moisture absorption. Flexible pavement with plastics is more durable than flexible pavement without plastics and can resist heavy traffic. The usage of plastic mix lowers the bitumen concentration by 10% to 15% while increasing the road's strength and performance.

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