Performance Evaluation Of Polythene Modified Hma Using UTM-5P

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Abstract: The continuously increase in traffic volume and poor construction practice during the last few decades in combination with a poor maintenance due to Government policy and shortage of funds has caused the road network deteriorated continuously in Pakistan. The increasing traffic load and compromise on quality of construction are the main causes of pavement failures, especially rutting and fatigue cracks. In this situation the problem should be investigated and its proper solution should be proposed. In the current study, Low Density Polythene (LDP) was used as one kind of additive to HMA to observe the improving properties of asphalt mix. The proportion of polythene was kept as 5%, 10%, 15%, 20%, and 25 % (3 samples for each proportion) by weight of Bitumen content. The Repeated load uniaxial strain test was carried out using Universal Testing Machine (UTM-5P) on marshal prepared samples. The results showed an improved resistance to permanent deformation of Polythene modified mixes as compared to conventional mix. It was also observed that HMA containing 20% LDP by weight of bitumen showed best performance in terms of resistance against accumulated strain.

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1. Introduction

Number of vehicles, Axle loads and tire pressures are increasing constantly from the recent past in Pakistan, which has resulted in an increased permanent deformation (i.e. rutting) and cracking. There is huge variation in the behavior of asphalt due to change in temperature from low to high due its rheological nature. The rheological properties can be investigated using DSR (AASHTO-T315). A number of modifiers can be used to enhance the asphalt binder's properties at normal service temperatures to improve its resistance to permanent deformation. This decreases its stiffness at low temperatures and enhances its resistance to low temperature cracking. The recycling of waste and industrial by-products (such as tires, waste polythene, ashes etc) are beneficial to friendly environment as well as reducing the cost of overall project.

Several million tons of waste is produced due to low density polythene (LDP) in the form of bags every year in Pakistan. Low Density Polythene is not readily recyclable and perseveres in the environment for a considerable period of time. Moreover, environmental problems initiates due to dumping and limited alternatives for recycling. Utilization of reclaimed Low Density Polythene (LDP) is of great significance to developing countries, particularly for reduction in environmental pollution created due to dumping of Low Density Polythene bags. Since a large quantity of construction materials are required for highway construction, using of only a small amount of recycled material will dispose of large quantity of Polythene waste. In this study the use of polythene as a modifier to asphalt mix properties was investigated. Altogether 18 samples were prepared, Out of which, three for conventional and 15 for polythene modified. Polythene was used in proportion of 5%, 10%, 15%, 20%, and 25 % (3 samples for each proportion) by weight of Bitumen content. The Repeated Load Uniaxial Strain tests were carried out using Universal Testing Machine (UTM-5P). The principle objectives of this study were to;

- Study the effect of adding polythene on HMA behavior in terms of its resistance to permanent deformation.
- Compare conventional mixes with polythene modified mixes.

2. Literature Review

Rutting is the most common type of flexible pavement distress in Pakistan which is caused due to uncontrolled wheel load and variation in temperature from low to high range. To investigate this problem; (Dr. M. A. Kamal et al, 2005) Indirect Tensile and Creep Tests using UTM-5P was performed on the samples taken from Islamabad-Peshawar (M-1) Motorway Section. In this section polymer modified asphalt concrete is used for the first time in Pakistan. They concluded that there is large reduction of about 85 % in resilient modulus for a temperature increase from 25 to 40°C. Resilient modulus also decreased upto 30% by increasing pulse width from 150ms to 450ms. The polymer modified bitumen showed increased resilient modulus and reduced values of accumulated strain values which indicate high resistance to rutting. Hussein et al (2006) conducted a study on HMA mix using polymers and concluded that Polymer Modified Asphalt Concrete Mixes (PMAM) showed better performance than that of conventional HMA in terms of higher Mr values and better resistance to rutting. There is best correlation of elastic behavior of modified bitumen with that of Mr and rutting resistance of PMAM. Sinan et al (2004) investigate the properties of asphalt concrete mix by using High Density polythene (HDPE) as bitumen modifier. They concluded that due to high stability and high Marshal Quotient of HDPE modified mix showed high resistance to rutting (permanent deformation) and this polymer modification also contribute to reduce the environment pollution by recycling these wastes.

