LABORATORY EVALUATION OF ASPHALT MIXES CONTAINING VARIOUS PERCENTAGES OF RECYCLED ASPHALT PAVEMENT

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ABSTRACT

Highway authorities around the world are striving to use larger quantities of recycled asphalt pavement (RAP) in order to meet economic and environmental constraints. Widespread road networks are a basis for economic development of any region. RAP use is not only cost effective and environmental friendly, helps in conservation of natural resources and is similar or even better in performance than control asphalt mixtures. This paper presents the experimental study to evaluate the moisture susceptibility of RAP incorporated hot mix asphalt (HMA) using Hamburg Wheel-tracking Device (HWTD). In this research all tested HMAs with RAP showed better performance than the virgin mixes. Mixtures containing RAP showed substantial variability and the variability increased with the increase in RAP content.

Keywords: Reclaimed asphalt; Moisture damage; Marshall Stability; ductility; penetration

INTRODUCTION

Since mid-1970s, RAP has been effectively used in HMA. It has proved to be economical, environmentally sound and effective in increasing the rutting resistance of asphalt mixtures. Advancement in asphalt plants and processing technology made it possible to use HMA mixes with RAP contents of 50% or more. Kennedy, McGennis and Roberts (1983). Experience has shown that HMA mixtures with RAP has performed same or even better than the mixtures produced from virgin materials both in Marshall and Superpave mix design, when properly designed and constructed Al-Qadi, Elseifi and Carpenter (2007).

In an era in which highway industry is striving to adopt more sustainable approaches, asphalt recycling is a step forward in the direction of maintaining pavement systems. High percentage of RAP has evident impact on durability and structural performance i.e., fatigue, fracture and permanent deformation characteristics of HMA mixtures. Al-Qadi, Aurangzeb, Carpenter (2012). Rutting in asphaltic concrete pavements is dependent on numerous factors i.e. gradation and quality of aggregate, stability of asphalt mixes, type of binder, percentage of the bituminous binder, air void contents, degree of compaction, environmental conditions including traffic, temperature and humidity, repeated traffic loading cycles, the substructure and the bearing capacity of the sub grade, Khan (2008). In current study Superpave method was used for evaluation of asphalt mixtures containing various percentages of RAP. RAP contents of 0, 10, 20, 30, 45, 60 and 100 percent were used to check the volumetric and then optimal value of RAP is used to get the effect of RAP contents on rutting and moisture damage. The objectives of the present study are to evaluate the moisture susceptibility of Hot Mix Asphalt (HMA) mixtures containing RAP content by using Hamburg wheel-tracking device and Cost Comparison of Hot Mix Asphalt mixture containing RAP with control Mix.

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In last few decades continual growth in traffic volume has resulted in premature pavement failures of approximately the whole road infrastructure of Pakistan due to increased axle load and high temperature, Khan (2008). Lack of enough funds for maintenance and rehabilitation of roads, RAP inclusion is current need for energy stricken country like Pakistan. RAP usage in HMA mixtures not only resulted in cost savings between 18 and 25% in the required virgin asphalt but also mixture stiffness with RAP content can also be observed up to 15% .Gardiner and Wagner (1999). Aged binder plays an important role in mixture's ability to resist the permanent deformation as it increases material stiffness of RAP. Sousa, Jorge, Craus, Monismith and Carl (1991). If proper angular coarse and fine aggregates are used, they impart great impact on rutting resistance Brown and Cross (1992). To check the effect of moisture on physical properties and mechanical behavior of asphalt pavements, Hamburg Wheel-Tracking Device (HWTD) tests are used to determine moisture susceptibility and rutting resistance. HWTD simulate the field conditions and their corresponding damages on HMA mixtures Hunter and Ksaibati (2008). It measures the combined effect of rutting susceptibility and moisture damage in terms of stripping, steel wheel of HTWD moves across the surface of asphalt concrete specimen that is immersed in hot water that generally is 40ºC to 50ºC but this can vary from 25 ºC to 70 ºC. This criterion is used for pass or fail of rutting and moisture susceptibilities. Cooley, Kandhal, Buchanan , Fee and Epps (2000).

