Effect of Waste Polyethylene Bags on Bitumen and Asphalt

Jazib Bashir Shaikh[1], Engr. Abdul Raqeeb Memon[1], Zubair Ahmed[1], Abdul Qadir Memon[1], Abdul Rehman Kori[1], Ismail Siyal[1*]

[1]*Mehran UET-Jamshoro, Sindh, Pakistan*

Abstract: **Plastics are everywhere in today's lifestyle and are growing rapidly throughout particularly in a developing country like Pakistan. As these are non-biode-gradable there is a major problem posed to the society with regard to the management of these solid wastes. Low density polyethylene (LDPE) has been found to be a good modifier of bitumen. Even, the reclaimed polyethylene originally made of LDPE has been observed to modify bitumen. On the other hand, throwing away the used polyethylene materials in big numbers remains a prevailing problem across the country. Thus, this study was made to examine the impact of polythene on the properties of asphalt concrete. Polythene was mixed in binder modifier in grinded form. The bitumen that would be used for the preparation of asphalt concrete mix was introduced to a mixture by melting. The method used was Marshall Mix design method to test the modified mixture properties. 18 samples were prepared in total (03 samples for each proportion). Six proportions of polyethylene by weight of the optimum binder content were selected to be tested (0%, 0.5%, 1.0%, 2.0%, 3.0% and 4.0%). The properties tested include Ductility, softening point, specific gravity, flash and fire point, penetration test, bulk density, stability and flow of the concrete mix. The proportion of the modifier was taken as 4.0%. The findings of this study tells us that polythene modifier increases the stability and other basic properties of bitumen to a considerable extent, thus polyethylene bags can be used as modifier in asphalt concrete mixes.**

Keywords: **Asphalt Mixture, Bituminous Binder, Bulk Density, Flow, Stability, Waste Polythene.**

I. INTRODUCTION

About 90% highways in Pakistan are asphalt concrete pavements. The construction and maintenance of these pavements require large amounts of aggregates and mineral fillers, which typically account for nearly 95% of the asphalt concrete. The increase of civil infrastructures has led to a fast decrease of available natural resources, and seeking for other alternative is crucial. Recycling aggregates or fillers from the construction and demolition (C&D) waste is a preferable one. It is not only economically viable but also environmental friendly. Plastic is a material that contains one or more organic polymer of large molecular weight, solid in its finished stated and it also can flow under specific state. It is durable and has very slow process of degradation. Plastic can be divided into two major categories which are thermoses and thermoplastics. Thermos is a condition of plastic when it is in solid form. This type of plastic is very useful in their durability and strength. Nowadays, the use of the plastic bag with several of sizes has been growing day by day. This development led to an increase in the amount of waste. This hazardous waste is disposed by land filling or incineration. Waste plastic does not undergo bio-decomposition. Therefore, whether it is land filled or incinerated, it still pollutes the land and the atmosphere. However, the discovery of the binding property of plastic in its molten state which can be used in road laying has help to well manage this waste plastic. Since, the topic of our thesis is "Effect of Waste Polyethylene Bags on the properties of Bitumen and Asphalt", based on Marshall Stability method. For this regard, we have collected the required material.

The design of asphalt paving mix, with other engineering materials design is largely a matter of selecting and proportioning materials to obtain the desired properties in the finished construction. The overall objective for the design of asphalt paving mix is to determine an economical blend and gradation of aggregates (within the limits of the project specifications) and asphalt that yield a mix having:

1. Sufficient asphalt to ensure a durable pavement
2. Sufficient mix stability to satisfy the demand of traffic without distortion or displacement
3. Sufficient voids in the total compacted mix to allow for slight amount of additional compaction under traffic loading without flushing, bleeding and loss of stability, yet low enough to keep out harmful air and moisture.
4. Sufficient workability to per efficient placement of the mix without segregation.

II. MATERIALS AND METHODS

The materials used for the purpose of this research were Waste Polythene bags, Bitumen (60/70), and Aggregates.

