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LABORATORY EVALUATION OF ASPHALT MIXTURES CONTAINING VARIOUS PERCENTAGES OF RECLAIMED ASPHALT PAVEMENT

Arshad Hussain[1], Qiu Yanjun[2]

School of Civil Engineering,
Southwest Jiaotong University, Chengdu-610031,
CHINA.
[1] arshad_nit@yahoo.com , [2] publicqiu@vip.163.com

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 most 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 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 and two different RAP sources, were studied in this research. 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.

Keywords: Reclaimed asphalt, Mixture design, Marshall stability, Ductility, Penetration

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 [1]. This 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, several studies have shown that the RAP mixtures have performed equal or better than the virgin mixtures [2, 3, 4]. 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 [5]. RAP has been used in hot mix asphalt pavements in various percentages that reached in some cases up to 80% [5]. Most studies have been used a range form 20-50% [1, 6, 7]. 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 properties. Past experience with RAP in Marshall and Superpave 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. In the current study only the Marshall method was used for the evaluation of asphalt mixtures containing various RAP ratios. RAP contents of 0, 10, 20, 30, 45, 60 and 100 % were evaluated in this study to see the effect of various RAP contents and sources on the mixture properties.

MATERIALS CONSIDERATION

Virgin Aggregates

In Pakistan, various aggregate sources are available for road constructions. For this research, virgin aggregates have been collected from two dominant aggregate sources Margalla and Dina, which are considered to be the largest live aggregate quarries in the country. The type of aggregate from Margalla and Dina is crushed limestone and quartzite respectively. The limestone from Margalla is one of the best mechanically fractured aggregate in the country free from rounded particles or river bed gravel. On the other hand Dina quarry aggregates contain riverbed and rounded gravels. The pavement construction and maintenance consume large amount of aggregates from these two quarries which diminishes the natural resources.

Virgin Binder

Asphalt binder 60/70 penetration grade which is being in use in most highways in the country has been acquired from Attock Refinery Limited (ARL) at Rawalpindi. ARL is using heavy crude oil blend ~ 7 to 10 crude containing 3-5% asphaltenes for the production of 60/70 and 80/100 grade asphalt. Most of local heavy crude are produced from northern part of the country. The asphalt binder price is increasing day by day due to increase in the cost of the crude oil.

RAP Material

RAP is the old asphalt pavement produced by milling existing asphalt pavement or crushing old removal from asphalt pavements. For this study the RAP material has been 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. The two RAPs, two virgin aggregates and virgin binder ARL60/70 were used in this research to investigate the effects of RAP on the resulting mixture properties. RAP contents of 0, 10, 20, 30, 45, 60 and 100 % were evaluated in this study to see the effect of various RAP content and sources on the mixture properties.

LABORATORY EVALUATION

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 gradations of virgin and RAP materials after extraction are shown in Table 1. The asphalt content of RAP was found to be 5.05% and 5.57% for the Mandra and Nowshera RAP respectively. The laboratory testing for this research was limited to 25mm nominal maximum aggregate size (NMAS) mixture. Four different mixtures combinations of two virgin and two RAP sources were designed and tested as shown below.

Margalla Base + Nowshera Rap denoted in this paper by (MB+N RAP)

Margalla Base + Mandra Rap denoted by (MB+M RAP)

Dina Base + Nowshera RAP (DB+N RAP)

Dina Base + Mandra Rap (DB+M RAP)

Table 1:Virgin and RAP gradation (after extraction)

Source Sieve Size (in)	Virgin	Mandra RAP	Nowshera RAP
		Percent Passing	
37.5	100	100	100
25	93	92	95
19	80	77	83
12.5	65	60	68
4.75	40	42	39
2.36	25	26	30
.18	18	20	19
0.6	14	15	13
0.3	11	12	10
0.075	4	8	5

Prior to use RAP in recycling asphalt, it is essential to evaluate the extracted binder properties and their blends with virgin binder. The recovered binder and its blends with virgin binder were tested for penetration and ductility and the results are presented in Table 2. Literature search reveals that normally low RAP content up to 20 % can be designed without changing the binder grade. From table 2 it can be seen that even with 40% RAP, the penetration and ductility show that the aged binders still have enough life. Since the virgin binder ARL 60/70 selected is soft binder (Graded as PG58-16 according to Superpave system) so this will serve as rejuvenating agent in the mixture.