MATERIALS AND METHODS

In this research, coarse and fine aggregates used were from Margalla quarry alongwith 60/70 penetration grade of bitumen from Attock Refinery Limited (ARL), Rawalpindi. The grade 60/70 was selected because it is normally used in practice and is suitable for colder to moderate temperature regions in Pakistan. RAP material in milled form was collected from Lahore Islamabad Motorway M-2 project. 4-inch diameter specimens for volumetric of RAP were prepared using Marshall testing procedure following ASTM D 6926 (2007) and Superpave procedure following ASTM D6925 for performance testing specimen preparation having NMAS of ½ inch for asphalt concrete wearing course (ACWC). Mixtures have been designed for heavy traffic loading and specimens were tested for moisture susceptibility test. Based on that, analysis of result obtained was carried out and later conclusions and recommendations were drawn.

EXPERIMENTAL MEASUREMENTS

Aggregate gradation used in testing was NHA class B according to NHA (1998) specifications for dense graded surface course mixtures. The nominal maximum aggregate size (NMAS) selected for class B wearing coarse gradation was ½ inch. Table 1 shows the selected gradation which is plotted with percentage passing verses sieve sizes. Asphalt percentage present in RAP material was determined through asphalt extraction by using AASHTO T 319-03, "Quantitative Extraction of Asphalt Binder from Asphalt Mixtures" and AASHTO T 170, "Recovery of Asphalt from Solution by Abson Method" AASHTO T 319-03 (2006) and AASHTO T170-00 (2005). The gradations of virgin and RAP materials after extraction are shown in Table 1. Asphalt binder from RAP mixture using chlorinated solvent is extracted using above AASHTO standard. These methods are used not only to determine optimum asphalt contents of asphalt mixtures also used to perform sieve analysis and if required, for additional testing on recovered aggregates. Centrifuge extraction method is applicable for both HMA & RAP sampled from pavement or stockpile. After complete centrifuge extraction method using chlorinated solvent. The asphalt content of RAP was found to be 4.46%.

Table 1. Virgin and RAP gradation (after extraction)

Sieve size (mm)	Virgin	M-2 RAP
	Percent passing	
19	100	100
12.5	82.5	94.35
9.5	70	83.65
4.75	50	63.9
2.38	30	46.65
1.18	10	16.3
0.075	5.5	8.3

Before using RAP in HMA mixture it is essential to evaluate the extracted binder properties ,AASHTO T 49-06(2011) AASHTO 51-08 (2008) and their blends with virgin binder. Blends of reclaimed binder and virgin binder were tested for penetration and ductility; the results are presented in Table 2 following ASTM D5 (2006) ASTM D113 (2008). Literature research shows that Low RAP content up to 20% can be designed without changing the binder grade. Table 2 shows the penetration and ductility of all the blends.

Table 2. Penetration and ductility for all the blends

RAP/Virgin ratio	Penetration	Ductility (cm)
0/100	63	120
10/90	59	106
20/80	56	97
30/70	48	88
45/55	41	74
60/40	28	65
100/0	20	15

For NMAS of ½ inch wearing course using Superpave procedure, 125 gyration 6-inch diameter specimens were prepared following ASTM D6925. As mixtures were designed for heavy traffic therefore 125 gyrations were taken by Asphalt Institute SP-2 (2001). Assumption is that total asphalt content in the mixture is equal to the 100% virgin wearing control mixture. The optimum asphalt content for the control mix was 4.15% based on 4% air voids and volumetric is shown in Table 3.

Table 3. Superpave Mix design criteria

Parameters	Class B	Criteria
Asphalt Content Optimum (%)	4.15	NA
VMA (%)	14.0	Min 14
VFA (%)	70.74	65-75
D/B Ratio	1.17	0.6-1.2
$\%G_{mm}$ @ $N_{initial}$	82.314	≤89

As the objective of this research was to investigate the effect of RAP in the mix on, moisture susceptibility of hot mix asphalt pavement containing RAP, So for this the percentage of RAP was varied by 0%, 10%, 20%, 30%, 45%, 60% and 100% in HMA mix. Their volumetric properties were found to get the optimal value RAP content to be used in mix. Therefore seven different RAP percentages and corresponding aggregate on different sieves were found.

