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USE OF WASTE PLASTIC BOTTLES AS A MODIFIER IN BITUMINOUS PAVEMENTS

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Abstract— **Disposal of non-biodegradable waste materials has become a serious problem and will cause environmental pollution if they are burnt for apparent disposal. Among these wastes plastic bottles are of main concern. In addition to solving disposal problems the waste plastic bottles in bituminous mixes will improve the properties of mix. Using shredding machine to cut cleaned waste plastic bottles into a size such that it passes through 2-3mm sieve. By heating the aggregate mix the aggregate will be efficiently covered by plastic. Mix resulting from hot bitumen and plastic bottle coated aggregate is used for road construction. The use of the innovative technology will not only increase the road life but also strengthen the road construction as well as will help to get rid of environmental pollution. Plastic roads would be a boon for extremely humid and hot climate, especially where temperatures normally cross 50°C and lashing rains generate chaos, creating big potholes in most of the roads. We have done a comprehensive study on the procedure of using plastic bottles waste in bituminous mixes in our research work and presented the various tests performed on bitumen and aggregates.**

Keywords— **Plastic Waste, Bitumen, Aggregates, Plastic Roads**

I. INTRODUCTION

A material of large molecular weight containing one or more organic polymers, can be molded by its flow, is called as 'Plastic'. Plastics degrade very slowly and are durable, the durability and sturdiness that plastic offers is superior to many materials out there. There are many types of plastics. The thing about plastics is that all of them have varying properties and behavior, some of them can be a great barrier to moisture and gas, some of them are transparent and durable while some are strong enough to stop a bullet i.e. Kevlar . However two main types of plastics based on their deformation are thermosets and thermoplastics (1). A thermoset sets irreversibly when heated. They are beneficial for their strength and durability, and are therefore used mainly in construction applications and automobiles.

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A thermoplastic when exposed to heat it softens and even at room temperature returns to original condition.

Polyethylene Tetraphthalate better known as PET is one of the most common plastics. Chemical formula for PET is (C10H8O4)n. It is mostly used in clothing and making containers for liquid and food. It is the most common type of polyester. Because of its remarkable moisture resisting properties it is used in making food and beverage containers.

It causes hygiene problems especially those associated with stagnation of water and because of its biodegradability. Many experiments have been carried out for solving this problem and to find whether we can reuse these waste plastic bottles productively. Several institutes have carried out experiments and they concluded that the aggregate covered by fine coat of waste plastic, when mixed with the binder is found to give better performance over a period of time, higher resistance to water and higher strength. Thus all types of Waste plastic bottle can be used for surfacing roads.

Constructing roads while adding plastic to bitumen will increase the life of road, its smoothness and also it will make the construction of road environment friendly as well as economically sound. Addition of plastic wastes to bitumen improve certain of bitumen properties and will reduces the plastic shrinkage cracking of wearing course and drying shrinkage to some degree, and experimentally proved that using plastic in road will perform better than those constructed with conventional bitumen and those roads are termed as Plastic Roads.

Plastic road would be a boon for extremely humid and hot climate, will be durable and eco-friendly as well. Thus plastic roads are of supreme advantages as it will aid in reliving the world from all categories of plastic waste.

Plastic might be one of the most useful materials available today but everything has its downside. No doubt many countries have strict regulations limiting the use and production of plastics. The production of plastic has been on a rise and 245 million metric tons of plastic was produced in 2008(2).Plastic is indestructible which means it can't be decomposed chemically completely. Plastic takes indefinite amount of time to decompose completely (3). Huge amounts of plastic wastes are being dumped in the oceans and the seas which pose a serious threat to the aquatic life. The fact that horrifies the most is that plastic wastes will still be present after many years to come which area serious threat for the future generations. This huge accumulation of plastic waste might render the affected parts of seas useless. When plastic is burned it produces several gases and these gases damage the ozone and are injurious to health (4).

As plastic is cheaper therefore many items such as household items, kitchen utensils are made from plastic rather than wood or aluminum. Also Pakistan is not primarily an industrial nation and having no industrial regulation which enables chemical factories to produce plastics overlooking the harmful effects it produces on the environment. Pakistan's plastic industry is growing at an average annual growth rate of 15% (5).

Soft drinks like Pepsi, 7up, Dew are extensively consumed in the world. These soft drinks are filled in plastic bottles which are made up of a polymer called Polyethylene terephthalate or simply PET (6).

