“Effectivness of waste polythene bags modified bitumen mixes and their comparative Economical Analysis”

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Abstract— In Pakistan Bituminous Concrete (BC) is mostly used in construction projects like road surfacing, airports, parking lots etc. It consists of asphalt or bitumen (used as a binder) and mineral aggregate which are mixed together & laid down in layers then compacted. The continuous increase in road traffic couple with an insufficient degree of maintenance due to shortage of funds has caused an accelerated and continuous deterioration of the road network in Pakistan. To alleviate this process, several types of measures are reported to be effective, for instance, securing funds for maintenance, improved roadway design, use of better quality of materials and the use of more effective construction methods. Improving the quality of materials used in road construction had been shown to improve road service performance in the wake of the increase usage. Practical experience over the last four decades have shown that the modification of the bituminous binder with polymer additives offers several benefits in asphalt concrete and has been tested in a number of countries around the World. Considering the environmental approach, due to excessive use of Polythenes in day to day business, the pollution to the environment is enormous. Since the Polythenes are not bio degradable, the need of the current hour is to use the waste polythene in some beneficial purposes. This Thesis presents a research conducted to study the behavior of BC mix modified with waste polythene.

Keywords— *Pakistan, Bituminous mixes, Polyethene bags.*

1 Introduction

I. Introduction

The increase in road traffic during the last two decades in combination with an insufficient degree of maintenance due to shortage in funds has caused an accelerated and continuous deterioration of the road network in Pakistan. To alleviate this process, several types of measures may be effective, e.g., securing funds for maintenance, improved roadway design, use of better quality of materials and the use of more effective construction methods. The road network in Pakistan has primarily flexible pavement design. Several factors influence the performance of flexible courses, e.g., the properties of the components (binder, aggregate and additive) and the proportion of these components in the mix. Bitumen can also be modified by adding a different type of additive .One of these additives is the polymers. [1, 2]

The addition of polymers typically increases the stiffness of the bitumen and improves its temperature susceptibility. Increased stiffness improves the rutting resistance of the mixture in hot climates and allows the use of relatively softer base bitumen, which in turn, provides better low temperature performance [3-5]. Polymer modified binders also show improved adhesion and cohesion properties.

Polymers can be also added to the asphalt concrete mixtures to form an aggregate coating material. The coatings would enhance surface roughness of the aggregates and thus, produce asphalt mixtures with superior engineering properties [6].

The polymers used in modifying bitumen are classified as Plastomers, or elastomers. Plastomers include ethylene vinyl acetate, polyethylene (un-stabilized and stabilized) and various compounds based on polypropylene [7]. These products may require high shear mixing, which depends on the modification process. They increase the viscosity and stiffness of bitumen at normal service temperatures. However, they do not increase the elasticity of bitumen significantly and on heating, they do not perform satisfactory.

A. Problem Statement

Permanent deformation, temperature, and overloading are various factors for the failure of hot mix asphalt (HMA) pavements. Several failure modes results in loss of serviceability and loss of stability of HMA pavement and pose certain safety risks as well. In consideration of increased traffic loads and in order to improve pavement performance, polymer modified asphalts have been developed during the last few decades.

Numerous waste materials result from manufacturing operations, service industry and household. The growth in various types of industries together with population growth has resulted in enormous increase in production of various types of waste materials. The creation and disposal of non-decaying waste materials such as blast furnace slag, fly ash, steel slag, scrap tires, plastics, etc. have been posing problems in developed as well as in developing countries. One solution to this crisis is recycling waste into useful product.

In addition, the use of plastic as carrying bags to contain various household products has become a common practice all over the country. However the disposal of waste plastic bags in

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large quantities has been a problem and is of great concern. To overcome this situation, the engineering analysis was conducted to investigate the possible use of waste plastic bags as the modi-

modifier of hot mix asphalt and to review the feasibility of the recycling technology for waste plastic bags to improve the performance of asphalt mix.

With this perspective, this study aims to determine the optimum percentage of low density polyethylene (waste plastic bags) that can be used as a modifier in hot mix asphalt and to carry out a comparison of low density polyethylene modified HMA with conventional HMA. Comparison of Marshall Parameters and comparison of rutting resistance will be performed to determine the potential prospects of adding polyethylene in improving the properties of the mix and economic analysis will be performed as well.