Abolfazl Hassani, et al conducted a research by using Poly-Ethylene Terephthalate (PET) as modifier in asphalt concrete mixture as aggregate replacement. They concluded that there is 2.8% reduction in bulk compacted mix density with the aggregate replacement of 20% by volume with -Ethylene Terephthalate (PET) granules [4]. It was also concluded that Marshal Stability and Marshal Quotient for control samples and PET modified samples (used as partial aggregate replacement) were almost same values. Recycling of PET with asphalt meets most of the specifications requirement that make it appropriate for use in road construction and also the recycling of PET reduces the environmental pollution. Othman. A (2010) studied the effect of Low Density Polyethylene (LDPE) modified bitumen on fracture toughness. He concluded that mixture modified with 4.5% Low Density Polyethylene showed the maximum fracture toughness. Low Density Polyethylene (LDPE) modified mix also improve the physical properties of HMA. There is considerable increase in indirect tensile and compressive strength for LDPE modified HMA.

Esmaeil Ahmadinia, et al; (2011) conducted a research by adding Polyethylene Terephthalate (PET) to stone mastic asphalt (SMA) mixture and concluded that that the addition of PET has a significant positive effect on the properties of SMA and it can promote the re-use of waste material in industry in an environmentally friendly and economical way. Polymer modification is necessary to satisfy the performance requirements o pavements for the Gulf countries which include eastern parts of Saudi Arabia, Kuwait, Bahrain, Qatar, United Arab Emirates and Oman. (Al-Abdul Wahhab et al; 1997).

The characterization of the different bitumen modified with 5% of SBS, EVA and plastic waste of each one of the studied polymers demonstrated that it is possible to obtain similar properties, or even better, than those of a commercial modified bitumen. (Liliana M.B. Costa et al; 2013).

3. Materials and Testing Methodology

3.1 Materials

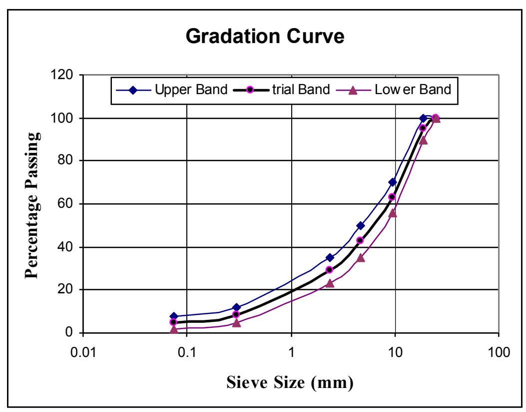

Figure 1: Gradation Curve for NHA class-A gradation

Table 1: Aggregate Gradation of NHA Class-A

Sieve Sizes	Master Blend (%age Passing)	Trial Blend (%age Passing)
25 mm (1 inch)	100	100
19 mm (3/4 inch)	90-100	95
9.5 mm (3/8 inch)	56-70	63
4.75 mm (No.4)	35-50	42.5
2.36 mm (No. 8)	23-35	29
0.3 mm (No. 50)	5-12	8.5
0.075 mm (No. 200)	2-8	5

Crushed aggregates were collected from Margalla quarries. A trial blend was selected for the study, which is the average of finer and courser side of the gradation curve being used by NHA Class-A, Tabulated in Table 1 and graphically shown in Figure 1.

Bitumen of grade 60/70 was used with a proportion of 4.5% by weight of total aggregates. The additive was Low Density Polythene (LDP) waste carry bags.

3.2 Preparation of Samples

The samples were prepared according to specifications mentioned earlier and compacted by “Marshal Compacter” with 75 blows on each side. A total number of 18 samples were prepared, Out of which three samples for conventional (without polythene), and 15 samples for Low Density Polythene modified by varying weights %age from 5 % to 25 % as shown in Table 2.

