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ASSESSMENT OF ADHESION AND MOISTURE SUSCEPTIBILITY OF WASTE PLASTIC AND CRUMB RUBBER MODIFIED BITUMEN

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Abstract- Inappropriate disposal of a large amount of waste material in the form of plastic and rubber tires is a serious environmental concern. The use of these waste materials in asphalt not only enhance the properties of asphalt binder but also serves an effective means form their safe disposal. In this study Polyethylene Terephthalate and Crumb Rubber have been used in various combinations to modify 60-70 pen grade bitumen. Bitumen Bond Strength test using Pneumatic Adhesion Tensile Testing Instrument and Rolling Bottle Test were performed to evaluate the adhesion and moisture susceptibility of the modified binder. The experimental results revealed that modified bitumen with 15% Polyethylene Terephthalate shows better adhesion and moisture susceptibility compared to crumb rubber modified and control binder.

Keywords- Waste Material, Asphalt, Bitumen Bond Strength, Rolling Bottle Test.

1 INTRODUCTION

Hot mix asphalt is used for flexible pavement over a long time in all over the world. By using this traditional job mix formula (Hot mix asphalt) different stress-related problems are created resulting in rutting, fatigue cracking, and moisture damage. These problems are created due to overloading, climate condition, low and high temperatures [1][2]. To overcome all the stress-related problems binder modification is the best solution [3]. Different binder modifications are used to overcome rutting, fatigue and moisture damage. Now a day's disposal of dumps is a major problem due to lack of space and destructive for the environment. As the population is increasing, solid waste increases which causes landfill space and health problems [4][5].

Esmaeil et al. studies the effect of PET as a modifier in asphalt binder. The optimum percentage of 6% PET are showed good results on properties of asphalt mixture [6]. Zhen Leng et al. explore that by using additives of waste PET gives good performance-enhancing rutting resistance 15% and fatigue resistance 60% [7]. Mansour Fakhri et al. studies the effect of deicing salt contains Calcium Chloride, Sodium Chloride and Magnesium Chloride on moisture susceptibility. Recycled Crumb Rubber (RCR) of 0%,1%,3% and 5% are used. Moisture susceptibility (Texas Boiling Water, Pull-off Adhesion Test, and Indirect Tensile Test) are used for explaining asphalt specimens. The calcium chloride showed less adverse outcomes as compared to other deicing solution and RCR [8]. Gibreil et al. studied the effect of high-density polyethylene (HDPE) and crumb rubber powder (CRP) as a modifier enhance physical properties and marshall properties of asphalt. By adding HDPE and CRP resistance to moisture damage raised significantly [9]. Mansourian and Gholamzadeh improved the moisture susceptibility by using a new nanocomposite material ((polypropylene/nano-clay) with a percentage of 2% by weight of the binder. The indirect tensile strength and surface free energy test results were improved [10]. Hamedi and Tahami studied the influence of Zycosoil as an antistripping agent in bitumen modification for moisture susceptibility. Surface free energy test results showed that there was a reduction in the debonding energy of stripping phenomena [11]. Zaidi et al. conducted a comprehensive study of HL on moisture damage in bitumen mastic and asphalt mixture. The

moisture damage assessment can be made by performing RBT, BBS test, etc. and asphalt concrete modified with HL showed improvement in adhesion and resistance to moisture damage [12].

Disposal of a large amount of waste material in the form of plastic and rubber tires is a serious environmental concern. Waste plastic and crumb rubber are commonly disposed off by landfilling and incineration hence causing serious environmental damage. The use of these waste materials in asphalt mixture can help in solving these environmental problems and at the same time giving a more durable asphalt mixture.
The following are the objectives of this research work:

- To investigate the effect of waste plastic and crumb rubber on properties of bitumen.
- To investigate the effect of waste plastic and crumb rubber on properties of asphalt mixture in terms of adhesion and moisture damage.

2 EXPERIMENTAL AND RESEARCH METHODOLOGY

2.1 Material used

The bitumen used in this study is 60-70 Pen grade bitumen, which is a very common type of binder used in Pakistan. The aggregate from Margalla queries is obtained. PET is taken from Plastic bottles which are made from polyethylene Terephthalate, wash them, and grind bottles in shredder plants. CR is taken from used tires scrap and grind rubber tires in shredder plants. After shredding these materials passing through sieve No.50/300 Microns/0.297 mm.