If plastic is really enhancing the properties of world roads then now would be the ideal time to utilize plastic in roads and unlock its full potential.

II. RESEARCH OBJECTIVES

Basic aim is to utilize the waste plastic efficiently and in productive way so that it can be valuable to society, however main objectives of current project work are:

- To increase the strength of aggregates by effectively coating them with plastic.
- To increase the strength of Hot Mix Asphalt (HMA) that is its Marshal Stability value.
- To increase the Flow Value of Hot Mix Asphalt by using plastic as a modifier.
- To find the different parameters related to Marshal Test Method such as VMA (Voids in mineral aggregate), VFB (Voids filled with Bitumen), Air Voids (AV) at optimum bitumen.

III. PROPOSED METHODOLOGY

Following Tests were conducted to investigate the properties of the aggregate as well as bitumen using AASHTO standard.

A. **Tests for Aggregate**

- Sieve Analysis of Aggregates
- Specific Gravity & Water Absorption Test
- Aggregate Impact Value Test
- Aggregate Crushing Value
- Flakiness & Elongation Index Test

B. **Tests for Bitumen**

- Penetration Test (ASTM D5/D5M)
- Softening Point Test (ASTM D36-06)
- Ductility Test (ASTM D113-99)
- Viscosity Test(ASTM D4402)
- Flash Point and Fire Point (D3143/D3143M-13)

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Table -1 Aggregate weight distribution used in research

Sample Size (inches)	Percentage Passing (%)	Percentage Retained (%)	Weight Retained (g)
¾"	100%	0%	0
½"	82.5%	17.5%	210
3/8"	70%	12.5%	150
No.4	50%	20%	240
No.8	30%	20%	240
No.16	10%	20%	240
No.200	5.5%	4.5%	54
Pan	—	5.5%	66
		Total Weight	100

C. Sample preparation

Aggregate Gradation B was adopted along with Penetration Grade 60/70 bitumen to design the Marshall samples. Different specimens were prepared by varying the amount of bitumen with an increment of .5%, to select the Optimum Bitumen Content

Fig. 1. Marshal Molds at different percentages of bitumen

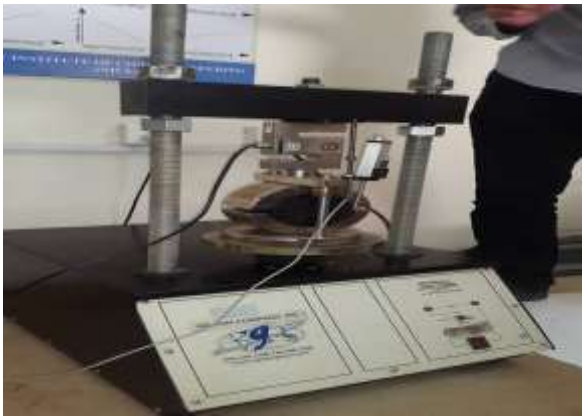

Fig. 2. Marshall Stability and Flow Test

IV. EXPERIMENTS AND RESULTS

The purpose of this research was to find out the effects of shredded plastic on aggregate properties. The results of tests carried out on plastic coated aggregate support the findings of the previous research which stated that coating aggregate with plastic enhances its strength properties. From our research we found out that increase in plastic content was inversely related to Impact, Crushing and Abrasion values.

Increasing the plastic content decreases these values, improving the quality of aggregates. However, beyond a certain limit of plastic content, there is no further decrease in these values. This optimum plastic content was found out to be 9% by weight of aggregate, which is quite close to that of previous researches.

A. Aggregate Impact Value

Results showed that as the plastic contents increases, aggregate impact value decreases. The value continues to decrease till the optimum plastic content which was found to be 9% of plastic by weight of aggregate. Beyond this value, there is no further decrease in Impact Value. Impact Value decreased from 20.95 % to 11.91 % proving that coating aggregate with plastic improved its toughness and ability to resist impact loading.

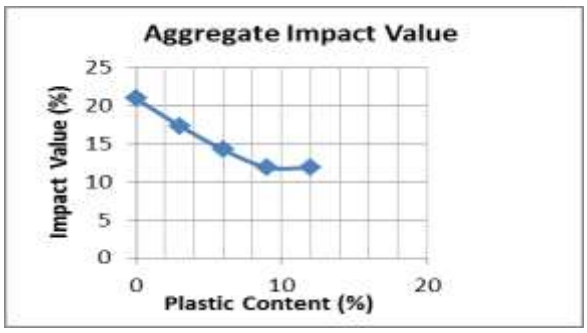

Fig. 3. Variation of Impact Value with Plastic Content

B. Crushing Value of Aggregate

Similar results were observed with the Crushing Value of aggregate. Increase in plastic content decreased the crushing value. However, percentages decrease was less between 6 to 9% beyond which there was no decrease in Crushing Value. Crushing Value dropped from 21.34 to 14.14 %, justifying that coating the aggregate with plastic increases its strength and making it strong enough to bear traffic loads.