A. Aggregates

It is a broad category of coarse to medium grained particulate material used in Construction, including sand, gravel, crushed stone, slag, recycled concrete and geo synthetic aggregates. Aggregates are the most mined materials in the world. The amount of mineral aggregate in asphalt paving mixtures is generally 90-95% by weight and 75- 85% by volume. Mineral aggregate is primarily responsible for the load supporting capacity of pavement; accordingly, asphalt paving performance is heavily influenced by aggregate.

B. Bitumen

Bitumen, an oil based substance, is a semi-solid hydrocarbon product produced by removing lighter fraction from crude oil during the refining process. It is a sticky material - black in color - that is mixture of organic liquids that are highly viscous in nature. Bitumen, in its natural form, is a tar like form of petroleum which makes it so thick and heavy so that it is heated before its individual use, or with other substance to form another material for desired use. However, refined bitumen is the residual fraction, present at bottom-side, obtained by fractional distillation of crude oil, thus, having the highest boiling point – say 525oC.

C. Plastic Bags

A plastic bag, polybag, or pouch is a type of container made of thin, flexible, plastic film, nonwoven fabric, or plastic textile. Plastic bags are used for containing and transporting goods such as foods, produce, powders, ice, magazines, chemicals, and waste. It is a common form of packaging. It is made from Polyethylene or Polythene. Most plastic bags are heat sealed together. Some are bonded with adhesives or are stitched. Many countries are introducing legislation to phase-out lightweight plastic bags.

D. *Methodology*

a) Selection and Gradation of Aggregate: Traditionally, paving mixtures ranging from coarse to fine are permitted to use as the gradation requirements are very broad. The coarse aggregates used were crushed stones and stone dust was used as filler material, all collected from the NKB Mix Plant in Jamshoro. Sieve analysis was done manually. The sizes of sieves ranged between 0.075mm to 37.5mm. The weight that had retained on each sieve was recorded and measured. Percentage passing through each size of the sieve was also calculated. In order to know if the chosen aggregates lie within the specified standard envelop, a Graph of percentage weight passing against sieve size was plotted. Trial mixes were made to combine the fine and coarse aggregates to obtain an all-in combined grading satisfying the specification. 5.3.

b) Preparation of Modified Bitumen: The unmodified bitumen was collected from the Kotri Site. It was then modified by adding different percentages (0.5%, 1%, 2%, 3%, and 4%) of powdered form of plastic bags. The powdered form of plastic bags was prepared through following process: Waste polythene bags were handpicked from the cafeterias and students' hostels within the Mehran UET, Jamshoro. The collected wastes were arranged, de-dusted, rinsed when necessary and dried in sun for some days until all of them were completely dry. The sun dried plastic bags were burned enormously until the plastic bags were converted into a wax type material known as Plastic Wax. That wax was collected in a steel container and was allowed to cool down at the room temperature. After few minutes of cooling, the plastic wax was converted into a solid matter. Generally, polymer utilization in asphalt concrete could be in form of aggregate or binder modifier. For the purpose of this research, polythene bag material was used as binder modifier. After the burning and cooling of plastic wax, the solid plastic wax was converted into a powder form by crushing it in the Impact Testing Machine. The plastic wax was crushed until the size between 0.3mm to 2.36mm was obtained. This crushed material was then sieved through the Sieves of respective sizes i-e 0.3mm and 2.36mm. Material passing through 2.36mm was taken for the research purpose and the material rested on 2.36mm was neglected. The reason for the selection of this size was to increase the contact of bitumen to its surface area during blending. The modified bitumen was prepared by heating bitumen with crushed plastic wax of sizes between 0.3mm and 2.36mm. Five proportions of polythene content (0.5, 1.0, 2.0, 3.0, and 4.0%) by weight of bitumen were considered. The continuous steering of the mixture was being done in High Shear Mixer until a uniform blend was achieved. The temperature of bitumen was maintained at 160-180oC with the help of Hot Plate. The High Shear Agitators rotational velocity was kept constant that was 8 revolutions/sec. The mixture was steered for 20 minutes.

c) Basic Tests on Modified and Unmodified Bitumen: The basic tests performed for the Modified and Unmodified Bitumen are: • Penetration Test • Specific Gravity • Flash And Fire Point • Ductility Test • Softening Point. These tests were performed for Unmodified and all other five proportions of Modified Bitumen (0.5, 1.0, 2.0, 3.0, and 4.0%). 61 The following graphs were plotted: a) Penetration vs. Plastic wax content b) Specific Gravity vs. Plastic wax content c) Flash and Fire Point vs. Plastic wax content d) Ductility vs. Plastic wax content e) Softening Point vs. Plastic wax content.

