Influence of Aging on The Penetration Performance of Waste Polymer Modified Asphalt Binder

[a] *Zohra Jabeen**, [b] *Arshad Hussain*, [c] *Lubna Tabassum*

a: School of Civil and Environmental Engineering (SCEE), National University of Science and Technology (NUST) Islamabad, Pakistan, zaujarehan@gmail.com
b: School of Civil and Environmental Engineering (SCEE), National University of Science and Technology (NUST) Islamabad, Pakistan
c: Design Section, National Highway Authority (NHA) Islamabad, Pakistan
* Corresponding author: Email ID: zaujarehan@gmail.com

Abstract- A promising strategy that has been widely accepted for improving the pavement deficiencies, is the use of commercial polymers for asphalt binder modification. However, their high cost is the major hurdle in their use, especially in the developing countries. Instead of these commercial polymers researchers are using waste plastic polymers to attain the same benefits. Their cost effectiveness and environment friendly quality is making them the most popular asphalt binder modifier all over the world. The current study aimed at studying the impact of aging on the penetration performance of waste polymer modified asphalt binder. Two such polymers, waste PET (polyethylene terephthalate i.e., plastic bottles) and waste LDPE (low-density polyethylene i.e., plastic bags) were collected from the vicinity, then cleaned, uncapped and shredded to a size less than 0.5mm and blended separately with 60/70 penetration grade bitumen using 2%, 4%, 6% and 8% waste polymers by weight of bitumen. Penetration test was performed on the unaged modified binder samples, short term aged (using rolling thin film oven test (RTFO)) modified binder samples, and long term aged (using pressure aging vessel test (PAV)) modified binder samples. To sum up, it could be said that the use of these non-biodegradable waste polymers enhances the physical performance of the binder and save the cost of material and environment from pollution as well.

Keywords- Aging, Modified Asphalt Binder, Waste PET Polymer, Waste LDPE Polymer.

1 Introduction

In order to handle the dramatic increase in the traffic volume and the demand for high quality pavement, researchers have been trying hard to improve the comprehensive performance of the asphalt binder by adding different modifiers [1, 2]. The modifier that gained recognition worldwide in pavement industry is polymer. Polymer modification increases the resistance against permanent distresses and failures. It can provide with the improved performance as well as durability. The pavements service life increases and maintenance cost reduced significantly by increasing the viscosity of asphalt binder at higher temperatures and improving the ductility at lower temperatures [3, 4]. Incorporating polymers to asphalt binder could improve the aging resistance [5, 6].

The commercial polymers such as polyethylene and its by products, styrene-butadiene-styrene (SBS), and ethylene-vinyl-acetate (EVA), are being used successfully for flexible pavement quality improvement all over the world, but in developing countries it's use is still limited due to their high cost. Rather in most recent studies waste polymers are being used instead, as a bitumen modifier successfully. They are cost effective and environment friendly, along with the quality of enhancing asphalt binder properties [7, 8]. In other words, we can say that the use of waste polymers results in overall lower product costs as well as is a step towards resolving the non-biodegradable i.e. plastic waste disposal issues without compromising the properties of asphalt binder rather enhancing the flexible pavement quality [9].

In Pakistan one kilometer patch of road has been constructed in Islamabad at Ataturk Avenue as a trial section using different waste polymers. So, there is a dire need to dig into details related to the use of such polymers in our country efficiently. Present study focuses on the use of these locally available waste polymeric additives as a modifier, than thoroughly examining the aging phenomenon on the penetration performance of modified asphalt binder. The aging of waste polymer modified asphalt binder is observed with RTFO and PAV in laboratory. Penetration test was then conducted for different samples of aged and unaged WPMB.

2 Research Methodology

The methodology used in carrying out this detailed research is summed up in a hierarchical chart as shown in figure 1. First of all, material was selected and then conventional testing i.e., Penetration test, was carried out after modifying the bitumen with waste PET and waste LDPE respectively.

