2012 International Conference on Traffic and Transportation Engineering (ICTTE 2012)

IPCSIT vol. 26 (2012) © (2012) IACSIT Press, Singapore

Evaluation of Asphalt Mixes Containing Reclaimed Asphalt Pavement for Wearing Courses

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Abstract. The use of Reclaimed Asphalt Pavement (RAP) has been enormously increased from the last two decades. In fact using RAP in pavement construction has now become common practice in many countries. Using RAP not only economical and environmental friendly but also preserve the natural resources and similar or even better in structural performance than virgin asphalt mixtures. This paper presents an experimental study to evaluate the effect of various types and percentages of RAP on the properties of asphalt mixtures.

Four mixtures, which were the combination of two different virgin aggregates (Limestone and Quartzite) and two different RAP sources were studied in this research. The mixtures were designed by Marshall method at a wide range of 0 to 100% RAP blends to handle low, medium and high traffic loads. RAP material was blended with virgin aggregate such that all specimens tested had approximately the same gradation. Mixtures containing RAP showed significant variability and the variability increased with the increase in RAP content. The results indicate that low RAP content up to 30 % can be used successfully in wearing courses construction.

Keywords: RAP, Marshall, Surface Course, Material Testing, Stability, Flow

1. Introduction

The use of reclaimed asphalt pavement (RAP) in the construction of new hot-mix asphalt (HMA) pavements has increased in recent years. RAP is old asphalt pavement that is milled up or ripped off the roadway (Kim, 2007). The Federal Highway Administration estimates that 100.1 million tons of HMA is milled each year (MAPA, website). Rap material can be reused in new asphalt mixtures because the components of the mix (the asphalt binder and aggregate) still have value. Using RAP in new mixtures can reduce the amount of new material that has to be added, saving money and natural resources. In addition, hot-mix asphalt mixtures with RAP can perform as well as mixtures made with all new material. Due to these advantages of using RAP, many state highway agencies are moving toward rising the percentages of RAP in their hot-mix asphalt pavements (EPA and FHWA, 1993). RAP has been used in hot mix asphalt pavements in various percentages that reached in some cases up to 80% (EPA and FHWA, 1993), and typically from 20-50% (Kim, 2007; Solaimanain, 1996; Lynn, 1992).

When RAP is reused in a new mixture, it is necessary to properly account for the old material in the new design. The aggregate from the RAP has to be included with the new aggregate, and that blend of aggregate has to meet certain physical properties. The experience with RAP in Marshall and Hveem mixtures has shown that properly designed and constructed RAP mixes can perform as well as, or even better than, mixtures made with all new materials. The mixtures with RAP designed by Superpave have also shown good performance. In the current study only the Marshall method was used for the performance evaluation of

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asphalt mixtures containing various RAP ratios. The wearing course mixtures with 10, 20, 30, 45, 60 and 100% RAP content were made and compare the results with the control design (No RAP content). The purpose of this research was to design good wearing surface with high RAP content without compromising the performance.

2. Materials and Methods

In Pakistan, various aggregate and asphalt sources are available for making asphalt concrete. For this research, virgin aggregates have been collected from two dominant aggregate sources (Margalla & Dina), which are considered to be the largest live aggregate quarries in the country. Similarly, asphalt binder 60/70 penetration grade which is being in use in most highways is acquired from Attock Refinery Limited (ARL) at Rawalpindi. The RAP material was obtained in form of chunks from two sites (Mandra & Nowshera) along national highway N-5, Pakistan. The RAP materials were subjected to severe aging and weathering on the site. The RAP chunks were crushed and screened into different sizes to meet the specified grading requirements. Before extraction of bitumen the 25mm size particles were removed as the control NMAS WAS 19mm.

In order to access the percentage of the asphalt present in the RAP material, asphalt extraction was done using AASTHO T 160, "Quantitative Extraction of Bitumen from Paving Mixtures" and AASTHO T 170, "Recovery of Asphalt from Solution by Abson Method". The binder content and gradation of RAP of both the sources after extraction and control gradations are shown in Table 1. The Mandra RAP gradation is little finer than the Nowshera but contains less bitumen than the latter one. All the testings were done in duplicate/triplicate and all the values mentioned in this paper were the average value.

Table 1. Control and RAP gradation and binder content (after extraction)

Property	Virgin	RAP Source	
	Control Gradation	Mandra	Nowshera
Binder content (%)	-	5.10	5.43
Sieve Size (inch)	Percent Passing	Percent Passing	Percent Passing
25	100	100	100
19	95	97	94
12.5	85	88	86
4.75	40	43	39
2.36	30	33	32
1.18	25	26	28
0.6	18	20	17
0.3	13	12	11
0.075	4	7	6

Two virgin and two RAP sources were used in various proportions (0, 10%, 20%, 30%, 45%, 60% and 100% RAP) results in four different combinations as shown below.The laboratory testing for this research was limited to 19 mm nominal maximum aggregate size (NMAS) mixture. Marshall mix design procedure was used for the design of mixtures for wearing course. Four different mixtures combinations of two virgin and two RAP sources were designed and tested as shown below.

