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RESEARCH ARTICLE

EFFECT OF RECLAIMED ASPHALT PAVEMENT ON THE BINDER RHEOLOGICAL PROPERTIES

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ABSTRACT

Using Reclaimed Asphalt Pavement (RAP) not only economical but also better performance and also conserve the natural resources. To incorporate RAP in asphalt mix design, it is vital to know the amount and quality of the residual binder. The residual binders obtained from two RAP sources using solvent extraction and arson recovery methods were blended with a virgin binder in different proportions. Dynamic shear modulus, stiffness and viscosity of the different blends were compared. Viscosity and PG grading blending charts were developed based on the corresponding test data. It was concluded that the properties of the blends depend on the individual properties of the binders. The stiffness of the binder is increasing with increasing RAP binder. This research only address the binder related study so to quantify RAP in asphalt mix design the other factors like aggregate and volumetric properties need proper considerations.

INTRODUCTION

The use of Reclaimed Asphalt Pavement (RAP) in different road related applications become more widespread in last two decades. The materials present in old asphalt pavements have residual value even when the pavements themselves have reached the ends of their service lives. Recognizing the value of those existing aggregate and asphalt resources, agencies and contractors in many countries have made extensive use of RAP in producing new asphalt pavements for decades. Use of RAP has proven to be economical and environmentally sound. In addition, the performance of pavements with properly prepared recycled asphalt in terms of fatigue, rutting, thermal resistance and durability proved to be satisfactory (Al Qadi *et al.,* 2007 and TFHRC). RAP is typically used between 10 to 30 % in hot recycling asphalt mixtures. The environmental and financial restrictions are forcing the researchers to incorporate high percentage of RAP in pavement construction. One of the main barriers in achieving this goal is the increased stiffness of the RAP binder. The Superpave system requires determining the rheological properties of asphalt binders for a good design and evaluation of hot mix asphalt. Flexible pavement distresses can be predicted by using the rheological characteristics of asphalt binders (Roberts *et al.,* 1996). The main rheological parameters of PG binders are dynamic modulus and phase angle at high temperatures and creep stiffness and rate of creep relaxation at low temperatures. These parameters are also used to characterize RAP binders and their blends. The main objective of this study was to evaluate the rheological properties of ARL60/70 with two different RAP sources binders in laboratory and see the performance of the different blends.

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MATERIAL CONSIDERATIONS

Aging of binders is a chemical process that is known to be source-specific; some binders are observed to age faster and become harder than others. Therefore, for proper reuse of the RAP material, there is a need to characterize aged properties and aging performance of binders so that the resistance to aging is taken into account in selecting the fresh binder, and in predicting performance of recycled asphalt pavements. RAP material was obtained in form of chunks from two sites (Source 1 & Source 2) along national highway N-5, Pakistan. No proper stock piling of the RAP materials was incorporated and they were subjected to severe aging and weathering which has adverse effects on the rheological properties. The virgin binder 60/70 penetration grade was obtained from Attock Refinery Limited (ARL), Rawalpindi. ARL is using local heavy crude oil blend of ~ 7 to 10 crude containing 3-5% asphaltenes for production of 60/70, 80/100 grade asphalt. Most of local heavy crude are produced from northern part of the country. In Pakistan the binders are still graded by penetration value and no PG binders are available for the experimental work. In previously research this binder was graded as PG 58-22 with softening point of 66.5 C^0 and flash point of 255 C^0. The ARL 60/70 binder was used in different percentages (0, 10, 20, 30, 60 and 100) with aged binder. For low RAP contents (5 to 20 percent) the impact of the characteristics of the RAP material on the final products is minimal so there is no need to do the tests. On the other hand, for high RAP contents, the RAP characteristics would have significant impact on the performance of the final products and therefore they need to be properly tested.