2.2 Mixing Proportion

For making a blend, first, the bitumen is heated at 150°C by placing it on the hot plate and constant temperature is maintained while PET and CR are added in it and the shear mixer is used for mixing at a speed of 1500 rpm for 40 minutes.

Table 1: Mixing proportion of PET and CR modified binder

Sr. No	Dosage	Mixing Time
1	Control +5% PET	40 minutes
2	Control +10% PET	40 minutes
3	Control +15% PET	40 minutes
4	Control +5% CR	40 minutes
5	Control +10% CR	40 minutes
6	Control +15% CR	40 minutes

2.3 Specimen Preparation and Testing Method

The effect of PET and CR binder was characterized by performing penetration and softening point test as per ASTM D5 [13], ASTM D36 [14] respectively. To investigate the bonding of bitumen with the aggregate after dry and wet condition PATTI (Pneumatic Adhesion Tensile Testing Instrument) was performed in terms of the BBS test as per ASTM D 4541 [15]. All samples were tested under dry and water cured conditions (24, 48, and 72 hours). The PET (5%, 10%, and 15%) and CR (5%,10% and 15%) by weight of binder were used in the control binder to check the bond strength of the bitumen aggregate system. The burst pressure at which stud detaches from the aggregate sample can be determined from PATTI which is then used in equation 1 to calculate Pull Off Tensile Strength (POTS).

$$POTS = \frac{(BP \times A_g) - C}{A_{ps}} \quad (1)$$

POTS is the pull-off tensile strength, BP is burst pressure
A_g is the contact area having a value of 2620 mm^2, C is the piston constant 0.286
A_{ps} is the area of pull-stub having a value of 127 mm^2, for this study F-4, stub type was used.

To investigate the moisture susceptibility of 60-70 pen grade, PET and CR modified binder, RBT as per BS EN 12697-11 [16] was performed. For the preparation of sample 170g aggregate and 8g bitumen was mixed. The bitumen coating on the sample was taken after 6, 24, 48, and 72 hours of rolling time.

The research methodology takes up for this work is given below in Figure 1.

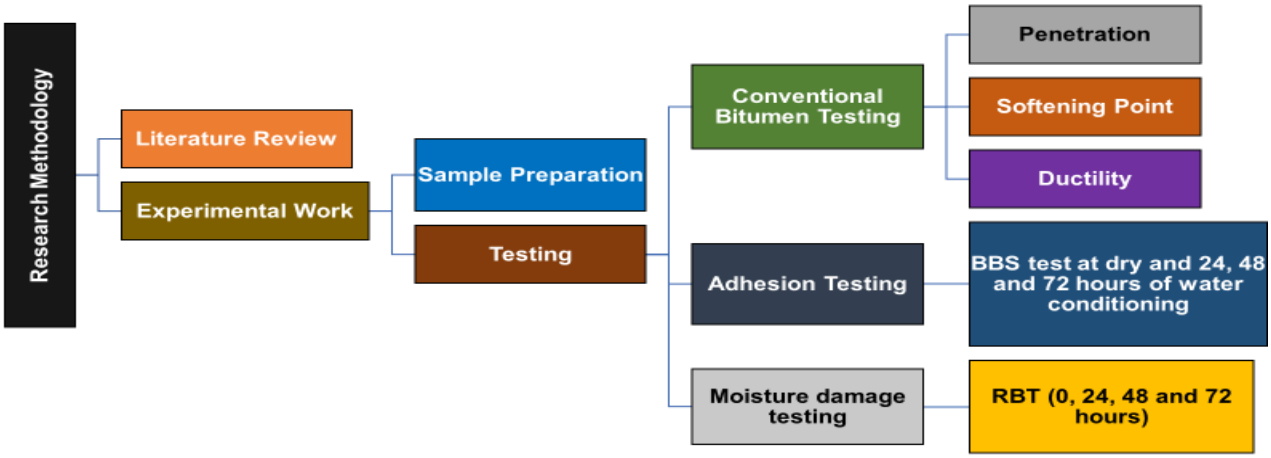

Figure 1: Research Methodology

3 RESULTS AND DISCUSSION

3.1 Conventional Testing

In this approach to study the effect of modifiers on bitumen conventional testing was performed. The purpose of performing penetration and softening point test are to check whether modified bitumen becomes soft or hard because softening and hardening of bitumen have a direct effect on adhesion and moisture damage [17]. The experimental results of conventional testing are shown in Figures 2.

