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INFLUENCE OF MORINGA OIL ON ADHESION AND MOISTURE SUSCEPTIBILITY OF RECLAIMED ASPHALT PAVEMENT

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Abstract- Due to high traffic loading and environmental exposure the bitumen binder becomes stiff which losses its physical and chemical properties. To use the high content of Reclaimed Asphalt Pavement (RAP) in asphalt mixture, recycling is done. Recycling of asphalt pavement not only save the money but also at the same time it protects our environment. Therefore, to recover its properties different types of rejuvenators have been used in RAP. In this study Moringa Oleifera (MO) lam seeds oil (0%, 3%, 6% and 9% by weight of binder) is used as a rejuvenator and Bitumen bond strength (BBS) and Rolling Bottle Test (RBT) is performed. Results of Conventional testing revealed that by adding MO oil in RAP binder penetration values increases and softening point decreases respectively, as percentage increases. Results of BBS testing shows that by increasing the percentage of MO oil in RAP Pull of Tensile Strength (POTS) values are decreased and failure changes from cohesive to adhesive after wet conditioning.

Keywords- Conventional, Reclaimed Asphalt Pavement, Recycling, Adhesion

1 INTRODUCTION

Due to the oxidation and environmental exposure, flexible pavements start to destroy after a few years. About 80% of the road network consists of flexible pavements. The construction of flexible pavements is increasing vividly. As the demand for flexible pavements is increasing, the demand for aggregate and bitumen binder is also increasing. In order to control the new demand of aggregate and bitumen binder in the construction of road, the Reclaimed Asphalt Pavement (RAP) should be used. The materials which are obtained from the milling, recycling and breaking of the old pavement is called RAP. It consists of aged binder, which is stiff and hard, although RAP is good in rutting but prone to failure in fatigue cracking and moisture damage. To use the higher percentage of RAP in asphalt pavement there is need to use the recycling agent (RA) or rejuvenators in RAP to overcome the lost characteristics of bitumen binder[1].

The aged binder comprises of asphaltene and maltenes, with the passage of time due to traffic loading and environmental exposure the ratio of asphaltene to maltenes disturb and binder become stiff and aged. The maltenes content decreases due to aging but asphaltene contents increase, this proportion changes the chemical structure of bitumen binder. The ratio of asphaltene to maltenes can be recovered by using a rejuvenator or RA. The care should be taken by deciding the amount of rejuvenator because the dosage of RA plays a vital role in restoring the bitumen binder properties. To decide the amount of RA, needed to obtain a particular grade (performance grade, penetration or viscosity grade), different criteria have been used such as rheological characteristics, high-temperature viscosity, performance characteristics etc.[2]. In order to decrease the stiffness, viscosity and brittleness in rap binder the rejuvenators which are obtained from natural resources are added. In the previous study maltenes base and vegetable base oil have been added in high aged binder and results show better in improving the flow characteristics [3]. The elasticity and viscosity of the aged binder have recovered in the previous study by adding different types of organic oil rejuvenators [4]. The recycled cooking oil is good in improving low-grade temperature [5]. Since the aged binder is brittle and stiff, therefore it is necessary to understand the low temperature cracking properties of the aged binder when using RAP [6]. Time-temperature behavior and mechanical

restoration can be obtained by with the determination of a dynamic shear rheometer [7]. The physical characteristics like penetration, ductility, softening, penetration index, viscosity, and penetration ratio of aged binder can be improved by its level of virgin binder at the optimum dosage of waste edible vegetable oil different for different bitumen binder [8].

Although the stiffness and brittleness properties of RAP binder can be used to avoid permanent deformation at the same time it loses physical properties and water penetrates into the cracks and moisture susceptibility increases due to cracking. Therefore, to overcome this issue MO oil is used as a rejuvenator to recover its lost physical characteristics and decreases the moisture susceptibility to the virgin binder level that 100% RAP can be used in the flexible pavement and it can save the money and also protect the environment.

1.1 Research significance

The RAP material, which is obtained from milling, ripping and breaking of roads comprises of aged binder. It cannot be used to 100% in the new construction road without adding rejuvenators because it loses the physical properties and moisture susceptibility is also compromised and it also causes environmental pollution because of emission of carbon compounds. There is need of recycling to reduce the use of natural resources and use renewable source. MO oil is used as rejuvenator to recover the properties (physical and moisture damage resistance) which has been lost during aging. It is renewable and green additive which can protect our environment and can save the cost by using with RAP binder

2 EXPERIMENTAL AND RESEARCH METHODOLOGY

Aggregate from Margalla crush and MO Oil as a rejuvenator is used. MO oil is a renewable and biodegradable source that is found in the Punjab region of Pakistan. It is an antioxidant agent in which the oleic acid is to be found about 70% which means that it has very low unsaturated contents. The RAP material was collected from N-5 Taxila, Pakistan on the tail road which is a one-way double lane. Aged binder was extracted by using centrifuge apparatus and ottava according to ASTM D2172 and ASTM D5404 respectively. The aged bitumen binder was heated at 145 ^{o}C for 45 minutes after that MO oil was added by varying percentages of 0%, 3 %, 6 % and 9% by weight of aged binder by glass rod giving successively heat and shake. The Chemical composition of MO oil is shown in table 1.