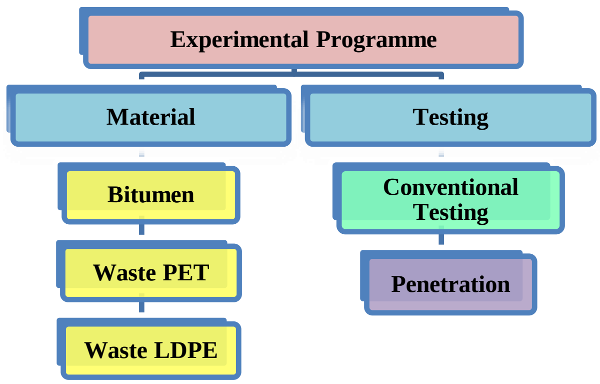

Figure 1: Hierarchical chart of Experimental Work

2.1 Material Selection

The selection of the materials was carried out by keeping in view their availability and cost efficiency. Researchers are using waste polymers like waste rubber and waste plastic successfully, instead of commercial polymers [10-14]. Keeping in view the facts and figures, following mixture of materials were used for preparation of modified binder samples.

- 60/70 Asphalt binder
- Waste polyethylene terephthalate (PET)
- Waste low density polyethylene (LDPE)

2.1.1 Asphalt Binder

The Penetration grade of 60/70 bitumen was acquired by the Attock Refinery Limited (ARL) Rawalpindi, and used as a base binder. In Pakistan the above-mentioned grade is used mostly. It performs better in colder regions as well as intermediate temperature regions. Moreover, it was easily and abundantly available in our area.

2.1.2 Waste Polyethylene Terephthalate (PET)

Polyethylene terephthalate a non-biodegradable waste, is a thermoplastic polymer. It is a clear and strong plastic that is commonly used for food packaging. Mineral water and soft drink bottles are mostly made by this PET plastic. In this research local waste plastic bottles as shown in figure 2a with PET code i.e., 1, were collected after proper identification. Then after removal of the stickers, caps, and cap rings the bottles were washed and dried. After that they were shredded to a size ≤ 0.5mm as shown in figure 2b, with the help of shredding machine.

Figure 2:(a) Waste PET Plastic Bottles;(b) Waste Shredded PET Plastic

2.1.3 Waste Low-Density Polyethylene (LDPE)

Low-density polyethylene (LDPE) another non-biodegradable waste having chemical formula $(C_2H_4)_n$, is also a thermoplastic made from the monomer ethylene. Its most common use is in plastic bags. In this research local waste plastic bags with LDPE code were collected after proper identification, cleaned and shredded to a width ≤ 1mm and length ≤ 15 mm. Figure 3 shows the waste plastic bags, code of LDPE plastic polymer and its shredding.

Figure 3: (a) Waste LDPE Plastic bags; (b) LDPE Plastic Code; (c) Shredded Waste LDPE Plastic

2.2 Preparation Of Waste Polymer Modified Asphalt Binders

Samples were prepared by adding waste polyethylene terephthalate (W-PET) into 60/70 penetration grade in different percentages i.e., 2%, 4%, 6% and 8% by weight of the base binder. A measured amount of neat binder for each percentage of modifier, was liquefied by heating till 180°C and then premeasured shredded waste PET was gradually added. High-rate shear mixer was used keeping the temperature 180°C at 2000 rpm, for about 60 minutes, to get homogeneous blend. In order to avoid segregation and maintain uniform distribution, waste modified asphalt binder was prepared in small quantity as needed and was used for sample preparation right after that.

Same procedure was adopted for the preparation of W-LDPE modified asphalt binder samples at four different percentages i.e., 2%, 4%, 6% and 8% by weight of the base binder. Mixing was done at 170°C and 2000 rpm, for about 40 minutes to get homogeneous blends.

