The Suitability of Using Reclaimed Asphalt Pavement in the Wearing Course of Flexible Pavement

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Abstract. **Since Pakistan is a developing country where the highways and roads are mostly constructed as flexible pavements. When the road reconstructed, the removal of wearing course through milling process produces waste containing aged bitumen bound onto the aggregates called as Reclaimed asphalt pavement (RAP). Economical challenges, disposal problems and environmental hazards are always emerging issues when existing road is demolished. All the above-mentioned problems can be minimized by making use of RAP in the wearing course of new flexible pavements which leads to the sustainable development. The purpose of this study is to investigate the suitability of using RAP partially in wearing course of flexible pavements. The determination of residual bitumen content in RAP and gradation of reclaimed aggregates according to the procedure given by AASHTO was initial part of the study, where after the OBC of the asphalt mix containing 100% fresh aggregates and asphalt mix containing 50% RAP using the method of Marshal mix design, was found to be 4.0% and 2.5% respectively. The bitumen content present in RAP was 3.0%. Further results shows that RAP can successfully be used along the neat bitumen and fresh aggregates in new bituminous wearing course as the stability increases by 46% when fresh aggregates are replaced by 50% RAP. On the other hand, fresh aggregates are saved to 50%, fresh bitumen is reduced by 37.5% at optimums which leads to reduction in overall cost of the project making the project economical and sustainable.**

Keywords**: Reclaimed Asphalt Pavement (RAP), Optimum bitumen Content (OBC), Marshal Mix Design**

I. INTRODUCTION

Since the flexible pavement is the pavement structure mostly favored in the construction of roadways in Pakistan, which consumes a massive amount of materials like aggregate, cement, bitumen and other additives during its construction and maintenance of pavement as well. An existing road pavement containing aged bitumen and aggregates when deteriorated, the Reclaimed asphalt pavement (RAP) (product obtained from pavement milling process of removing the paved surface) is always an emergent waste. Disposal problems and hazards to the environment are always the main emerging issues where there an improper handling of demolished pavement occurs.(10) Reusing of deteriorated pavement materials may become a possible substitute for pavement construction. Social, environmental, and frugal profits are the cheering factors for pavement recycling. (3)

Before we go for repaving, the milling off the asphalt pavement surface always gives the old asphaltic material whether in the form of big mass or in smaller pieces when grinding is also made on same material at the same time of its removal known as what we call the Reclaimed Asphalt Pavement (RAP).

Fig. 1

Many problems such as disposing of reclaimed asphalt materials from the site where from it is removed to the place where it is to be dumped, high transportation costs of RAP from site and virgin materials from crushing plant to the site and high production cost of asphalt may be reduced and project time can also be saved by making the use of RAP for the new roadway projects.

II. LITERATURE REVIEW

A The high cost of crude oil during the Arab oil embargo led to the popularity of making use of Recycling asphalt pavements in the 1970s. When partial funding were provided to the State transportation departments by FHWA through Demonstration Project 39 to construct paving projects using recycled asphalt and to document the effective use of resources in light of increased or decreased material costs.(1) As a Result of which, the RAP started handling by construction practices and technologies. The National Cooperative Highway Research Program (NCHRP) published Recycling Materials for Highways in 1978.(2) and Guidelines for Recycling Pavement Materials was also published by NCHRP in 1980 introducing pavement materials for recycling, methods and their procedures to be applied for recycling suitably for pavement layers.(3)

B In the early 1990s, It was calculated by FHWA and the U.S. Environmental Protection Agency that the asphalt pavement were reclaimed every year more than 90 million tons from which the RAP recycled was over 80% , making

asphalt the most frequently recycled material. RAP is most commonly used as an aggregate, but it is also used as a granular base or subbase, stabilized base aggregate, and embankment or fill material. RAP is a high-quality material that can replace more expensive virgin aggregates and binders. Further information was issued by FHWA on the state of the practice regarding pavement recycling by publishing Pavement Recycling Executive Summary and Report in 1996.(4)

C Yomiyu Reta, et al (2017), (5) made an experimental study on the partial replacement of the base course material with the reclaimed asphalt pavement at Jimma, Ethiopia. He used Reclaimed asphalt pavement (RAP) in its natural state to investigate its effect on the engineering properties of Base course making RAPs blend with Crushed stone aggregates. According to his experimental study, the use of RAP as viable and the optimum RAP content of 30% by the weight of crush stone aggregate in the RAP-CSA mix may suitably be used in Base course layer. (5)

D Brajesh Mishra (2015), After United Nations, India ranks 2nd in the world having total road network of 4.2 million kilometers. Brajesh Mishra (2015)(6) observed higher road levels when compared to adjoining properties of urban locality due to periodic resurfacing without going through milling process because of shortage of landfills so he thought of getting rid of the problem by reusing of RAP in flexible pavement. Experimental study was made and the results were then compared with MORTH (The Ministry of Road Transport and Highway) specifications to ensure the appropriateness of the material for reusing.