Table 1- The Chemical Composition of Moringa Oil

Rejuvenator Composition	**Moringa Oil (%)**
Palmitic acid	6.45
Oleic acid	73.22
Stearic acid	5.50
Arachidic acid	4.08
Behenic acid	6.61

The effect of moringa oil in the aged binder was characterized by performing penetration and softening point test as per ASTM D5, ASTM D36 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. For the preparation of the sample, the bitumen binder and sandstone aggregates were heated at 145 ^{o}C to ensure the proper bonding of stud with aggregates.

To investigate the moisture susceptibility of aged and rejuvenated binder, RBT as per BS EN 12697-11 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 flow chart of research methodology is given below in figure 1.

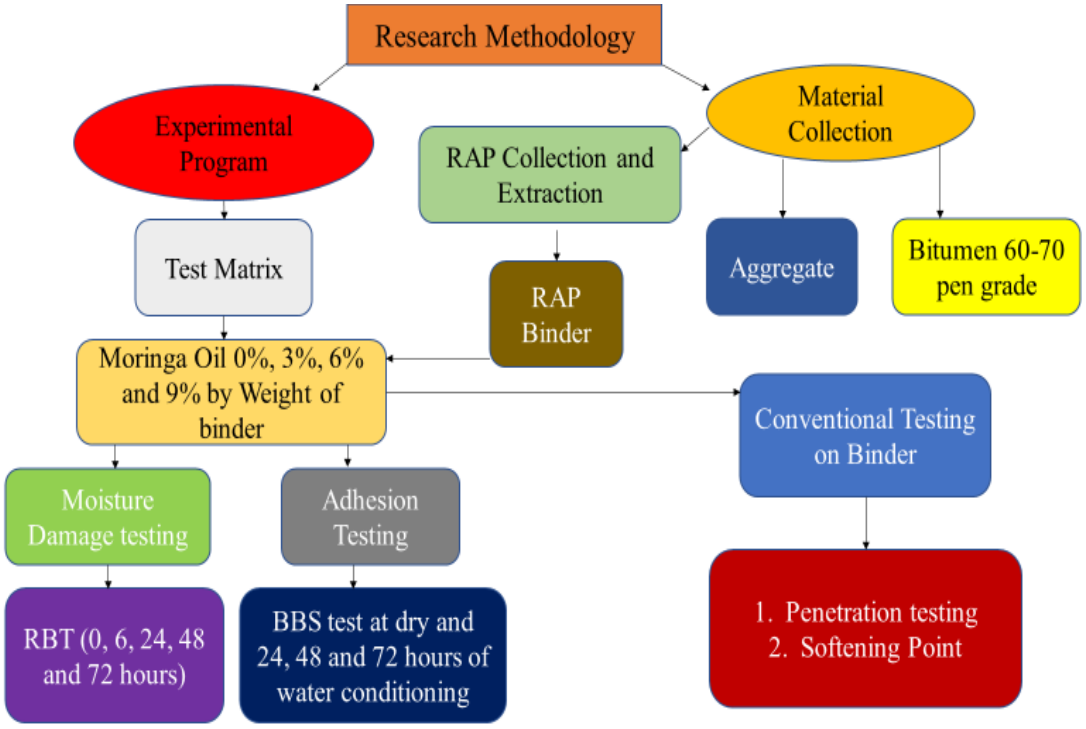

Figure 1- Research Methodology

3 RESULTS

3.1 Physical testing

To check the effect of MO oil in the RAP binder physical testing (penetration and softening point test) was performed. From figure 2 the value of penetration of RAP binder was decreased 57% of the 60-70 pen bitumen. By adding 3% by weight of binder of MO oil in the RAP binder the value of penetration was increased about 42% as compared to the 60-70 pen bitumen. By adding 6% amount of MO oil in the RAP binder the value of penetration was increased about 31%. By adding the 9% amount of MO oil in the RAP binder the value of penetration meets the 60-70 pen bitumen.