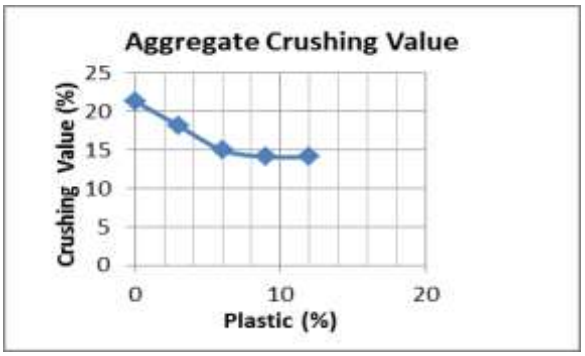

Fig. 4. Variation of Crushing Value with Plastic Content

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C. Los Angeles Abrasion Value

With an increase was a decrease in abrasion value. This could be seen from the graph that the abrasion value reduced from 20.16% to 10.84%. Beyond the optimum 9% of plastic content, abrasion value remained constant. Thus, coating aggregates with plastic enhances their ability to sustain wear and tear under wheel loads.

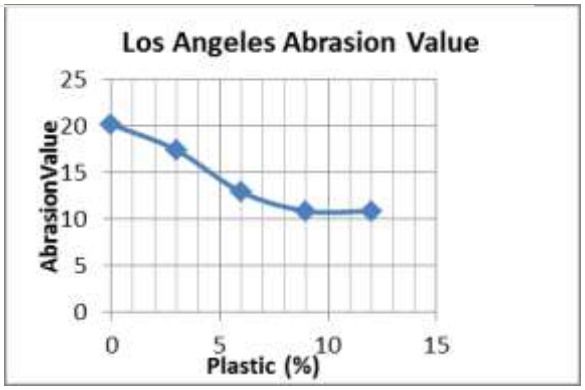

Fig 5. Variation of Abrasion Value with Plastic Content

D. Marshall Stability Value

The stability value increased till the optimum value of 4 % of bitumen. Further increase in bitumen content caused stability value to decrease. Maximum stability came out to be 11.739 KN.

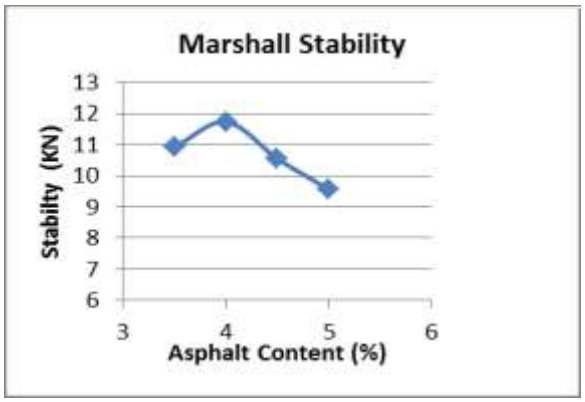

Fig. 6. Stability Value vs. Asphalt Content

E. Flow Value

As the asphalt content increases, flow value increases. Although flow should have been minimum at 4 % asphalt content since stability is maximum, yet it lies in the required range of 2-4 mm. This is because stability and flow are inversely related as shown by the results. At 5 % bitumen, stability value was minimum while flow value is maximum, exceeding the specified range.

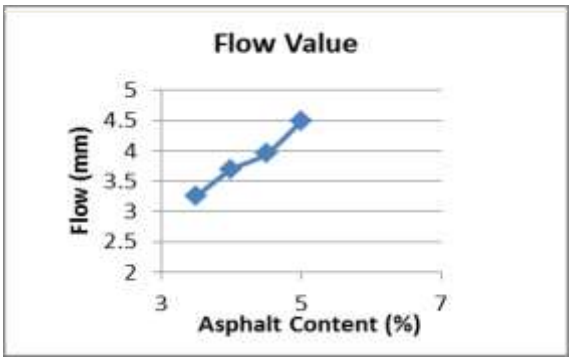

Fig. 7. Flow Value vs. Asphalt Content

F. Air Voids (Va)

The relation is quite simple, as the asphalt content increases percentage of air voids decreases. This is because more intergranular voids get filled with bitumen therefore reducing the volume of air voids present. Bitumen content of 4, 4.5 and 5% fulfilled the criteria of 3-5% of air voids.