II. LITERATURE REVIEW

The use of polyethylene (PE) in asphalt pavements is not new. Patents using various methods to incorporate polyethylene into asphalt pavements were filed more than 25 years ago (Haberl 1980). Some important studies that discussed the use of polymer in HMA include: Biegenzein 1982; Jelling 1991; Schilling and Schreuders 1992; Ho and Zanzotto 1994; Moran and Sokol 1995; Negulescu and Daly 1996; Osborn 1997; Liang and Woodhams 1998; Collins and Jones 2000, Fawcett 2000; Fawcett and McNally 2000 and Yousefi 2004.

Polyethylene tends to phase separate from asphalt because it is an aliphatic material of non-polar nature. For this reason, many researchers have tried to blend other polymers, such as styrene-butadiene-styrene (SBS) or ethylene-vinyl acetate (EVA) polymers, with low-density polyethylene (LDPE) to improve the hot storage stability of the modified asphalt[13].

In 2003, polyolefin's (LDPE, LLDPE, HDPE and polypropylene) constituted the largest segment of global thermoplastic. A polymer material that turns to liquid when heated and becomes solid when cooled. There are more than 40 types of thermoplastics, including acrylic, polypropylene, polycarbonate and polyethylene. Products, at approximately 92 000 kilotons (83 460 million kg) or about 63% of the total commodity resin consumption (Chemical Market Associates, Inc.2003).

It is not surprising that researchers have been very interested in incorporating waste polyethylene into asphalt pavements, as a modifier.

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III. DIFFERENT TESTS AND RESULTS

The experimental phase of this research started with the preparation of control samples, which basically represent unmodified/conventional HMA and modified samples in which polyethylene was added in different percentages. Having found the optimum asphalt content in conventional mix, optimum polyethylene content was determined following the presented study methodology. Lastly, a comparative analysis, based on performance evaluation, of both the mixes was then carried out and important conclusions are proffered.

Table 1: Simple Bituminous Test Results

Test	Actual value	Specification
Penetration Value	86	80-100
Softening Point	56 °C	43°C min
Flash Point	240 °C	232 °C
Fire Point	250 °C	242 °C
Ductility	89 cm	100 cm

A. Quality test on Aggregate

i. Los Angeles Abrasion Test

This test Measures the hardness of coarse aggregate, i.e. the resistance of wear using Los Angeles method to determine the Los Angeles Abrasion Value (L.A.A.V**)**. Aggregate used in road construction should be strong enough to resist the wear due the heavy traffic load. If the aggregate have high abrasion value the stability of road pavement is likely to be adversely affected.

Los Angeles abrasion test studies all possible reasons causing wear. In the L.A. abrasion machine Attrition, Abrasion, and crushing are all present as follows:

1. Attrition: By the friction between the aggregate particles.
2. Abrasion: By the friction between the steel balls and the aggregates.
3. Crushing: By hitting the walls of the testing machine.

Table 2: Sample Grading

Sieve Size		Mass of Indicated Sizes, g.			
Passing	**Retained**	**Grading**			
mm inch	**mm inch**	**A**	**B**	**C**	**D**
37.5 1.5	25.0 1.0	1250 ±25			
25.0 1.0	19.0 ¾	1250 ±25			
19.0 3/4	12.5 ½	1250 ±25	2500 ±10		
12.5 1/2	9.5 3/8	1250 ±25	2500 ±10		
9.5 3/8	6.3 ¼			2500 ±10	
6.3 1/4	4.75 #4			2500 ±10	
4.75 #4	2.63 #8				**5000 ±10**
Total		**5000 ±10**	**5000 ±10**	**5000 ±10**	**5000 ±10**

FIGURE 1: Los Angeles Apparatus

i. Impact value of Aggregate

Aggregate impact value gives the relative strength of aggregates against impact loading. Toughness is the property of material to resist impact due to traffic loads. The road stones are subjected to the pounding action or impact and there is possibility of aggregate stone breaking into smaller pieces. The road aggregate should therefore be tough enough to resist fracture under impact.