RESULTS AND DISCUSSION

Marshall testing procedure following ASTM D 6926 was used to prepare 4-inch diameter specimens having NMAS of ½ inch for ACWC. Mixtures were designed for heavy traffic loading. The results of Marshall Mix Design of all the seven mixtures using different percentages of RAP content are summarized in Table 4. All mixture satisfies the minimum stability of 10KN and the flow is in between 8 to 14 mm which is in accordance to MS-2 manual for Marshall Mix design. Due to increase in RAP content, variability comes in the volumetric parameters as shown in Table 4. It shows that the stability increases with increase in RAP and almost double for 100 RAP content.

Table 4. Marshall Mix design for all RAP containing mixtures

RAP (%)	Air voids (%)	VFA (%)	VMA (%)	Stability (KN)	Flow (mm)	Unit weight (Kg/m3)
0	4.03	71.20	13.98	13.60	9.4	2363
10	3.95	72.66	14.43	14.23	9.2	2350
20	3.99	72.17	14.33	15.23	10.1	2353
30	4.48	68.99	14.46	17.24	9.3	2350
45	3.53	74.96	14.10	18.21	9.6	2360
60	3.62	75.08	14.53	19.52	10.8	2348
100	3.70	75.42	15.05	26.78	11.4	2333

Table 5. Wheel tracker results

Mixtures	Rutting wet condition (mm)	Improvement in rut depth (%)
NHA-B	13.277	**20.7**
RAP 20%	10.525	

Controlled and RAP modified specimens of class B gradation were tested against moisture susceptibility in wet mode at temperature of 50°C in Hamburg Wheel Tracking Device (HWTD) AASHTO T 324-04 (2007). The HWTD is having three mode on which test can be conducted that is dry, air and wet mode. In this research wet mode was utilized, specimens were submerged under water at our desired temperature. After complete 20,000 numbers of passes wet condition the graph is plotted against number of passes and rut depth shown in Fig. 1. Plot below shows that controlled mixture rut depth is more as compared to rut depth obtained from specimens having RAP content. The rut depths obtained for controlled and RAP containing mixture were well in acceptable range as the failure depth was set at 20mm to check the stripping effect in mixture. This decrease in rutting potential is primarily because of RAP material which is having more stiffness than virgin aggregate mix. From Table 5 it is clear that after 20,000 passes the RAP containing mixture's resistance to rutting is increased up to 24.7% for 20% RAP in wet state at 50°C as compared to the controlled mixtures. Moisture damage results shows that HMA with control mix is having stripping inflection point above 10000 passes that is 12000 passes so only routine maintenance is required before the design life Fig. 2. HMA mixture containing RAP percentage is having SIP above 14000 passes which indicate good performance pavement Fig. 3. This is because of stiffness of RAP material which increases SIP value.

Table 6. Cost summary of ACWC control mix

Ser	Description	Amount (Rs)
1	Manpower	389334
2	Material	6,709,795
4	Transport/ Plant Operation	2739236
Total Amount		**9,838,365**

Table 7. Cost summary of ACWC containing RAP

Ser	Description	Amount (Rs)
1	Manpower	389334
2	Material	5430055
4	Transport/ Plant Operation	2587693
Total Amount		**8407082**

Cost analysis for asphalt production is categorized into materials, transport/plant operation and manpower (i.e., construction or lay down). The most expensive production cost category among others is Material. Asphalt binder is the most expensive and economically variable material. So the most economical use of RAP in surface or intermediate layers of flexible pavements where the less expensive binder from RAP can replace a portion of the more expensive virgin binder Page and Murphy (1987). For this research study cost comparison of control HMA and HMA containing recycled asphalt pavement is done in which all of the major cost dominant factors are included. Asphalt concrete wearing course (ACWC) rate assessment as per actual expenditure occurring is done on per cum of ACWC. Following Table 6 and Table 7 shows the Cost summary of ACWC Control Mix and ACWC containing RAP. Assessment is done on average daily progress of Asphalt laying by two Asphalt plants installed which produce 1800 tons of ACWC i.e., 762.71cum of asphalt. Comparison shows that by using RAP in HMA we can save cost of 15% in ACWC. Fig. 4 shows the Percentage Decrease in cost of ACWC control Mix and RAP containing ACWC.