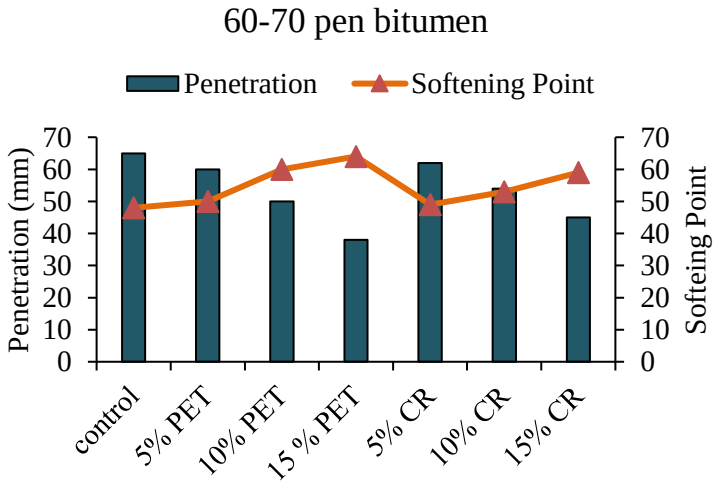

Figure 2: 60-70 pen grade modified and unmodified bitumen penetration and softening point values

The addition of 15% PET by weight of binder in 60-70 pen bitumen decreases the penetration value by 43%, whereas an increase of 34% in the softening point was observed as compared to the control binder. In 15% CR modified 60-70 pen bitumen a decrease of 32% in penetration value and an increase of 23% in value of softening point was observed as compared to the control binder.

Hence, as the dosage of PET and CR increases, penetration values decrease, and softening point increases which means the addition of PET and CR in 60-70 pen bitumen, the binder becomes harder. The addition of PET in binder makes the binder harder than CR.

3.2 Evaluation of adhesion using BBS test

In the experimental evaluation of the effects of PET and CR on adhesion, the Pneumatic Adhesion Tensile Testing Instrument (PATTI) was used. The main test advantage is that the adhesion between bitumen and aggregate can be found easily in the sense of force. The addition of 15% PET and CR by weight of binder in 60-70 pen bitumen 36% and 31% POTS values increase in dry condition compare to control binder respectively. The error bar in the figure-3 shows the positive mean deviation values from the 60-70 pen bitumen.

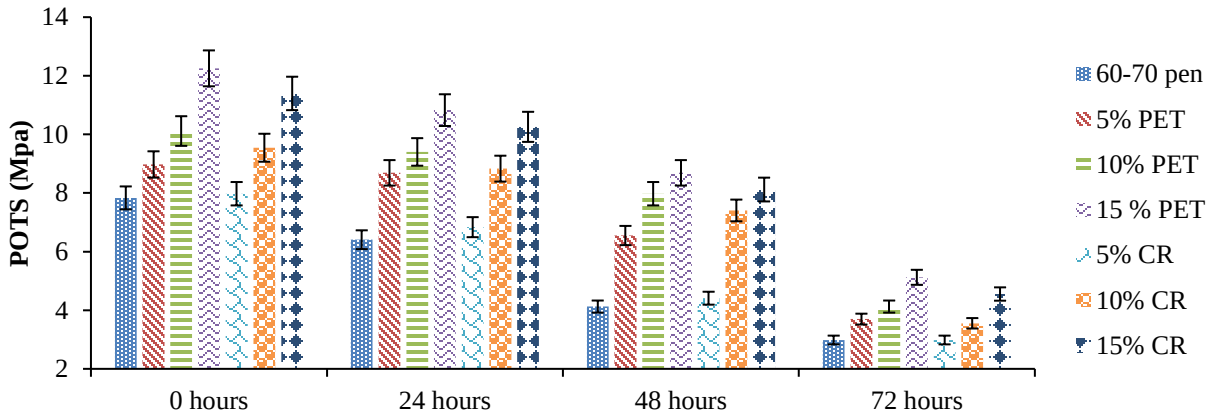

Figure 3: POTS values of 60-70 pen grade modified and unmodified bitumen at dry and wet conditioning

After 24, 48, and 72 hours of wet conditioning the POTS values of the PET and the CR decrease but remain higher than that of the control binder because the water penetrates the bitumen-bitumen interface and bitumen-aggregate interface which weakens the bond [18].

In 60-70 pen modified bitumen with the PET higher POTS values as compared to control binder were observed in dry conditions. But the PET modified bitumen showed lesser values after water conditioning as compared to dry conditions. CR shows lesser values of POTS in dry and water conditions as compared to PET but shows improved results as compared to the control binder.