Table 3: Aggregate Impact Value Tests Result

% of Polyethylene	**Aggregate Impact Value (%)**
0	14.28
2	12.56
4	11.21
6	8.83

FIGURE 2: Aggregate Impact Value Apparatus

B. Quality Test on Bitumen

A. Penetration Test

The penetration test determines the hardness or softness of bitumen by measuring the depth in tenths of a millimeter to which a standard loaded needle will vertically penetrates the bitumen specimen under known conditions of loading, time and temperature. The bitumen grade is specified in terms of the penetration value. This is the most widely used method of measuring the consistency of a bituminous material at a given temperature. It is a means of classification rather than a measure of quality. (The engineering term consistency is an empirical measure of the resistance offered by a fluid to continuous deformation when it is subjected to shearing stress). Penetration is related to viscosity.

ASTM D5 gives the test procedure for measuring penetration at 77 °F (25 °C) and lower temperatures. Specimens are prepared in sample containers exactly as specified (ASTM D5-97) and placed in a water bath at the prescribed temperature of test for 1 to 1.5 hours before the test. For normal tests the precisely dimensioned needle, loaded to 100 ± 0.05 g, is brought to the surface of the specimen at right angles, allowed to penetrate the bitumen for 5 ± 0.1 s, while the temperature of the specimen is maintained at 25 ± 0.1 °C. The penetration is measured in tenths of a millimeter. At least three determinations are made on the specimen. A clean needle is used for each determination.

Table 4: Penetration Tests Result

% of Polymer in Bitumen	Penetration Value
0	86
2	69
4	62
6	55
8	48
10	37
12	22
14	Nil

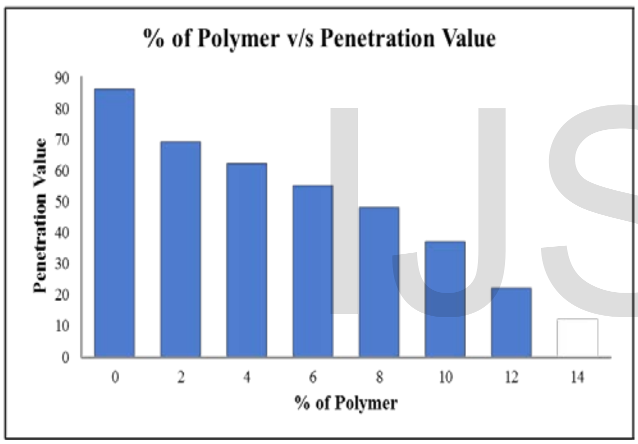

FIGURE 3: Penetration Value V/S % of Polymer

A. Softening Point

The softening point is the temperature at which the substance attains a particular degree of softening under specified condition of test. The softening point of bitumen is usually determined by Ring and Ball test. It is also an indirect measure of viscosity or, rather, the temperature at which a given viscosity is evident. Generally higher softening point indicates lower temperature susce

ptibility and is preferred in warm climates.

Two horizontal disks of bitumen, cast in shouldered brass rings, are heated at a control rate in a liquid bath while each supports a steel ball. The softening point is reported as the mean of the temperatures at which the two disks soften enough to allow each ball, enveloped in bitumen, to fall a distance of 25 mm. Samples of asphalt loaded with steel balls are confined in brass rings suspended in a beaker of water and glycerine or ethylene glycol at 25 mm (1 inch) above a metal plate. The liquid is then heated at a prescribed rate. As the asphalt softens, the balls and the asphalt gradually sink toward the plate. At the moment the asphalt touches the plate, the temperature of the water is determined, and this is designated as ring and ball (RB) softening point of asphalt. Specimens are prepared exactly as specified (ASTM D36-95).

The blend of different percentage of plastic waste has been prepared and their softening points were determined as given in Table 3.2. It is observed that the softening point increases by the addition of plastic waste to the bitumen. Higher the percentage of plastic waste added, higher is the softening point. The influence over the softening point may be due to the chemical nature of polymer added.

Table 5: Softening Point Tests Result

% of Polymer in Bitumen	Softening Point C°
0	56
0.5	59
1	63
1.5	66
2	68

B. Flash and Fire Point

The studies of flash and fire points of the plastic waste-bitumen blend helps to understand the inflammability nature of the blend.

At high temperatures depending upon the grades of bitumen materials leave out volatiles. And these volatiles catches fire which is very hazardous and therefore it is essential to qualify this temperature for each bitumen grade.