Laboratory Testings

The extracted asphalt binders and their blends with ARL 60/70 were subjected to performance testing to determine their PG

Table 1. Creep stiffness and creep rate change

RAP Type	Increase stiffness rate MPa / % RAP			Decrease creep rate MPa/ % RAP		
	-6^0C	-12^0C	-18^0C	-6^0C	-12^0C	-18^0C
Source 1	0.618	1.204	1.913	-0.0014	-0.0019	-0.0014
Source 2	0.713	1.198	2.034	-0.0014	-0.0017	-0.0014

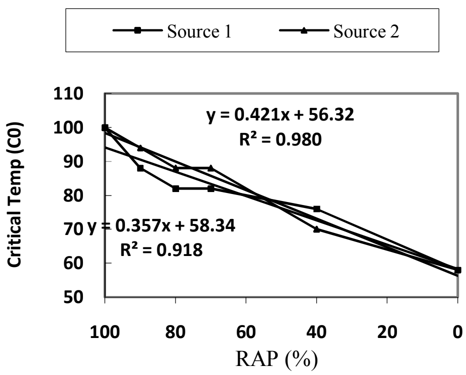

Fig. 1. Blending chart for PG grading

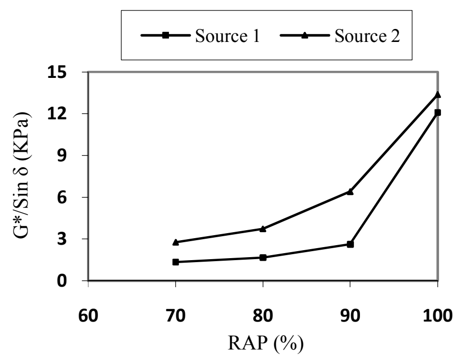

Fig. 2. G^*/Sinδ trend at high RAP content at 88^0C

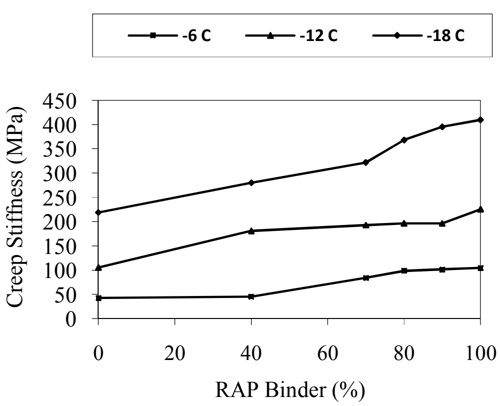

Fig. 3. Creep stiffness of blends with source 1

grades according to AASHTO R 29-02. The tests conducted were Dynamic Shear Rheometer (DSR), Bending Beam Rheometer (BBR) and Rotational Viscometer (RV) tests.

DSR testing

In this study, DSR testing was accomplished by using Malvern's Bohlin Shear Rheometer. All the tests were conducted in controlled strain mode at 10 rad/s (1.59 Hz)