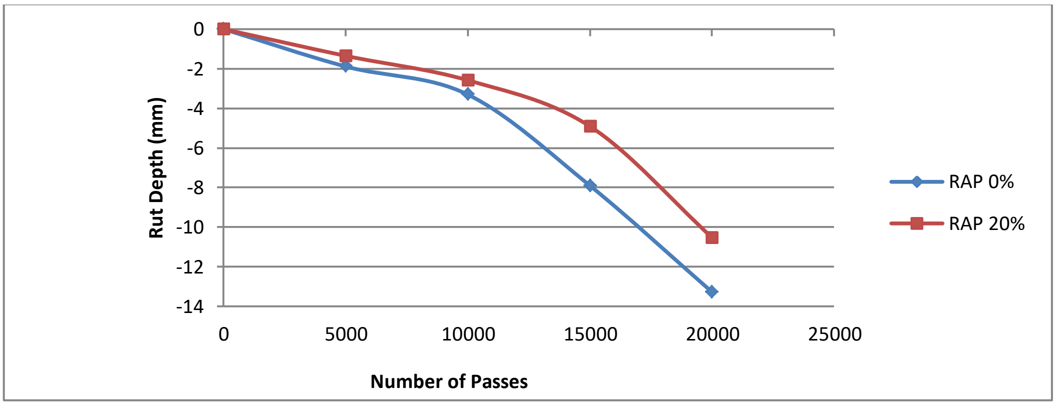

Fig. 1. Rut depth versus number of passes

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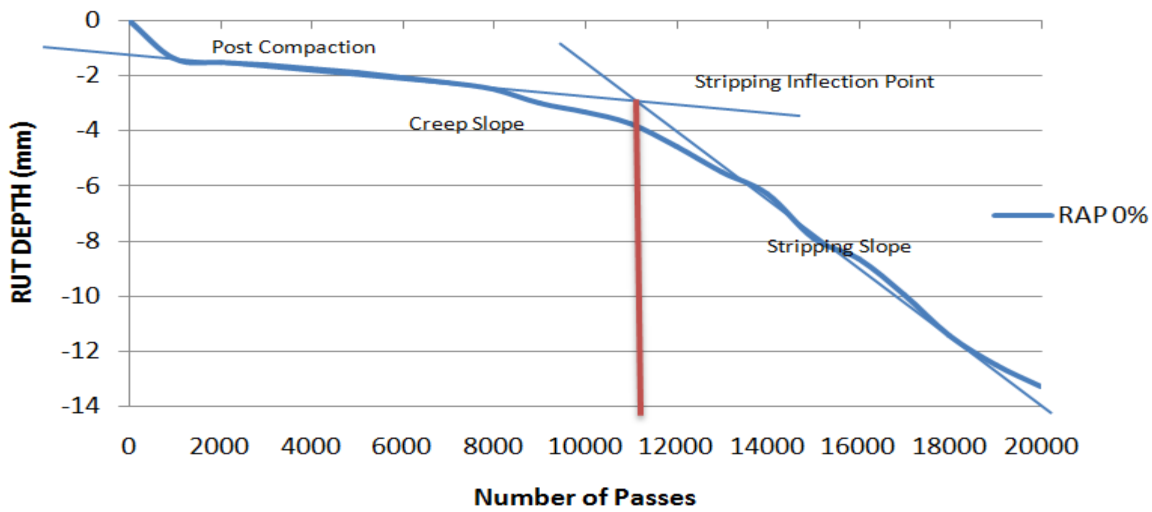