The value of the softening point of the RAP binder was increased by 38% as compared to the 60-70 pen bitumen. By adding 3% of MO oil the value of softening point decreased about 20% of the 60-70 pen bitumen. By adding 6% of MO oil in the RAP binder the value of softening point decreased about 10% of the 60-70 pen bitumen. By adding 9% of MO oil in the RAP binder the value of softening point meets the 60-70 pen bitumen.

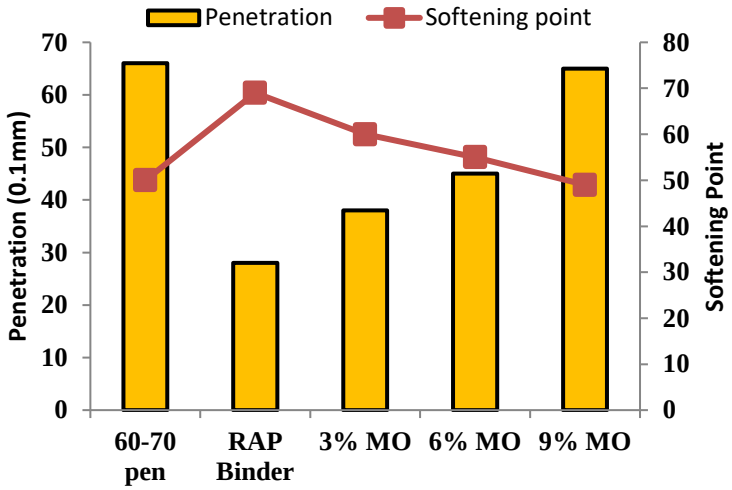

Figure 2- 60-70 pen bitumen, RAP and modified binder penetration and softening values

3.2 BBS testing

The experimental investigation of 60-70 pen bitumen, reclaimed asphalt pavement (RAP), and modified binder (0%, 3%, 6% and 9% MO oil) is done by using the Pneumatic Adhesion Tensile Testing Instrument (PATTI). All samples were tested under dry and wet conditions (0, 24, 48 and 72 hours). The 60-70 pen bitumen, RAP and modified binder were used to check the bond strength of bitumen and aggregate. The percentages of RAP binder with moringa oleifra lam seeds oil (MO oil) were checked at 0%, 3%, 6% and 9%. The burst pressure at which stud disperse from the aggregate can be found from PATTI which is then used in equation 1 to find Pull off Tensile Strength (POTS).

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

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-stud having a value of 127 mm^2, for this study F-4, stud type was used.
From figure 3 the value of POTS of RAP binder at dry condition increased by about 52% as compared to the 60-70 pen bitumen. By adding the 3% amount of MO oil in the RAP binder the value of POTS increased about 27%, 6% amount of MO oil added in the RAP binder to increase the value of POTS by 13% and addition of 9% amount of MO oil in the RAP binder the value of POTS meets the value of the 60-70 pen bitumen binder at dry conditioning respectively.
After 72 hours of water conditioning the POTS values of 60-70 pen bitumen, RAP and modified binder decreased as compared to dry conditions. It is because the water penetrates the interface between bitumen and aggregate which weakens the bond thus POTS values decrease [9]. The error bar in the figure-3 shows the positive mean deviation values from the 60-70 pen bitumen.

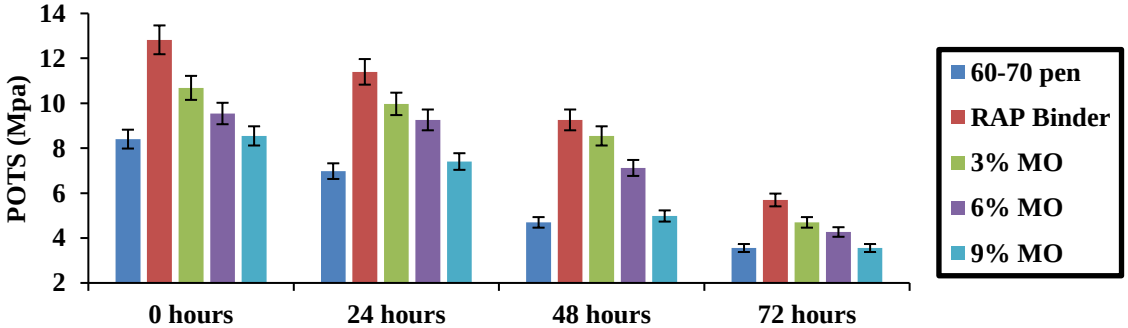

Figure 3- POTS values of RAP, 60-70 pen bitumen, and MO modified binder after dry and wet conditioning.