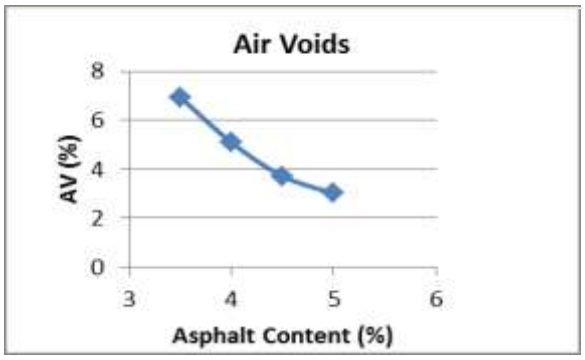

Fig. 8. Air Voids vs Asphalt Content

G. Voids in Mineral Aggregate (VMA)

As the asphalt content increases, voids in mineral aggregate decrease. This is due to the fact that more bitumen is available to coat the aggregate particles. The value continues to decrease till the optimum value of 4.5% which shows that all the aggregate particles have been coated completely.

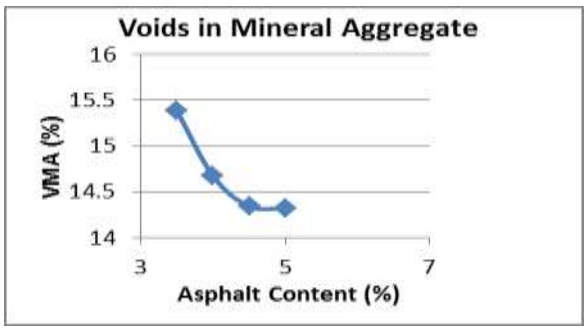

Fig. 9. VMA vs. Asphalt Content

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H. Voids Filled with Bitumen (VFA)

The relation between asphalt content and voids filled with bitumen is directly related. With an increase in percentage of asphalt, VFA increases. The reason being, more effective bitumen is available to fill the voids. Asphalt content of 3.5% fails to meet the criteria of 65% of VFA.

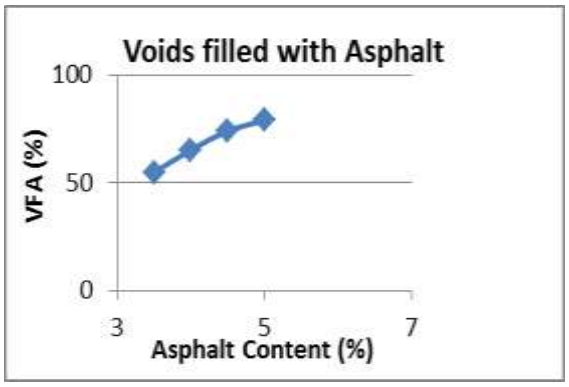

Fig.10. VFA vs. Asphalt Content

Optimum Bitumen Content (OBC)

Optimum Bitumen Content (OBC) is that percentage of bitumen that corresponds with 4% of Air Voids. According to our results OBC came out to be 4.2% by weight of aggregate. Other parameters that are consistent with this value of OBC are:

Table -2 Marshall Parameters at OBC

Marshall Stability	**11.1 KN**
Flow	**3.75 mm**
Voids in Mineral Aggregate (VMA)	**14.5%**
Voids Filled with Asphalt (VFA)	**70%**

I. Plastic Coated Specimen

Optimum values of each modifier, that is plastic and bitumen were used for this sample. 9% plastic and 4.2% bitumen were added and mixed to make this specimen. Three samples were made and the average results are shown below:

Table -3 Marshal Parameters at OPC and OBC

Marshall Stability	**15.21 KN**
Flow	**4.1 mm**
Air Voids	**3.84%**
Voids in Mineral Aggregate (VMA)	**14.3%**
Voids Filled with Bitumen (VFA)	**68.6%**

The results show an increase in Marshal Stability Value by 27% when compared with sample without plastic. Flow value also increased and slightly exceeded the limit of 4mm.This result is an indication of better adhesion provided by waste plastic between aggregate and asphalt. The increase in Flow Value might be due decrease in internal friction by addition of waste plastic into the mixture. Percentage of air voids, voids in mineral aggregate and voids filled with bitumen decreased with the addition of plastic. Decrease in air voids prevents the absorption of moisture and oxidation of bitumen due to the trapped air. Hence, plastic has the properties of a good binder and could be used by replacing a specific amount of asphalt binder with it. Further testing is required in this area to find out the amount of binder that could be replaced.