2.3 Aging

Aging is the change in chemical composition of bitumen due to atmosphere and the high temperatures [15]. In laboratory, the effect of short-term aging was stimulated by Rolling Thin Film Oven (RTFO). The temperature in RTFO was 163ºC and the samples were aged in the chamber for 80 minutes. To simulate the effect of in-service aging (long term aging) of asphalt binder Pressure Aging Vessel (PAV) was used. The samples were kept under high temperature i.e. 100ºC and high pressure i.e. 2.1 MPa for 20 hours.

3 Material Testing

Conventional test was performed on virgin, aged, modified aged and modified unaged asphalt binder samples. Modified asphalt binder was obtained through extensive physical testing by determining an optimum content of waste PET and waste LDPE.

The test include penetration for determining consistency of bitumen at room temperature (AASHTO Specification T49). In this test, a standard loaded needle is vertically penetrated in the sample of asphalt binder under standard condition and its penetration depth is measure up to tenths of a millimeter. Penetration values are more for softer binder. According to AASHTO T49-03 temperature was maintained at 25°C, load was 100 grams, and the test time was 5 seconds. Using ARL 60/70 specimen, three values from each specimen were taken after performing penetration tests. The results of the test were shown on a screen attached with the penetrometer. All values obtained fulfilled the required criteria as per specification.

4 Results

In current research, the influence of aging on penetration performance of unaged and aged modified binder samples was analyzed using aging index. Aging index is basically the ratio of physical/performance property of aged binder to the same property of unaged binder. The aging index used in this research work includes penetration aging ratio (PAR). It is calculated by formula given below:

$$\text{Penetration Aging Ration (PAR)} = \frac{\text{Aged Penetration Value}}{\text{Unaged Penetration Value}} \times 100$$

4.1 Penetration Test

The penetration value is used to show the stiffness as well as hardness of the binder at 25ºC. Lower penetration value indicates that binder has become stiff. From the results, it is observed that after increasing the waste polymer content from 2% to 8%, decrease in the penetration value of asphalt binder is considerable. This shows that the consistency of the modified asphalt binder increased at normal temperature. The results are based on the average of two readings as shown in table 1.

Table 1: Penetration results for W-PET modified Asphalt Binder

	Penetration		
Additive rate	**Unaged**	**RTFO aged**	**PAV aged**
0%	65	59	48
2%	57	48	40
4%	49	40	33
6%	41	31	26
8%	38	27	22

The decrease in the penetration value of 4% waste PET modified asphalt binder is 25% as shown in figure 4, whereas it is 21% in case of waste LDPE modified asphalt binder as compared to the unmodified binder as shown in figure 6. This decrease is the indication of the higher stiffness by the addition of polymers, that makes them perfect for warmer regions. Figure 5 and 7 represents the results of PAR for unmodified and waste polymer modified binder after the short term and long-term aging. It is observed that penetration values of unmodified and modified binder decreased after aging. Moreover, higher the waste content, lower the value of penetration aging ratio that shows reduction in the degree of aging. Therefore, waste polyethylene terephthalate and waste low density polyethylene addition improves the binder's resistance to oxidative aging.