Table 2: Penetration and Ductility for all the blends

RAP Source	RAP/Virgin Ratio	Penetration	Ductility (cm)
Mandra	0/100	66	>100
	40/60	35	54
	70/30	31	40
	80/20	14	29
	90/10	12	20
	100/0	7	16
Nowshera	0/100	66	>100
	40/60	49	90
	70/30	32	70
	80/20	29	35
	90/10	22	18
	100/0	15	13

As NMAS for base course mix is 1 inch therefore 6-inch diameter specimens were prepared for Marshall testing following ASTM D 5581. Mixtures have been designed for heavy traffic only using the Modified Marshall criteria shown in Table 3. It was assumed that the total asphalt content in the mixture is equal to the 100% virgin base course control mixtures. The optimum asphalt content for the control mixes were 3.69% and 4.75 % for Margalla and Dina aggregates respectively based on 4% air voids.

Table 3: Modified Marshall Mix Design Criteria [8]

Mix Criteria	Heavy Traffic (>106 million ESALs)	
	Minimum	Maximum
Compaction(No. of blows on each side of the specimen	112	
Stability (Minimum)	18014 N	
Flow (0.25mm)	12	21
Percent Air Voids	3	5
Percent voids in mineral aggregate for 4% air voids and 25mm NMSG	12	-
Percent voids filled with asphalt (VFA)	65	75

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.

$P_{nb}= [(100^2-rP_{sb})P_b/100(100-P_{sb})\}-\{(100-r)P_{sb}/(100-P_{sb})]$ [9]

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

RESULTS AND DISCUSSIONS

The results of Marshall Mix design of all the four mixtures with various RAP content are summarized in Table 4. With increasing RAP content the mixture stability increases for the first three mixtures group but for the last one there is no significant change in the stability values. The entire mixtures satisfy the minimum stability of 18 kN but for Dina source with high RAP content the mixture exceeds the maximum flow limit of 5.25mm for modified Marshall. Marshall high flow values indicate excess binder content. Generally the variability in the volumetric parameters increases with increase RAP content. The RAP source effect on the first two mixtures which consist of crushed limestone is shown in Fig.1 below. The stability increases linearly with increase in RAP. As the first mixture consist of crushed limestone and also the Nowshera RAP aggregate is also crushed so result in good combination and give high stability. Also the N RAP binder is less aged than the M RAP binder as indicated by the penetration and ductility values. Similarly for the third mixture the stability increases with increase RAP content with good linearity (R^2=0.939) but for the fourth mixture the increase is not significant (R^2= 0.795).

Table 4: Marshall Mix Design for all Mixtures

RAP (%)	Air Voids (%)	VFA (%)	VMA (%)	Stability (kN)	Flow (mm)	Unit Weight (Kg/m^3)
			Control Margalla Base			
0	4	68.40	12.66	31.2	3.55	2393
			MB+N RAP			
10	3.75	71.46	13.14	30.53	3.45	2383
20	3.70	71.45	12.96	34.86	4.18	2388
30	4.70	63.73	12.96	36.63	3.49	2388
45	3.20	74.58	12.59	42.52	3.96	2398
60	3.82	71.70	13.50	47.91	4.71	2373
100	3.52	75.40	14.31	71.34	5.03	2453
			MB+M RAP			
10	4.60	72.23	16.57	28.86	3.91	2293
20	4.30	74.00	16.54	30.33	3.50	2298
30	4.18	73.57	15.82	38.24	5.06	2318
45	4.69	68.54	14.91	37.05	3.97	2343
60	5.07	68.31	16.00	44.32	3.57	2313
100	4.18	73.41	15.72	60.63	4.68	2363
			Control Dina Base			
0	4	73.80	15.25	22.5	4.27	2416
			DB+N RAP			
10	3.93	73.85	15.03	21.87	4.46	2338
20	3.75	72.63	13.70	29.83	4.62	2403
30	3.88	68.38	12.27	38.78	4.69	2443
45	3.25	72.64	11.88	38.29	4.63	2463
60	3.24	73.53	12.24	48.26	5.50	2453
			DB+M RAP			
10	4.55	67.22	13.88	32.69	4.59	2398
20	5.66	62.14	14.95	33.13	4.40	2368
30	4.78	66.00	14.06	31.99	4.68	2393
45	4.36	69.76	14.42	31.56	5.71	2383
60	4.39	70.66	14.96	29.48	5.41	2368

The fourth mixture is combination of rounded riverbed aggregate and also the M RAP is also rounded so no prominent change in stability with increase in RAP. Similarly the effect of the virgin aggregate source on the Stability of the N RAP contained mixtures is shown in Fig.2 below. The Marshall stability increases for Margalla and Dina aggregates with increase in RAP with good linearity having R^2 value of 0.917 and 0.929 respectively.