Table 2: Specifications of LDP modified HMA

S. No.	HMA Mix	Percentage of LDP Additive	No of Samples
1	Conventional	Nil	3
2	Modified with LDP	5	3
3	Modified with LDP	10	3
4	Modified with LDP	15	3
5	Modified with LDP	20	3
6	Modified with LDP	25	3

3.3 Testing in UTM-5P

Universal Testing Machine (UTM) is the advance computer based Machine which is used for determination of Modulus of Resilience (Mr) and Permanent Deformation (Rutting) characteristics of asphalt concrete (UTM-5P User Manual). Resilient Modulus is generally affected by varying temperature and pulse width. UTM software can replicate varying road conditions through increases in frequency and force of axial loads. In this project the samples were tested by varying the Pulse Width (time of loading) and keeping the temperature constant.

3.4 Testing Parameters

UTM-5P was used for testing these samples. Repeated load uniaxial strain test using UTM-5P was performed on the cores according to the following conditions;

- Constant temperature of 40ºC
- Pulse period (ms): 2000
- Pulse width (ms): 1000
- Test loading stress (kPa): 100
- Terminal pulse count: 1800

4. Results and Discussions

4.1 Resilient Modulus (Mr)

Resilient Modulus of Asphalt is both Temperature and Loading dependent. At high temperature the asphalt act as viscous fluid and is more susceptible to rutting. It means that with increase in temperature it’s Resilient Modulus Decreases. At low temperature Asphalt act as Elastic material and will provide more resistance to permanent deformation. It means that with temperature decreasing (at low temp) Resilient Modulus increases. So asphalt is called Visco-elastic material. Similarly it also depends on time of loading (i.e. Pulse width). With increase in pulse width (i.e. slow moving vehicle) Resilient Modulus decreases. There is interrelationship between Pulse width the time of loading in actual pavements under the wheel load. Normally, a pulse width of less than 450 ms is considered for high speed vehicles and greater than 450 ms for low speed vehicles. With increase in pulse width (loading time) the resilient modulus decreases.

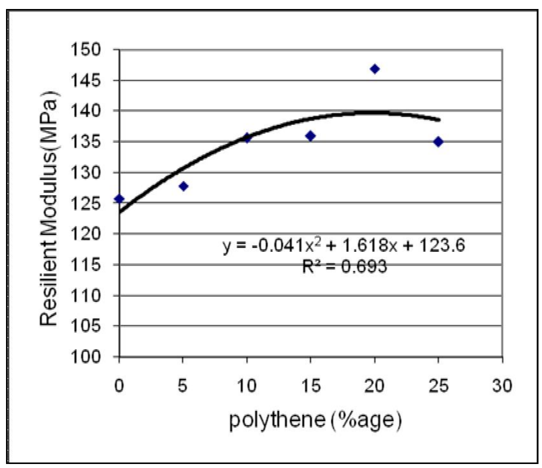

Figure 2: Relationships between Polythene % and Resilient Modulus (MPa)

The current study was limited only for slow moving vehicles, so a pulse width of 1000 ms and a pulse period of 2000 ms were taken and all the samples were tested at a temperature of 40°C. The Resilient Modulus for conventional HMA and polythene Modified Samples were tested at 40°C have been tabulated in Table 3 and shown graphically in figures 2 & 3. A higher value of resilient modulus was observed for samples mixed with polythene as compared to the conventional mix, tested under the identical load and temperature conditions. Hence in this study the values of resilient modulus are low because the samples were tested at high temperature (40ºC) and high pulse width (1000 ms). But the polythene modified bitumen particularly 20% polythene modified shows high values of resilient modulus as compared to conventional at the same temperature (40ºC) and pulse width (1000 ms).

Table 3: Resilient Modulus values for various polythene percentages

HMA Mix	Resilient Modulus (MPa)
Conventional	125.7367
5 % LDP	127.8000
10 % LDP	135.6567
15 % LDP	135.9467
20 % LDP	146.9100
25 % LDP	135.0133