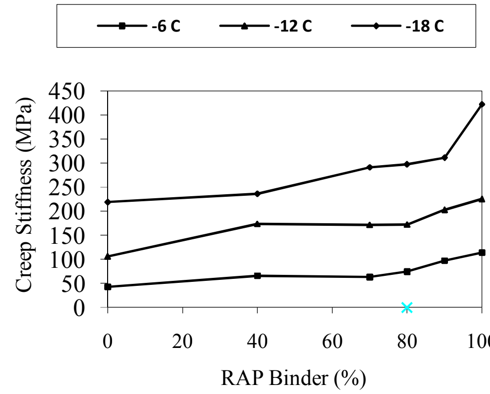

Fig.4 Creep stiffness of blends with source 2

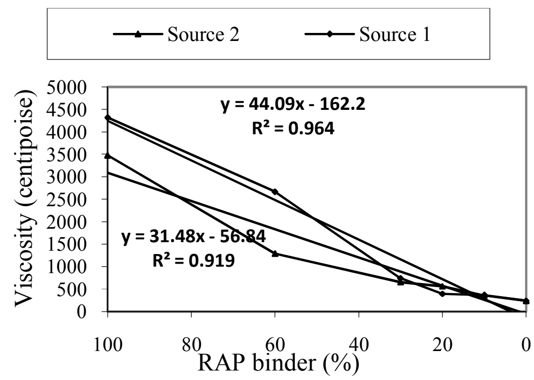

Fig. 5. Viscosity blending chart at 135^0C

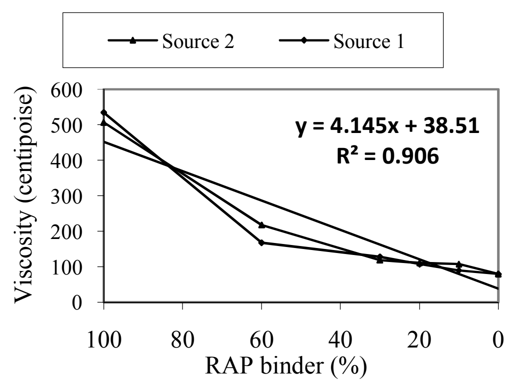

Fig. 6. Viscosity blending chart at 165^0C

according to AASHTO T315. A parallel plate of 25mm was used for all the blends testing. On all blends, each test was performed at 58^oC for the first trial as suggested by AASHTO R 29, whereas for subsequent trials the temperature was automatically selected at interval of 6^oC by the software. The temperatures were increased or decreased until a value for $G^*/\sin\delta \leq 1.00$ kPa was obtained. First, the DSR test was performed on virgin binders ARL 60/70 to determine the high critical temperature to satisfy the criteria of $G^*/\text{Sin}\delta \geq 1$Kpa. Then the DSR was performed on all the blends to establish the rheological properties—dynamic shear modulus (G*) and phase angle (δ) to determine the G*/Sin δ value.

BBR testing

The BBR test was performed according to AASHTO TP 1, to measure how much a beam deflects under a constant load at a constant temperature. The BBR basically subjects a simple asphalt beam to a small load (1000mN) over 240 seconds. The specimens (102 mm *12.5mm *6.25mm) were prepared using a rectangular aluminium mold. The test was performed at three temperatures (-6,-12,-18). The two parameters determined were creep stiffness (S) and m-value.

RV testing

This test was performed on all the extracted binders and their blends with ARL 60/70. The viscosity was determined at a speed of 20 rpm and two temperatures, 135 C^0 and 165 C^0 which covers the compaction and mixing temperature ranges.

RESULTS AND DISCUSSION

The objective of this study was to evaluate the rheological properties of binder with various RAP percentage using Superpave system. In this section the Superpave testing on the binder and their blends are presented and discussed. The DSR gives rheological parameters i.e., complex shear modulus (G^*) and phase angle (δ). The blending chart for high critical temperature grade obtained from DSR is shown in Figure 1. After DSR testing on the virgin, extracted binders and their blends it has been observed that stiffness ($G^*/\sin\delta$) of the binders increases with the increase in the RAP percentage but it decreases with the increase in the temperature. It is also noticed that at all temperatures; stiffness is more significantly influenced with changes in the RAP content especially once the RAP percentage is high as shown in Figure 2. The effect on the stiffness on the virgin binder at low RAP content is not significant. The results of BBR show that the creep stiffness (S value) increases with the increase in the RAP content and decrease in temperature shown in Figure 3 and Figure 4. Although it increase with slow rate as shown in Table 1 (Maximum 2.034 MPa/% RAP). The increase rate was higher at the lower temperature. The Low temperatures also affect the m-value and cause the increased flexural creep stiffness of the binders and their blends. This increased stiffness tends to cause low temperature cracking in the pavements. The decrease rate for the creep values was very small (Table 1) and this small rate of change suggest that increasing RAP content does not decrease the creep rate significantly. The blending charts for viscosity at $135C^0$ (Compaction temperature) and $165C^0$ (Mixing temperature) are shown in Figure 5 and Figure 6 respectively. With the increasing RAP content, the viscosity increases with a good linearity which confirm the blending option.

Findings and Conclusions

The evaluation and testing on the binders using Superpave system, terminates on the following conclusions.

- As expected, increasing the amount of RAP binder in blend increases the stiffness of the binder. But decrease with the increase in temperature.
- The Source 1 RAP has a little high % of residual binder and shows a little less aging than the Source 2 RAP.
- The results of BBR show that the creep stiffness (S value) increases with the increase in the RAP content under low temperature conditions.
- Increasing the RAP binder percentages increases the stiffness, viscosity and critical temperature of the blend.

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