3.2.1 Failure surface analysis

When stub detaches from the aggregate surface, there are two types of failures, one is an adhesive failure and the other is a cohesive failure. Visual identification of bitumen remains on aggregate sample determines the type of failure. When bitumen remains on the aggregate surface area greater than 50% then it is cohesive failure else it is an adhesive failure. In the case of 50% bitumen remains on aggregate the failure is cohesive-adhesive.

Table:2 60-70 pen Bitumen with the percentage of coverage area

	60-70 pen	5% PET	10% PET	15 % PET	5% CR	10% CR	15% CR
0 hours	70C	77C	70C	68C	71C	83C	87C
24 hours	59C	69C	61C	63C	67C	74C	76C
48 hours	50C/A	58.5C	49.9A	49A	50C/A	59C	63C
72 hours	30A	43A	38A	36A	39A	38A	41A

CT* curing time; A, adhesive failure; C, cohesive failure; C/A, 50% adhesive 50% cohesive failure

Table 1 shows the percentage of bitumen coverage and the failure type after dry and wet conditioning of the sample. In 60-70 pen bitumen modified by PET higher bond strength were achieved and failure changes from cohesive to adhesive after 24 hours of water conditioning. Whereas in 60-70 pen bitumen modified by CR show higher bond strength and failure changes directly from cohesive to adhesive after 48 hours of wet conditioning.

3.3 Moisture damage evaluation using RBT

Rolling bottle test was performed to measure the affinity between bitumen and aggregate. From figure 4, it can be concluded that the increase in rolling time decreases the bitumen coverage. PET and CR modified bitumen adhesion effects are clear as compared to the control binder. The 15% PET and CR modified binder increases 30% and 15% coverage as compared to control binder after 72 hours of rolling time. In the PET and the CR modified bitumen of the 60-70 pen grade adhesion effect is prominent in PET modified bitumen as compared to the CR and control binder.

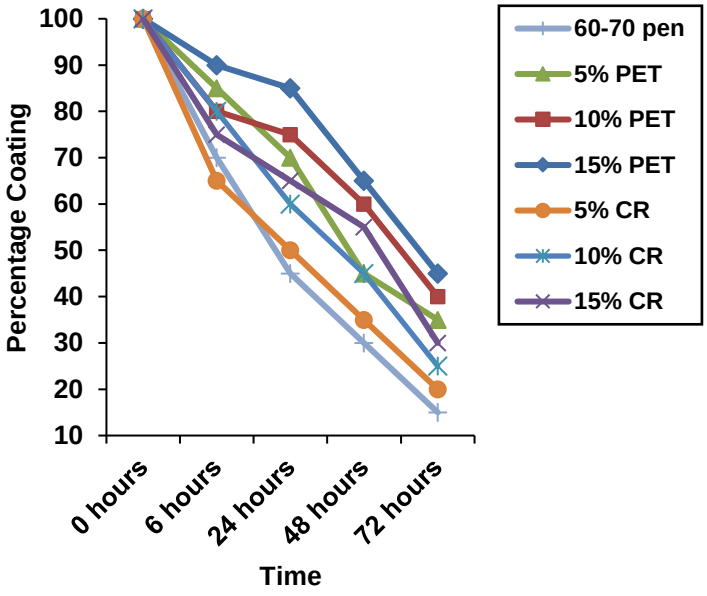

Figure 4: Comparison of the percentage of bitumen coverage of 60-70 modified and unmodified bitumen at different duration

4 CONCLUSION

The following conclusions have been drawn from the results obtained during the study.

- With the addition of 15% PET and CR, the penetration value decreases 43% and 32%, thus the softening point increase 34% and 23% respectively as compared to the 60-70 pen grade bitumen. Thus, the addition of PET and CR modified bitumen become hard thus penetration values decrease and softening point increases.

- The addition of 15% PET and CR in control binder POTS values increases by 36% and 31% respectively as compared to 60-70 pen bitumen at the dry condition. After 72 hours of water conditioning the POTS values of 60-70 pen bitumen, PET and CR modified binder decreased as compared to dry condition. Hence, PET modified binder shows higher POTS values as compared to the CR and 60-70 pen bitumen binder.

- By adding the amount of 15% PET and CR shows 30% and 15% more bitumen coverage as compared to the 60-70 pen bitumen binder. At 72 hours of rolling time, PET binder shows more bitumen coverage as compared to the CR and 60-70 pen bitumen binder.

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