3.2.1 Failure Pattern analysis

At dry conditioning, bitumen makes a strong bond with aggregate. When stud displaces the aggregate the remaining bitumen on aggregate confirms the type of failure. When bitumen remains on aggregate is more than 50% then failure is cohesive if it is less than 50% then it is adhesive. At dry condition, more bitumen remains on the aggregate surface which means failure is cohesive. After water conditioning, water penetrates the bitumen-aggregate interface which deteriorates the bond thus adhesive failure takes place.

Table 1- RAP, Virgin, and MO modified binder bitumen coverage and failure type.

CT*	60-70 pen	RAP Binder	3% MO	6% MO	9% MO
0 hours	60C/A	75C	55C	80C	60C
24 hours	45A	60C	50C/A	60C	50C/A
48 hours	35A	40A	30A	25A	35A
72 hours	25A	30A	25A	20A	30A

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

From the above table, failure type changes from cohesive to cohesive-adhesive then adhesive failure at 24 hours of water conditioning at 9% MO modified binder. At RAP binder failure change to cohesive to adhesive after 24 hours of wet conditioning.

3.3 Rolling Bottle Test

The RBT is performed to check the moisture susceptibility of 60-70 pen bitumen, RAP and modified binder.

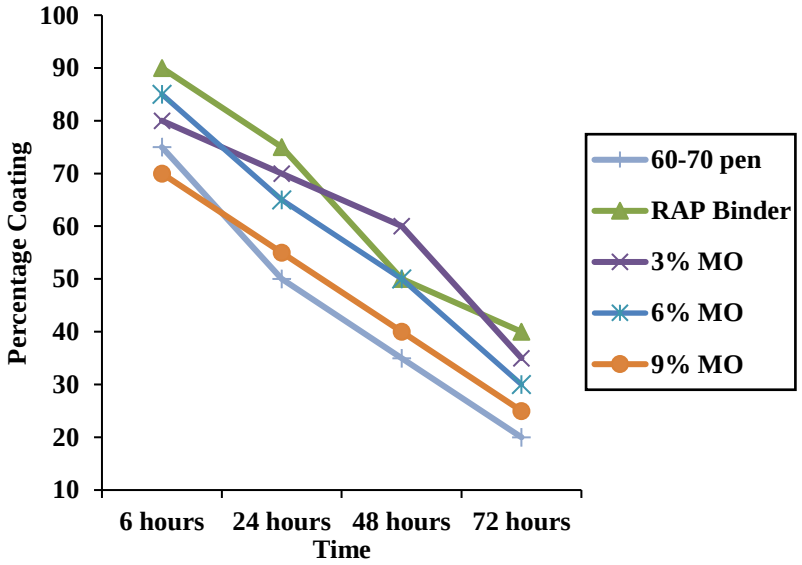

Figure 4-Comparison of bitumen coverage between 60/70 pen, RAP and modified binder at different duration.

From figure 4, it can be seen that with the increase in rolling time the affinity of bitumen decreases. At 72 hours of rolling time RAP binder shows 20% more bitumen coverage as compared to the 60-70 pen bitumen. By adding 3% and 6% amount of MO oil in the RAP binder shows 15 % and 10% more bitumen coverage as compared to the 60-70 pen bitumen respectively. While adding 9% amount of MO oil in the RAP binder shows similar results as compared to 60-70 pen bitumen.

4 PRACTICAL IMPLEMENTATION OF RESEARCH WORK IN INDUSTRY

The RAP material, which is obtained from milling, ripping and breaking of roads comprises of aged binder. While using MO oil in the RAP binder maximum RAP content can be used in the industry which give the similar results to virgin binder. If the production of MO oil is increased in Pakistan at large scale which can be proven cost effective and environmental friendly rejuvenator for the RAP binder. The aged binder has been used in the industry maximum up to 60%.

5 CONCLUSION

Following conclusions can be drawn from the conducted study:

- With the addition of 3% and 6% MO oil in the RAP binder, the penetration value increases 42% and 31%, thus the softening point decreases 20% and 10% respectively as compared to the 60-70 pen bitumen. While with the addition of 9% MO oil in the RAP binder gives the similar result of 60/70 pen bitumen.
- RAP binder shows 52% higher POTS values as compared to the 60-70 pen bitumen. The addition of 3% and 6% MO oil in the RAP binder POTS values increases by 27% and 13% respectively as compared to 60-70 pen bitumen. After 72 hours of water conditioning the POTS values of 60-70 pen bitumen, RAP and modified binder decreased as compared to dry condition.
- At 72 hours of rolling time RAP binder shows 20% more bitumen coverage as compared to the 60-70 pen bitumen binder. By adding the amount of 3% and 6% MO oil in the RAP binder shows 15 % and 10% more bitumen coverage as compared to the 60-70 pen bitumen respectively. While addition of 9% of MO oil in the RAP binder shows similar results as compared to 60-70 pen bitumen.

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