Fig. 2. Results from Testing with the HWTD for Control Sample

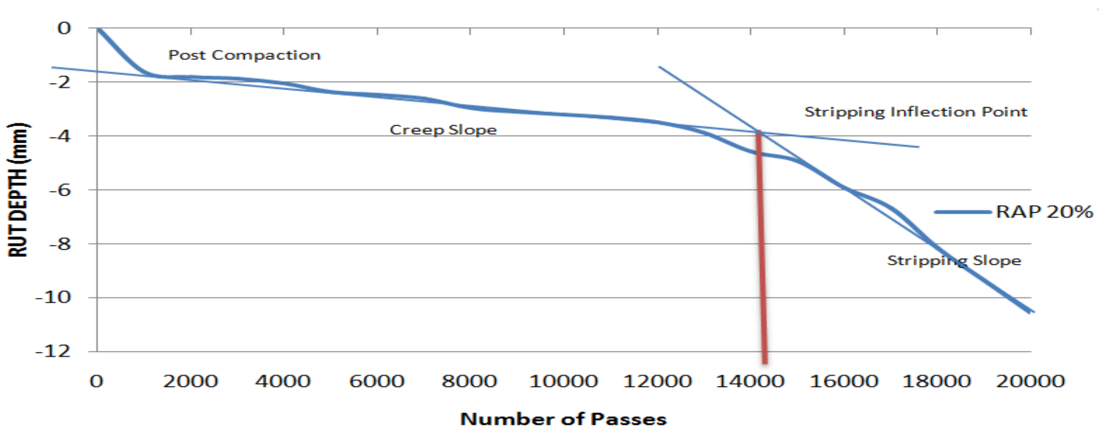

Fig. 3. Results from Testing with the HWTD for 20% RAP Containing Sample

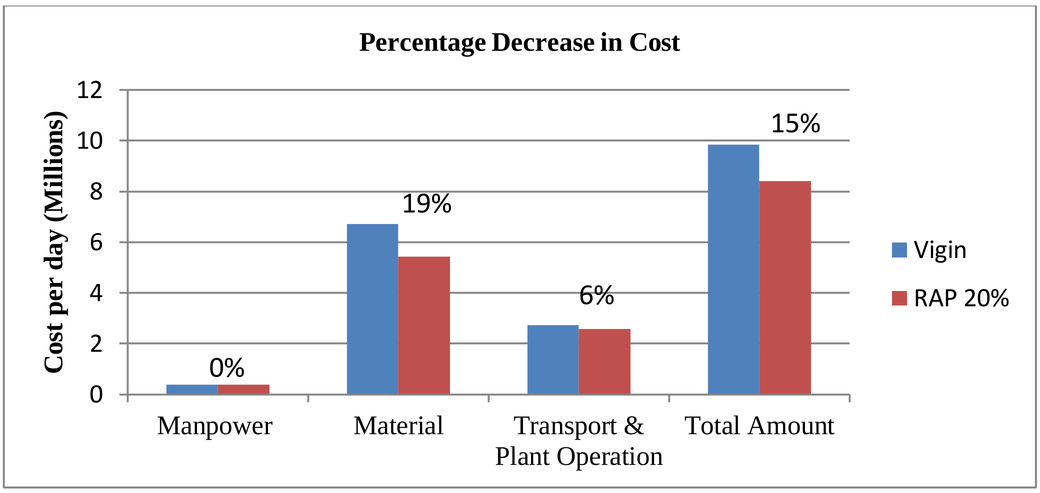

Fig. 4. Percentage decrease in cost

CONCLUSION

Laboratory evaluation of different Marshall Mixtures containing RAP and Performance test of Wheel tracker concludes that the blending of virgin and RAP material overall improve the mixture properties. The main conclusions drawn from this research are the following:

1. The Marshall stability generally increases shows good linearity with increment in RAP content. The stability of the 100% RAP mixtures is almost double the stability of the virgin mixtures.
2. Using up to 20% RAP in design will help in conserving the natural resources, reducing the HMA price and improves the performance.
3. RAP bitumen content after centrifuge extraction method using chlorinated solvent comes out to be 4.46% and gradation is on finer side.
4. The recovered binder and its blends with virgin binder were tested for penetration and ductility; the results showed that up to 45% RAP the penetration and ductility of the aged binder still has enough life. Since the virgin binder ARL 60/70 selected is soft binder so this will serve as rejuvenating agent in the mixture.
5. The resistance against rutting of HMA containing RAP increased up to 20.7% as compared to control mixture.
6. Cost comparison of control mix with HMA containing RAP showed that by using up to 20% RAP cost of 15% can be saved.

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