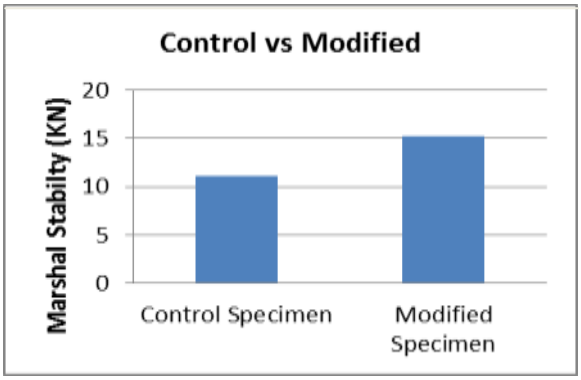

Fig. 11. Stability Value Comparison

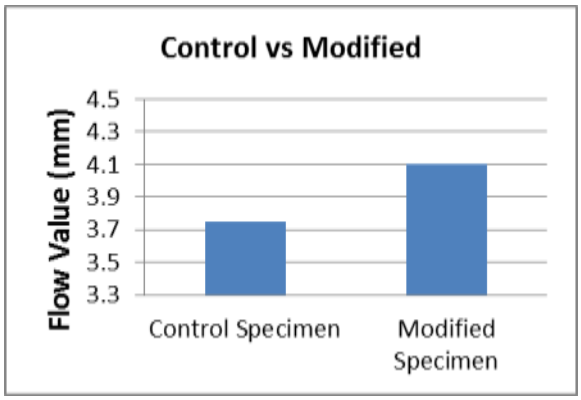

Fig.12. Flow Value Comparison

V. CONCLUSIONS

The focus of this research was to analyze the effect of waste plastic bottles on asphaltic pavements. A lot of conclusions were drawn and there are further recommendations to broaden the scope of this area of research.

Control specimen had an Aggregate Impact Value of 20.95%. It decreased to 11.91% for plastic percentage of 9%. So, there was a 43.15% decrease in impact value which means an increase aggregate's toughness and resistance to impact loading.

Aggregate Crushing Value reduced from 21.34% to 14.14%. Value reduced by 33.74% at plastic percentage of 9%. This is an indication of aggregate, strong enough to bear traffic loads.

Los Angeles Abrasion Value decreased from 20.16% to 10.84%. This value reduced by 46.23%, indicating an increase in the ability of aggregate to resist wear and tear.

Marshal Stability and Flow Values of control specimen came out to be 11.1 KN and 3.75mm respectively. VMA was 14.5% and VFA was 70% at 4% air voids.

Marshal Stability Value increased to 15.21 KN for plastic coated specimen. This value increased by 27.02% compared with the conventional mixture. Increase stability Value means stronger and greater load bearing pavements.

Flow Value also increased to 4.1 mm due to decrease in internal friction and increase in flexibility by addition of waste plastic.

Percentage of Air Voids, Voids in Mineral Aggregate and Voids Filled with Bitumen, all lied within the permissible ranges and adhered to the ASTM specifications.

Decrease in Air Voids and Voids filled with bitumen showed that waste plastic could replace the need of bitumen, by some amount. However, detailed study and testing needs to be carried out for that purpose.

In order to enhance the properties of low quality or weak aggregate, waste plastic bottles could be used to coat them with plastic, thereby increasing their strength, durability and stiffness. This plastic could also be added in the mix for flexible pavements that have better strength, durability and flexibility. Waste plastic when used for this purpose would help in easing the burden on environment and will lead towards a greener and cleaner Pakistan.

Our recommendations for future study relating to this topic are:

Analyzing the properties of bitumen by adding shredded waste plastic bottles in it.

Varying the amount of plastic and bitumen to determine the content of bitumen that could be replaced by plastic.

Estimating the amount of money saved due the reduced amount of bitumen used and reduction in waste production by the use of plastic.

Analyze the effect of plastic coating on the Stiffness and Fatigue life of asphalt mixtures.

Using Super Pave Mix design and comparing the results with conventional method.

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