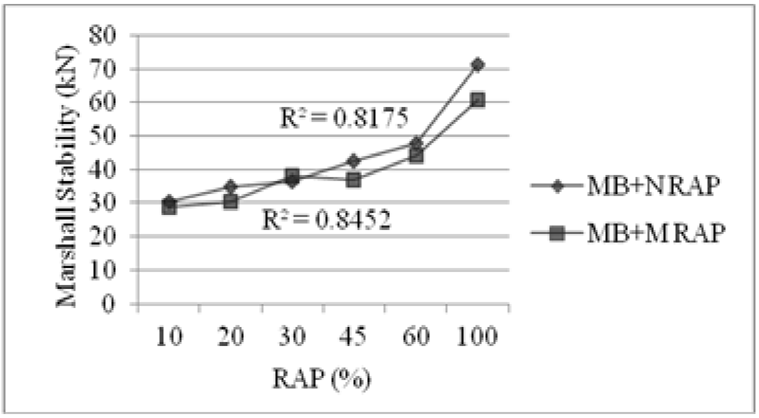

Figure 1: **Effect of RAP source on Marshall Stability**

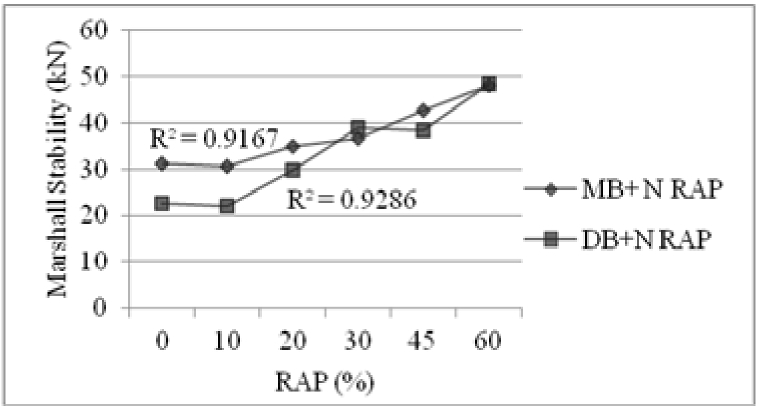

Figure 2: **Effect of virgin Aggregate source on Stability**

The flow values for all the mixtures are presented in Fig.3 which indicated that most of the values are within the specifications limits of 3 to 5.25mm. These analysis shows that RAP blending is a viable option for base course construction in the country. 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 results in laboratory compaction. Few mixtures exceed the maximum flow limits but most RAP blends fall within the specified limits for the volumetric properties. The low RAP content up to 30% can be used for heavy traffic and higher RAP content can be used for medium and low traffic.

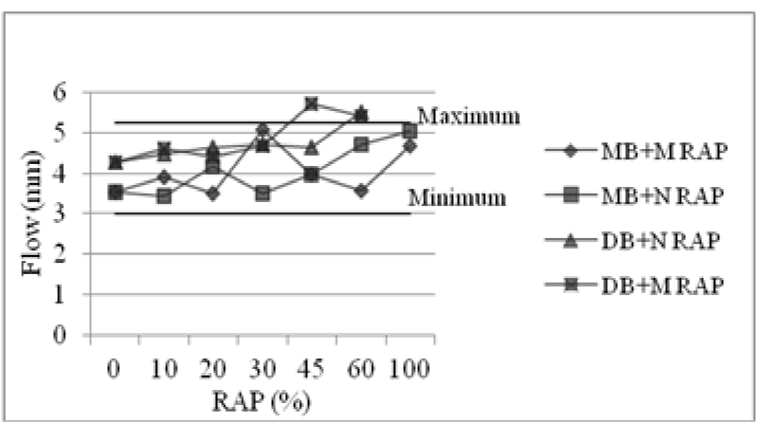

Figure 3: **Marshall Flow values for all the Mixtures**

SUMMARY

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 as virgin mixtures.
- Generally the Marshall stability increases with increase in RAP content with good linearity. The stability of the 100% RAP mixtures is two times the stability of the virgin mixtures.
- The crushed limestone gives better performance with both the RAP sources as compared to the quartzite. When mostly riverbed and rounded particles are used the stability does not change significantly and the flow exceeds the maximum limit.
- 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 different NMSG to see the RAP mixture performance.

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