d) Marshall Stability and Marshall Flow Tests: The Marshall Mix Design is very necessary to carry out in order to determine the effect on the properties of asphalt concrete due to Modified Binder. For designing hot asphalt concrete mixtures, the method employed was Marshall Mix Design Method by using manual compaction. The mix design was carried at the bituminous content of 4.0%. 18 samples each of 1200 gram in weight according to proposed mix design were designed. 3 samples for each proportion of Modified and Unmodified bitumen were prepared. The average values of three samples for the Bulk Specific Gravity, Marshall Stability and Flow properties were determined. 75-blows on each side were given to all the examined asphalt concrete mixtures as per the standard. In accordance with AASHTO T 166, the Density and Bulk Specific Gravity of specimens of compacted asphalt mixtures were determined. The following graphs were plotted: a) Bulk density content vs. Plastic wax content b) Marshall Stability vs. Plastic wax content c) Flow vs. Plastic wax content.

III. CALCULATIONS AND RESULTS

a) Selection and gradation of aggregate:

In order to create aggregate distribution in asphalt mixtures, aggregate grading curves were performed according to NHA Specifications. From the table and graph given below, we can clearly see that the chosen aggregates satisfactorily lie in the specified standard envelope.

Sieve Size (mm)	Percent Passing by Weight		Weight Retained	Cumulative Weight Retained	Cumulative Percentage Retained	Percentage Passing
	Min Limit (%)	Max Limit (%)	(gm)	(gm)	(%)	(%)
37.5	-	-	-	-	-	-
25	100	100	0	0	100	**100**
19	90	100	0	0	100	**100**
12.5	75	90	159	159	15.9	**84.1**
9.5	56	70	159.1	318.1	31.81	**68.19**
4.75	35	50	229.1	547.2	54.72	**45.28**
2.38	23	35	138.4	685.6	68.56	**31.44**
1.18	5	12	203.5	889.1	88.91	**11.09**
0.075	2	8	81.2	970.3	97.03	**2.97**
Pan	-	-	30.2	1000.5	100	**0**

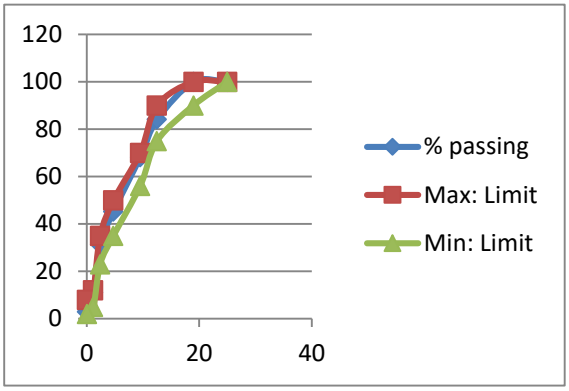


Fig. 1

b) Softening point:

The Softening Point test was performed as per AASHTO Designation T 53 — 74. It is observed from the results that Softening Point of the bitumen increases with the increase in content of Plastic.

Effect on Softening Point of Bitumen

S. No	Percentage Added Of Plastic Bags (%)	Softening Point (ºC)
1.	0	46
2.	0.5	50
3.	1.0	51
4.	2.0	54
5.	3.0	61
6.	4.0	63

c) Ductility:

AASHTO Designation T 51 — 74 was used for the performance of Ductility Test. The results showed that the Ductility of the Bitumen is increased as increase in percentage of Plastic.

Effect on Ductility of Bitumen

S. No	Percentage Added Of Plastic Bags (%)	Ductility(cm)
1.	0	135
2.	0.5	140
3.	1.0	140
4.	2.0	140
5.	3.0	140
6.	4.0	140

d) Flash and Fire:

The Flash and Fire point test was performed as per AASHTO Designation T 48 — 74. The observed values from this test showed no regular trend however maximum flash and fire points were observed at the content of 2.0% of the Plastic bags.