Margalla Wearing + Nowshera Rap denoted in the paper by (MW+N RAP)
Margalla Wearing + Mandra Rap denoted by (MW+M RAP)
Dina Wearing + Nowshera RAP (DW+N RAP)
Dina Wearing + Mandra Rap (DW+M RAP)

As NMSG for wearing course was ¾ inch, therefore conventional 4 inch diameter molds were used to make marshal specimens using 75 blows on each side for compaction. As heavy traffic and overloading has been one of the main reasons behind early deterioration of our pavements, therefore all mixes have been compacted for heavy traffic criteria. Bulk specific gravity and water absorption of the Marshall mixes were determined according to AASHTO T 166. After determining the bulk specific gravity of the test specimens, the stability and flow tests were performed according to AASHTO T 245. The optimum asphalt content for the control mixes were 4.37% and 4.79 % for Margalla and Dina wearing courses respectively based on 4% air voids. It was assumed that the total asphalt content in the mixture is equal to the 100% virgin wearing course control mixtures. The percentage of new binder was calculated by using the following equation for the 10 to 60% RAP mixtures. The 100% RAP mixtures were compacted without adding any virgin binder since the RAP binder present is higher than the optimum binder.

$P_{nb} = \{(100^2 - rP_{sb})P_b/100(100-P_{sb})\} - \{(100-r)P_{sb}/(100-P_{sb})\}$------------(Asphalt Institute, 1986)

Where

P_{nb} = Percent of new asphalt binder in recycled mix expressed as whole number

r = New aggregate expressed as a percent of the total aggregate in the recycled mix expressed as a whole number

P_b = Percent, estimated asphalt content of recycled mix assumed to be the same as that of 100 percent virgin HMA mix

P_{sb} = Percent, asphalt content of RAP

3. Results and Discussions

The Marshall Mix design of both RAP sources with Margalla and Deena aggregates are summarized in Table 2. All the mixtures fulfill the minimum stability criteria of 6 kN and also satisfy the VMA and VFA requirements. The first three mixtures did not meet the minimum flow criteria (>2mm) with high RAP contents. Generally the properties of the mixtures improve with the addition of RAP material which shows that recycling is a viable option for HMA design. The variability in the mixtures properties is due to the variability in RAP material which generally increases with the increase in RAP percentages.

Table 2. Marshall Mix Design for all Mixtures

Rap (%)	Air Voids (%)	VFA (%)	VMA (%)	Stability (KN)	Flow (mm)	Unit Weight (Kg/m^3)
Control Margalla Wearing						
0	4	71.5	14.15	9.89	2.63	2376
MW+N RAP						
10	4.06	74.75	16.08	9.59	2.04	2358
20	3.93	72.84	14.47	10.92	2.56	2353
30	4.24	70.70	14.47	18.40	3.07	2353
45	4.87	67.66	15.02	11.73	2.10	2348
60	3.84	74.74	15.20	14.98	1.80	2348
100	3.69	77.47	16.38	21.19	0.91	2333
MW+ M RAP						
10	3.75	72.18	13.48	10.96	2.29	2368
20	4.36	68.83	13.99	20.22	2.23	2363
30	4.58	69.09	14.82	10.69	2.67	2358
45	2.19	83.38	13.18	9.44	1.96	2408
60	3.01	78.89	14.26	7.82	1.45	2378
100	3.36	76.66	14.40	13.39	0.66	2373

Control Dina Wearing						
0	4	75.5	16.25	12.65	2.91	2354
DW+N RAP						
10	3.54	74.35	13.80	11.60	2.25	2433
20	3.13	76.26	13.19	7.71	2.30	2422
30	4.62	71.32	16.11	11.74	2.43	2328
45	3.62	74.70	14.31	20.95	1.64	2378
60	3.92	73.92	15.03	19.78	1.11	2358
DW+M RAP						
10	3.31	73.18	12.34	7.54	2.03	2433
20	4.05	67.75	12.56	17.42	2.31	2413
30	3.44	76.80	14.83	10.48	1.91	2368
45	4.07	73.79	15.53	19.55	2.25	2353
60	3.23	77.92	14.63	19.92	2.65	2378

The flow values for all the mixtures are presented in Fig.2 which indicated that most of the values are within the specifications limits of 2 to 4mm when up to 30% RAP is used in the mixtures but above 30% RAP the mixtures fail to satisfy the minimum flow limits of 2mm. The low flow values at high RAP content is an indication of loaded under stress and may be due to less or no virgin binder in case of 100% RAP.