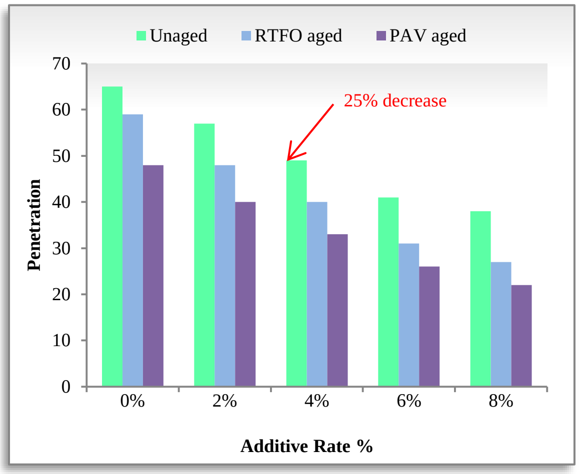

Figure 4: Penetration Values of W-PET Modified Binder

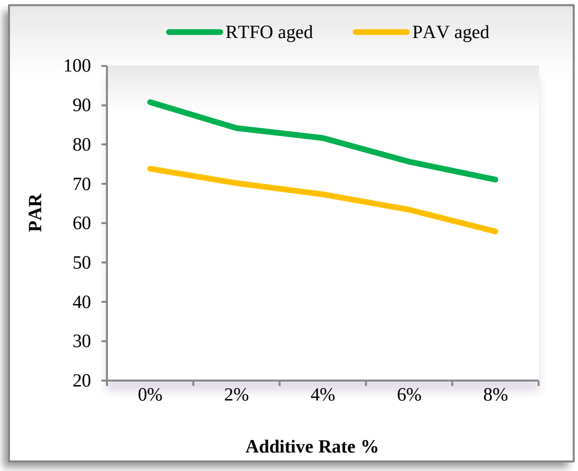

Figure 5: PAR Graph for W-PET Modified Binder

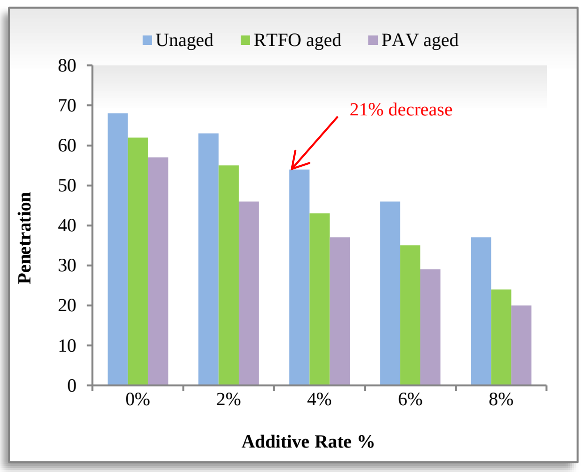

Figure 6: Penetration values of W-LDPE Modified binder

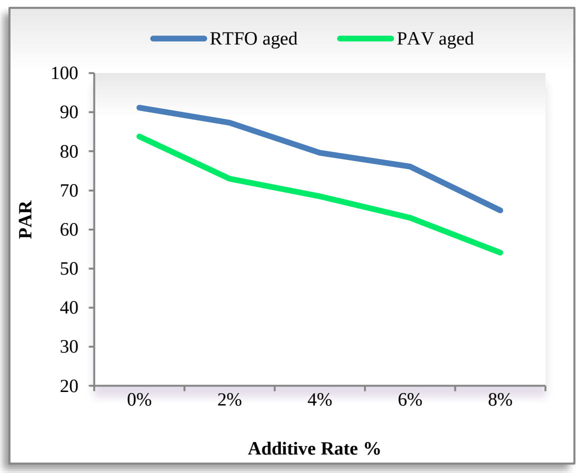

Figure 7: PAR Graph for W-LDPE Modified Binder

5 Conclusions

After successful completion of extensive lab testing, carried out in an effort to obtain the targeted objectives of this research work, the below mentioned conclusions could be derived.

1. Results indicate that the addition of W-PET and W-LDPE improved the penetration performance of the binder.
2. Penetration value of the W-PET modified and W-LDPE modified binder decreased by 25% and 21% respectively, which indicate high resistance of the modified binder against rutting due to improved stiffness.
3. Penetration aging ratio at 4% addition of the waste polymers decreased by 10% for W-PET and 12% for W-LDPE after the short-term aging which indicate binders improved resistance to oxidative aging.

6 Recommendations

1. Investigations should be done by using different combinations of plastic wastes as an asphalt binder modifier and evaluate their effects on physical and performance properties before and after aging.
2. Effect on the low temperature performance and effect on Fatigue properties of asphalt binder and asphalt should be studied before implementing W-PET and W-LDPE modified asphalt binders in cold areas.

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