Effect on Flash and Fire Point of Bitumen

S. No	Percentage Added Of Plastic Bags (%)	Flash And Fire Point (ºC)
1.	0	330 and 365
2.	0.5	305 and 350
3.	1.0	308 and 352
4.	2.0	340 and 375
5.	3.0	335 and 370
6.	4.0	315 and 355

e) Penetration:

This test was performed as per AASTO Designation: 49-74. It is observed that the Penetration decreases up to 2.0% content of Plastic Bags, after which it increases.

% Added of Plastic	0	0.5	1.0	2.0	3.0	4.0
Avg. Penetration (mm)	67	60	59	39	43	57

f) Specific Gravity:

The Specific gravity test was performed as per AASHTO T 228 — 68. It can be seen from the results that Specific Gravity showed no regular trend. The maximum value of Specific Gravity was observed at 3.0% content of Plastic Bags.

% Added of Plastic	0	0.5	1.0	2.0	3.0	4.0
Avg. Bulk S.G	2.3	2.3	2.296	2.286	2.26	2.29

g) Bulk Specific Gravity:

$$S.G = \frac{W1}{W3 - W2}$$

Where,

W_1 = Sample Weight in Air

W_2 = Sample Weight in Water

W_3 = Surface Saturated Dry (S.S.D) Weight of Sample

It is found from this test that the average bulk specific gravity decreases up to 3.0% of Plastic Bags, after which it increases.

% Added of Plastic	0	0.5	1.0	2.0	3.0	4.0
Avg. Bulk S.G	2.3	2.3	2.296	2.286	2.26	2.29

h) Marshall Stability:

The formula to calculate Marshall Stability Value is given below:

Stability Value = (DGR x Proving Ring Constant) kg
Where,
DGR = Dial Gauge Reading
Proving Ring Constant = 13 (For MKS system)

It is obvious from the results that the Marshall Stability certainly increases at the content of 0.5% of Plastic Bags later than it decreases continuously.

% Added of Plastic	0	0.5	1.0	2.0	3.0	4.0
Avg Marshall Stability (Kg)	1287	1560	1278	1136	915	828

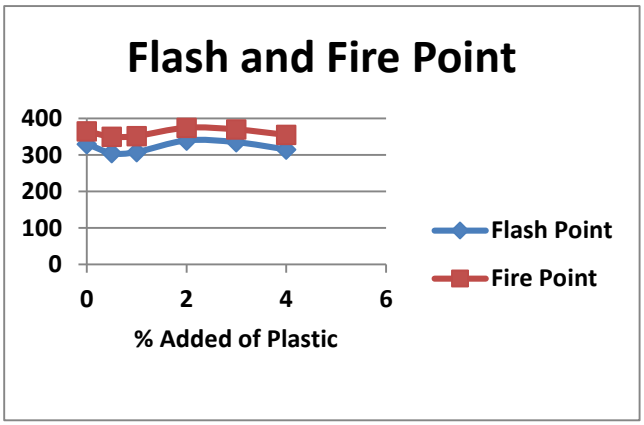
i) Marshal Flow

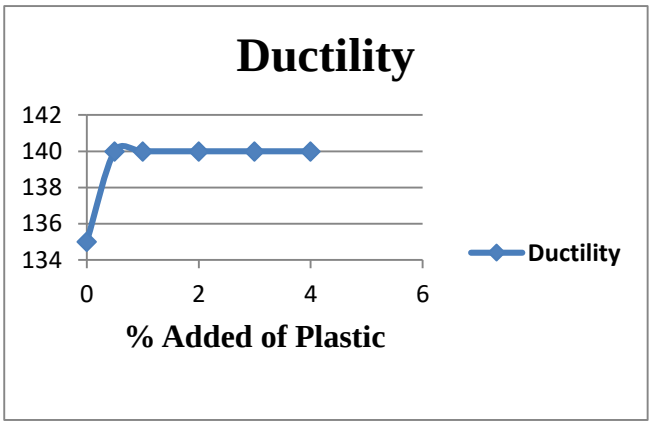
The formula to calculate Marshall Flow Value is given below:

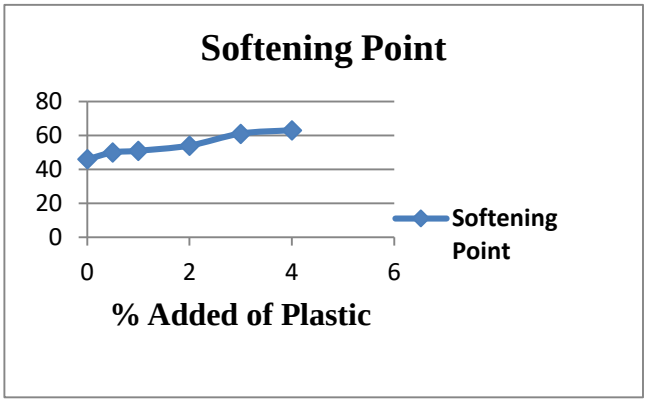
Flow Value = (DGR x Proving Ring Constant) 0.25mm
Where,
DGR = Dial Gauge Reading
Proving Ring Constant = 0.04

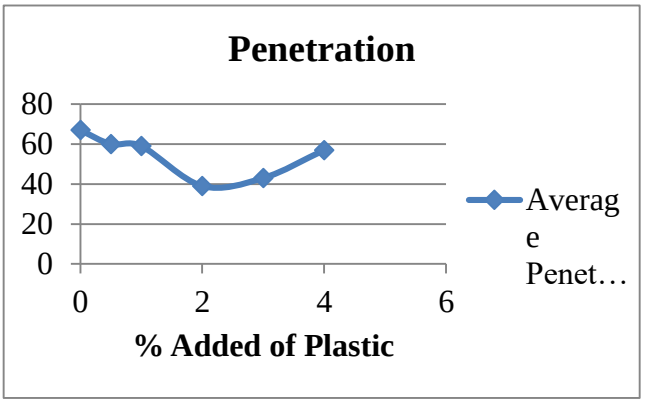
It is observed from the following results that no regular trend was obtained for Marshall Flow Values. However the maximum flow was obtained at 3.0% content of plastic bags, after which it decreases.

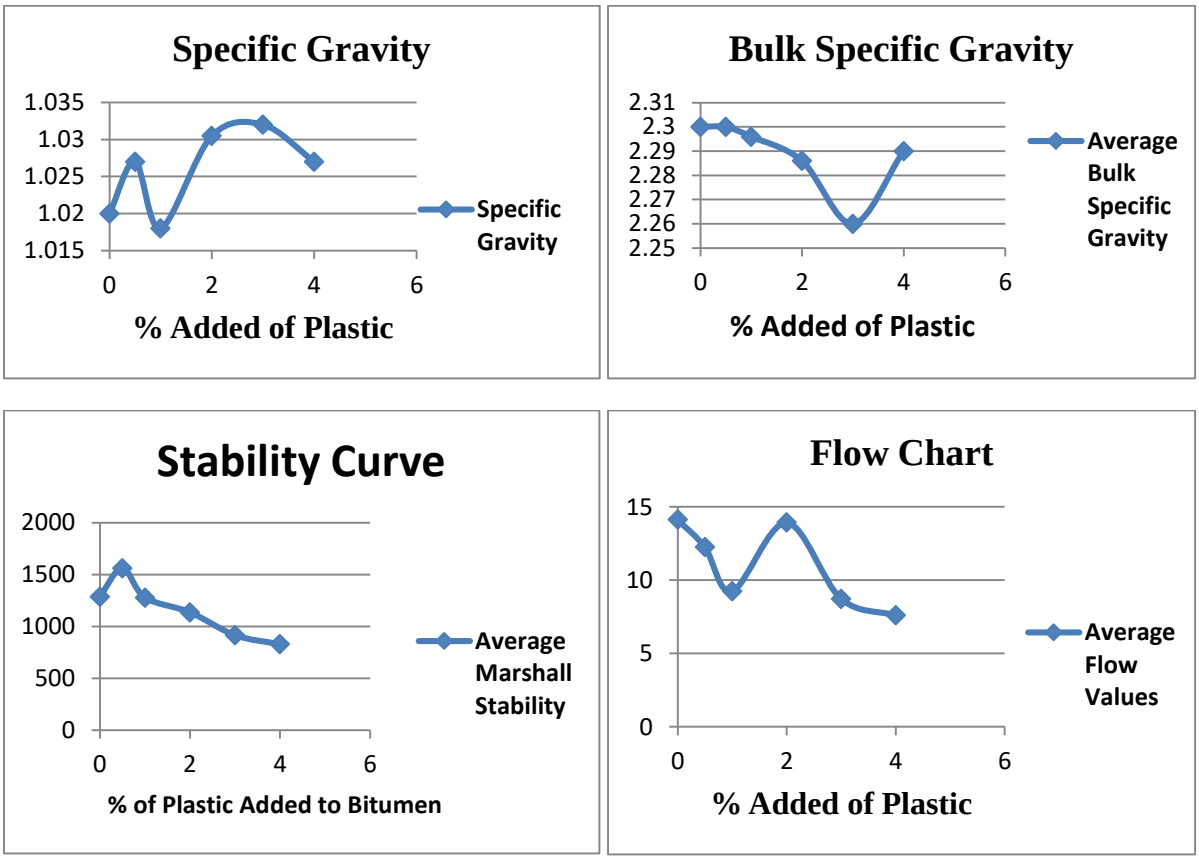
% Added of Plastic	0	0.5	1.0	2.0	3.0	4.0
Avg. Flow Value (0.25 mm)	14.13	12.26	9.24	13.93	8.73	7.6