Flash point "the flash point of a material is the lowest temperature at which the vapour of a substance momentarily takes fire in the form of a flash under specified condition of test". Fire point "the fire point is the temperature at which the material gets ignited and burns under specified conditions of test". Pensky –Martens closed cup apparatus or open cup are used for conducting the tests. Flash and fire point of plain bitumen is 175-2100C. From the experimental results it is observed that the inflammability of the blend is decreasing as the percentage of polymer increases (Table 3.3). The blend has developed better resistance to burning. The polymer bitumen blend road surfaces will be less affected by fire hazards.

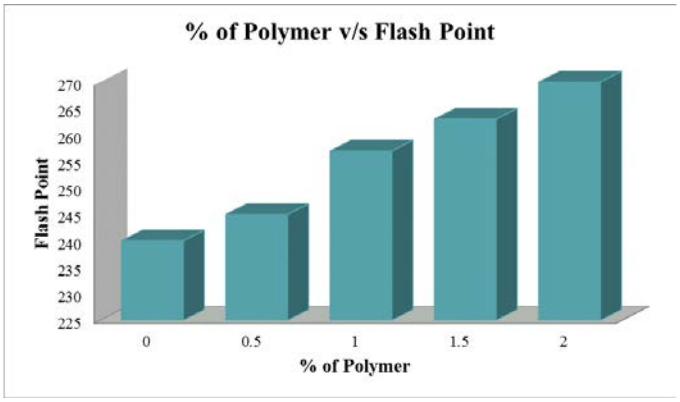

FIGURE 4: Flash Point Value V/S % of Polymer

A. Ductility

It is important that the binders form ductile thin films around the aggregate. Ductility is the property of bitumen that permits it to undergo great deformation or elongation. Ductility is defined as the distance in cm, to which a standard sample or briquette of the material will be elongated without breaking. Dimension of the briquette thus formed is exactly 1 cm square. The bitumen sample is heated and poured in the mold assembly placed on a plate. These samples with molds are cooled in the air and then in water bath at 27 °C temperature. The excess bitumen is cut and the surface is leveled using a hot knife. Then the mold with assembly containing sample is kept in water bath of the ductility machine for about 90 minutes. The sides of the molds are removed, the clips are hooked on the machine and the machine is operated. The distance up to the point of breaking of thread is the ductility value which is reported in cm. The ductility value gets affected by factors such as pouring temperature, test temperature, rate of pulling etc.

Samples with different percentage of plastic waste in bitumen were prepared and ductility was checked. Table 3.4 shows that the ductility is decreasing by the addition of plastic waste to bitumen. The decrease in the ductility value may be due to interlocking of polymer molecules with bitumen.

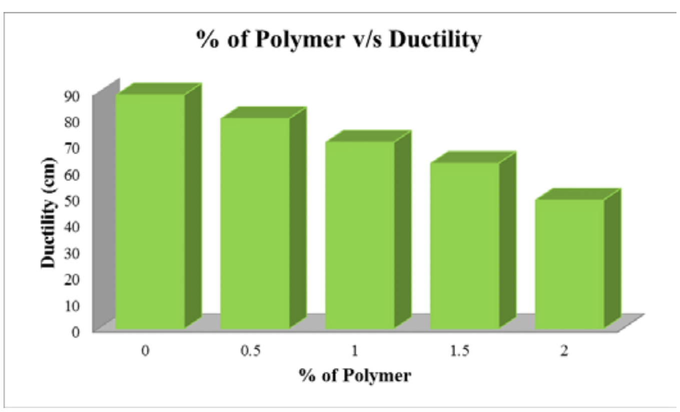

FIGURE 5: Ductility Value V/S % of Polymer

B. MARSHALL MIX DESIGN METHOD

The mix design determines the optimum bitumen content. The Marshall Stability and flow test provides the performance prediction measure for the Marshall Mix design method. The stability portion of the test measures the maximum load supported by the test specimen at a loading rate of 50.8 mm/minute. Load is applied to the specimen till failure, and the maximum load is designated as stability. During the loading, an attached dial gauge measures the specimen's plastic flow (deformation) due to the loading. The flow value is recorded in 0.25 mm (0.01 inch) increments at the same time when the maximum load is recorded.