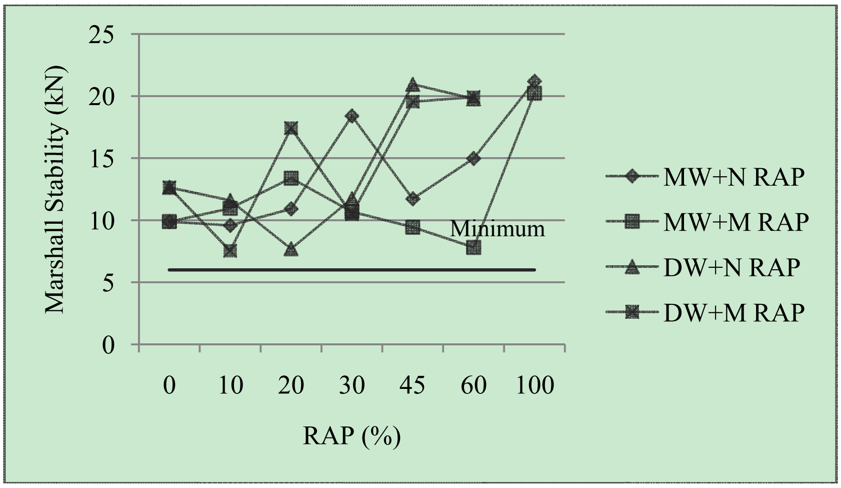

Figure 1 Marshall Stability for all mixtures

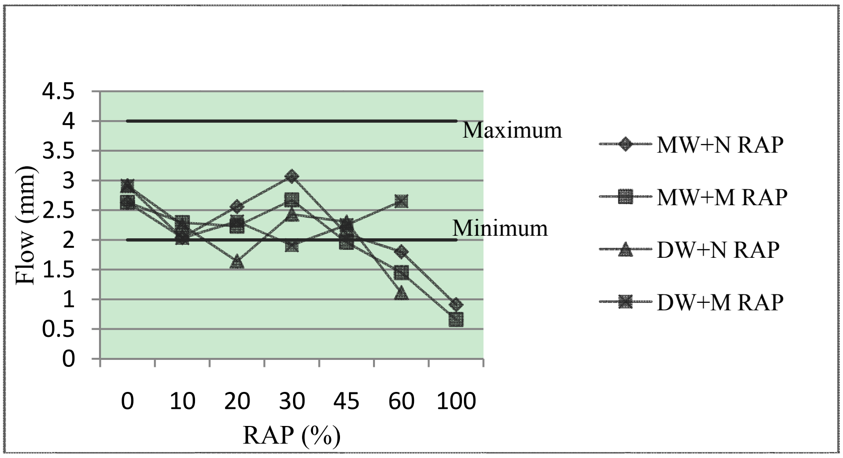

Figure 2 Marshall Flow for all Mixtures

The laboratory testing confirmed that good quality mixtures can be design using RAP material. The quality of the virgin aggregates and also the quality of RAP material greatly affect the mixture volumetric properties. Even the 100% RAP mixtures of both the sources give good stability value. The RAP content up to 45% can be used successfully for heavy traffic and higher RAP content can be designed for medium and low traffic. The higher RAP mixtures can be designed using modified binders and also adding some rejuvenating agents to reduce the aged binder stiffness.

4. Conclusions

Based on extensive laboratory evaluation of different Marshall Mixtures containing RAP concludes that the blending of virgin and RAP material overall improve the mixture properties. The main conclusions drawn from this research are the following:

- In laboratory the RAP mixtures designed using Marshall method perform the same or even better than the conventional mixtures.
- Generally the Marshall stability increases linearly with increase in RAP contents. The stability of the 100% RAP mixtures for Nowshera RAP is more than double the stability of the virgin mixtures and for the other RAP source also increases in the stability with 100% RAP.
- Overall the Nowshera RAP gives better performance with both the aggregate sources as compared to the Mandra RAP.
- When using RAP percentage above 45%, most of the mixtures failed to satisfy the minimum flow criteria indicating that the aged binder not participating well and the mixtures are under stress during loading.
- Using RAP in design even up to 30% will help in conserving the natural resources, reducing the HMA price and improve the performance.
- It is suggested to construct a trial section using virgin and RAP blends to verify the suitability of RAP mixtures to the country climate condition and traffic loadings.
- It is recommended for future study to use modified binder and 25mm NMAS to see the RAP mixture performance as base course material.

5. Acknowledgements

The authors acknowledge the Pakistan-United States Science and Technology Cooperative Program for funding this research. Thanks are extended to National Institute of Transportation (NIT) of National University of Sciences and Technology (NUST), Islamabad for providing the testing facilities. Thanks are also extended to ARL for providing the asphalt binders for testing.

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