Effect on the General Properties of Bitumen

IV. CONCLUSION

In this study, mixes are prepared with 60/70 grade bitumen used as a binder. The effect of addition of waste polyethylene in form plastic wax in the bituminous mixes has been studied by varying concentrations of polyethylene from 0% to 4.0%. Following conclusions can be drawn based on the results obtained in the study: It can be concluded from the results that the Marshall Stability certainly increases at the content of 0.5% of Plastic Bags after which the Stability decreases on further increase of Plastic content.

- The maximum Flow was obtained at 3.0% content of plastic bags, after which it decreases.
- It is found from this study that the Average Bulk Specific Gravity decreases up to a certain limit of Plastic Content, after which it increases. We can also conclude from the results that Softening Point of the bitumen increases with the increase in content of Plastic.
- The flash and fire point values were improved at the content of 2.0% of the Plastic bags. Thus it can be used in Hot Climatic regions.
- Based on the results of investigation of Plastic Modified Bitumen, it can be noted that, additive by 2.0% decreases Penetration, but the further addition of Plastic Wax results in the increased value of Penetration.
- The Specific Gravity showed no regular trend. However, the maximum value of Specific Gravity was observed at 3.0% content of Plastic Bags. 90 When all results are considered together, it can be concluded that, in the modification of Bitumen with Waste Polyethylene Bags results in improved engineering properties of bituminous mixes. Hence, this investigation explores not only in utilizing most beneficially, the waste plastics, but also provides an opportunity in resulting in improved pavement material in surface courses thus making it more durable. Another thing that must be kept in mind is that in order to get the Plastic Wax, we need to ignite the waste plastic bags, which would consequently result in environmental pollution. So, burning of plastic bags must be carried under very controlled environment.

V. RECOMMENDATIONS

- In order to verify the results and conclusions of this research, more research study is needed. Many Engineering properties such as Marshall Properties i.e Bulk Specific Gravity, Stability and Flow, Softening, Penetration, Specific Gravity, Flash and Fire point and Ductility have been studied in this investigation by using only 60/70 grade bitumen

with waste Polyethylene. However, some of the properties such as fatigue properties, resistance to rutting, dynamic indirect tensile strength characteristics, dynamic creep behavior, air voids and void filled aggregates needed to be investigated.

- In present study polyethylene is added to them mix in dry mixing process. Polyethylene can also be used for bitumen modification by wet mixing process and comparisons can be made.
- Combination of paving mixes formed with other types of plastic wastes which are largely available, wastes to replace conventional fine aggregates and filler an different types of binders including modified binders, shall be tried to explore enough scope of finding suitable materials for paving mixes in the event of present demanding situations.
- Moreover, demonstration projects need to derive trustworthy estimates of the importance and effects of the polyethylene smodified asphalt.

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