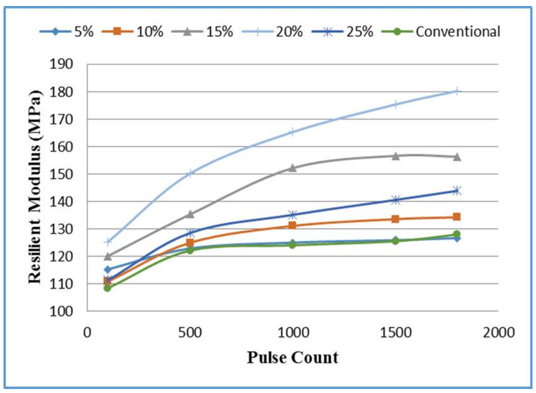

Figure 3: Relationships between Resilient Modulus and Pulse Count

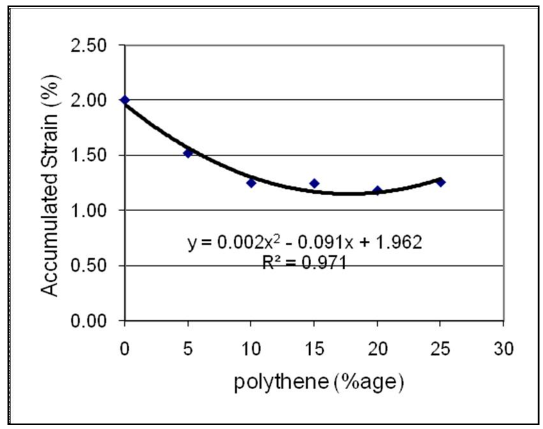

Figure 4: Relationships between Polythene %age and Accumulated Strain

4.2 Permanent deformation

Accumulated strain is a measure of permanent deformation (rutting). Figure 5 shows a relationship between accumulated strain and the pulse count (number of repeated loads). In Polythene modified samples deformation was decreased i.e., increased the rutting resistance. As shown in Table 4 and graphically shown in Figures 4 & 5, the accumulated strain for 20% LDP modified samples has the lowest value. In other words 20% LDP modified samples indicates highest resistance to rutting. On the other hand conventional samples have higher values of accumulated strain, so high susceptible to rutting.

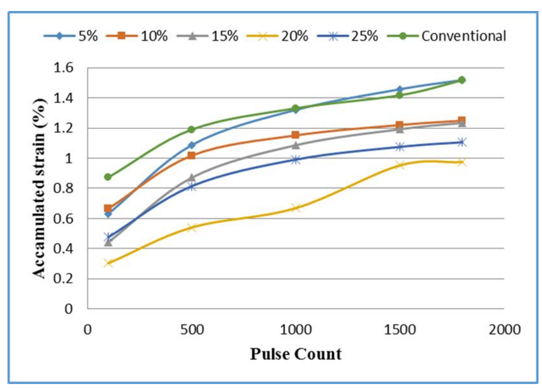

Figure 5: Relationships between Accumulated Strain and Pulse Count

Table 4: Accumulated Strain values for various polythene percentages

HMA Mix	Accumulated Strain (%)
Conventional	2.0005
5 % LDP	1.5200
10 % LDP	1.2501
15 % LDP	1.2456
20 % LDP	1.1817
25 % LDP	1.2573

5. Conclusions and Recommendations

1. In this research, Asphalt concrete mixed with Low Density Polythene (LDP) of 5%, 10%, 15%, 20% and 25% was compared with conventional HMA samples. Based on the results, following are the conclusions of this study:

2. Polythene modified HMA shows lower values of Accumulated Strain as compared to Conventional HMA due to less deformation under repeated loading.

3. Initially the accumulated strain decreases up to 20% LDP and then it increases. It means that 20% LDP content is the optimum value for maximum resistance to rutting.

4. Polythene modified samples also shows a higher value of Resilient Modulus at 20% LDP as compared to conventional samples.

5. It can be concluded that waste LDP-modified bituminous binders provide better resistance against permanent deformations and resistance to cracking due to their high stability and high resilience modulus.

6. Use of waste plastic in the pavement industry will contribute to recirculation of plastic wastes as well as to protection of the environment.

7. Overall performance of Polythene Modified Bitumen showed better results than that of the conventional mix under the same loading and environmental conditions in terms of their resilient modulus and permanent deformation.

Recommendations

1. There is a need of further study on different modifiers which enhance the HMA properties according to Pakistani climate (i.e., Crumb Rubber, fiber Glass, HDP).
2. The current research may further be extended for varying temperature conditions.
3. The current research may further be extended for various loading frequencies.
4. Control on Axle load and tire pressure is essential to save the premature failures of pavements.

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