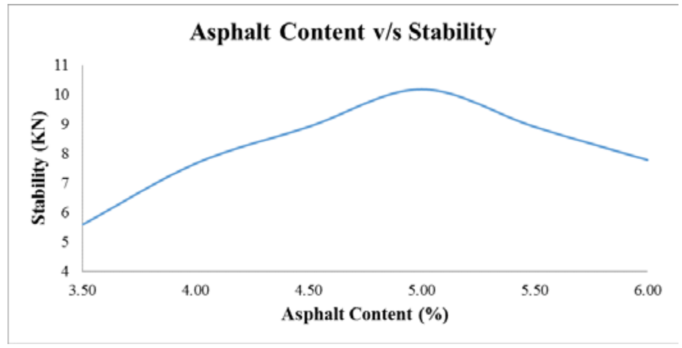

FIGURE 5: Asphalt Content V/S Stability

I. COMPARISON BETWEEN ORDINARY BITUMEN MIX AND WASTE PLASTIC BITUMEN MIX

PROPERTIES	MODIFIED MIX	CONTROL MIX
Marshall Stability Value	More (16.17 KN)	Less (10.17 KN)
Binding Property	Better	Good
Softening Point	More (68 °C)	Less (56 °C)
Penetration Value	Less (48)	More (86)
Rutting	Less (3.27 mm)	More (6 mm)
Stripping (Pot Holes)	No	More
Seepage of Water	No	Yes
Durability	Better	Good
Cost	Less	Normal
Environmental Friendly	Yes	No
Maintenance Cost	Almost Nil	More

IV. Recommendations

It is necessary to work out a project proposal to carry out further studies on various aspects such as collection, processing

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and effective utilization of this waste material. To start with, such a study could be initiated, with the following components:

1. Estimation of the types, quantity and useful components present in the waste plastic materials in the city and surrounding areas.
2. Methodology for collection and sorting out the useful components of the plastic waste
3. Methodology for processing the plastic bags as required for use in the preparation of modified bitumen, including cleaning, shredding and further processing of the plastic waste materials
4. Identification of two or three construction companies / entrepreneurs who could incorporate appropriate mixing units in their bitumen boiler / hot mix plant to add and mix the required proportion of the processed plastic additive
5. Carrying out further laboratory investigations, construction of some test tracks and field studies on the performance of pavements using the modified bitumen

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Conclusion

4 The polymer bitumen blend is a better binder compared to plain bitumen and it has a higher stiffness at high service temperature (summer) that will result in reduced rutting.

5 Asphalt –aggregate bonding is improved which will result in reduce stripping or moisture susceptibility.

6 The blend has increased softening point. This phenomenon indicates that the resistance of the binder to the effect of heat is increased and it will reduce its tendency to soften in hot weather. Thus, with the addition of polyethylene the modified binder will be less susceptible to temperature changes. The effect of softening point of a binder on resistance to permanent deformation, of bituminous pavement mixes, has been studied by various researchers. An example is hot rolled asphalt where it was found that the rate of rutting in the wheel tracking test at 45°C, was halved by increasing softening point by approximately 5ºC (Fernando & Guirguisl, 1984). Therefore it is expected that by using the polyethylene in the bituminous mix the rate of rutting will decrease due to the increase in softening point.

7 The increase in the softening point shows that there will be less bleeding during summer. Bleeding accounts, on one side, increased friction for the moving vehicles and on the other side, if it rains the bleedings accounts for the slippery condition. Both these adverse conditions are much reduced by polymer Bitumen Blend.

8 The blend has decreased Penetration value. This means that the addition of polyethylene makes the modified bitumen harder and more consistent. This is good in the sense that it improves the overall performance of HMA by increased rutting resistance, durability, load carrying capacity, improved resistance to weathering effects, increased stability and improved binding properties of HMA.

9 The adhesion between aggregate and asphalt binder is increased by coating polyethylene on aggregates which helps to reduce stripping.

10 The abrasion resistance of aggregates is improved which will result in the reduction of raveling.

11 The blend has developed better resistance to burning as Flash and Fire point increases with the addition of polyethylene. The polymer bitumen blend road surfaces will be less affected by fire hazards.

12 Coating of plastics over the aggregate improves the quality of the aggregate as it impact value decreases with the addition of polyethylene. Moreover a poor quality of aggregate can be made useful by coating with polymers.

When polymer is coated over aggregate, the coating reduces its affinity for water due to non-wetting nature of the polymer and this resists stripping. More over the polymer bitumen blend is having higher binding property too. This also resists stripping and hence pothole formation is very much reduced.

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