E According to the literature review, it is observed that the RAP can successfully be used in sub grade and base layers after the suitable blending has been assured, leads to reduction of overall depth of layers as water absorption is strongly affected with the aged bituminous coating on aggregates. The required gradation of RAP can be achieved by pulverizing the material in crusher. The study was made on varying RAP content i.e; 0/100, 10/90, 20/80, 30/70, 40/60 and 100/0. The best results were observed at 30% RAP blended with 70% fresh aggregate, with saving of 25% – 30% in overall construction cost. (6)

F Dr. RK Pandey (2016), The significance of using RAP for bituminous pavements was studied by Dr. RK Pandey (2016) in India. (8) According to him RAP is an emergent technique which has been getting popularity step by step over the years because of its constructive effect on parameters like Marshall Stability , moisture resistance and density as well. The significant advantages can be observed using RAP i.e; Preservation of resources, sustainable development of project, lessen the dumping of reclaimable material, diminution in material and energy cost etc. The use of RAP is successful in the construction whose percentage to be used again depends upon condition of RAP. Though for most of the projects 40% – 60% is mostly adopted while preparing asphalt mix containing 100% RAP is not considerable. (7,8)

G G. Canon Falla, et al, (2016), In general, the share of recycling the RAP especially in the surface course layer is lower than what it could be. G. Canon Falla, et al, (2016) presented their report of research on the feasibility of using 100% recycling of asphalt pavement in surface course. (9) The object of the study was to observe the feasibility of using such high rate of RA in developing asphalt mix with high durability through laboratory tests. The study as focused on the limiting factor that determine the maximum percentage of RAP to be used in the surface course of new pavement. According to the literature review, the higher amount of RAP results in obtaining the gradation curve outside the specified limits so it necessitates the addition of virgin aggregates up to some percentage to obtain gradation within specification limits for wearing course. The maximum percentage of RA from the literature review was found to be 70%, if milled properly. The asphalt mix for wearing course is highly affected by the heterogeneity of reclaimed aggregates therefore for wearing course containing high amount of RAP to have durable mix, the RA should be milled properly in such a way that it must not stockpiled with lower quality material of deeper layers. (9)

III. MATERIALS AND METHODS

A. Bitumen

Table. 1

Properties	Result
Penetration	65
Ductility	140+cm
Softening Point	46 ℃
Flush and Fire Point	315℃ and 380℃
Specific gravity	1.00
Bitumen Grade	60/70 grade

B.Aggregates

Table. 2

Properties	Result
Stripping value	18%
Aggregates Impact Value	18.25%
% Abrasion value	30.4%
Specific gravity of fine aggregates	2.753
Sp. Gr of Hot Bin#01 (25 – 20mm) aggregate	2.55
Sp. Gr of Hot Bin#02 (20 – 13mm) aggregate	2.53
Sp. Gr of Hot Bin#03 (13 – 5mm) aggregate	2.53

C. Reclaimed Asphalt Pavement (RAP)

Table. 3

Properties	Result
Present Bitumen Content (%)	3.16%
Specific gravity	2.471

D. Methodology

Marshal mix design was incorporated to evaluate the properties of asphalt mixes (HMA) prepared for both the specimens containing 100% fresh aggregates and other containing 50% RAP and 50% fresh aggregates.
Initially suitable blending was made. So, as to obtain aggregates blend in such a way to satisfy the gradation specifications for asphalt mixes. The specimens were prepared at varying bitumen contents i.e 2.5%, 3.0%, 3.5%, 4.0%, 4.5%, 5.0% for asphalt mix containing 100% aggregates and 1.0%, 1.5%, 2.0%, 2.5%, 3.0%, 3.5% for asphalt mix containing 50% RAP and 50% fresh aggregates. 3 specimens were prepared on each variations resulting in total number of 18 specimens on 100% Fresh aggregate samples and 18 specimens of mixes containing 50% RAP aggregates.

i. Gradation of fresh aggregates

Table. 4

Sieve size (mm)	Hot Bin #01(% passing)	Hot Bin #02 (% passing)	Hot Bin #03 (% passing)	Hot Bin #04 (% passing)
25mm	100	100	100	100
19.5mm	65.9	100	100	100
12.5mm	2.55	85.1	100	100
9mm	0.36	38.06	96.4	100
4.75mm	0.2	0.571	4.1	99.31
2.36mm	0.2179	0.2364	0.65	81.37
300 um	0.1981	0.2178	0.6066	24.716
0.075 um	0.1839	0.2178	0.577	13.928

ii. Gradation of RAP Aggregate

Table. 5

Sieve Size	% passing	Specifications
25mm	100	100
19.5mm	80.7	90 – 100
12.5mm	46.5	-
9mm	29.7	56 – 70
4.75mm	12.4	35 – 50
2.36mm	4.5	23 – 35
300um	0.8	5 – 12
0.075um	0.4	2 - 8

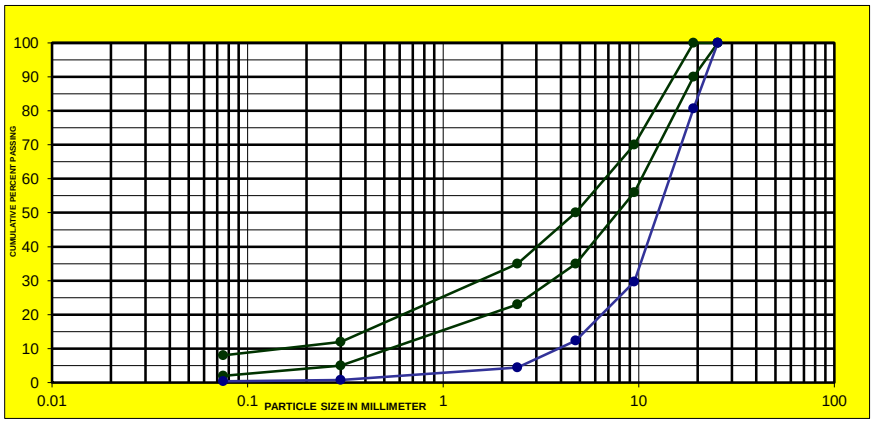


Fig. 1

iii. Blending of 100% fresh aggregates

Table. 6

Sieve size	H.B#01. 12%	H.B#02. 35%	H.B#03. 16%	H.B#04.37%.	Blend	Specifications
25mm	12.0	35	16	37	100	100
19.5mm	7.9	35	16	37	95.9	90 – 100
12.5mm	0.3	29.8	16	37	83	-
9mm	-	13.3	15.4	37	65.8	56 – 70
4.75mm	-	0.2	0.7	36.7	37.6	35 – 50
2.36mm	-	-	0.1	30.1	30.2	23 – 35
300um	-	-	0.1	9.1	9.2	5 – 12
0.075um	-	-	-	5.2	5.2	2 - 8

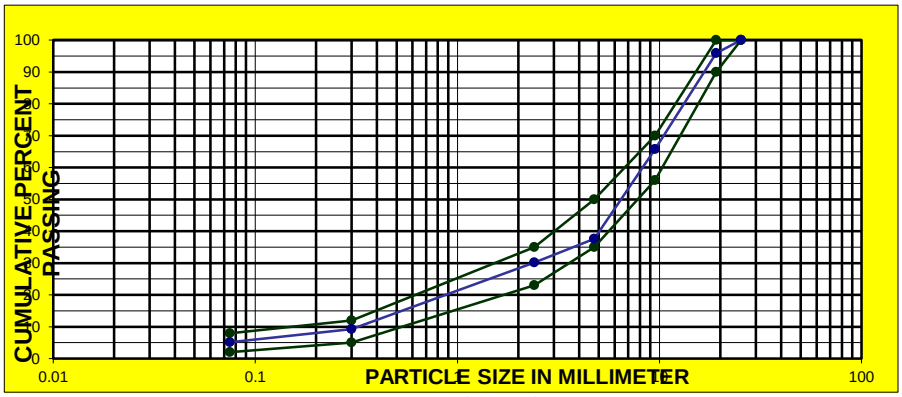


Fig. 2. Blend curve of 100% fresh aggregates

iv. Blending of RAP and fresh Aggregates

Table. 7

Sieve Size	H.B#03 15%	H.B#04 35%	RAP 50%	Blend	Specifications
25mm	15	35	50	100	100
19.5mm	15	35	40	90.4	90 – 100
12.5mm	15	35	23	73	-
9mm	14.5	35	15	64.3	56 – 70
4.75mm	0.6	34.75	6	41.6	35 – 50
2.36mm	0.1	28.5	2.3	30.8	23 – 35
300um	0.1	8.7	0.4	9.1	5 – 12
0.075um	-	4.9	0.2	5.1	2 - 8

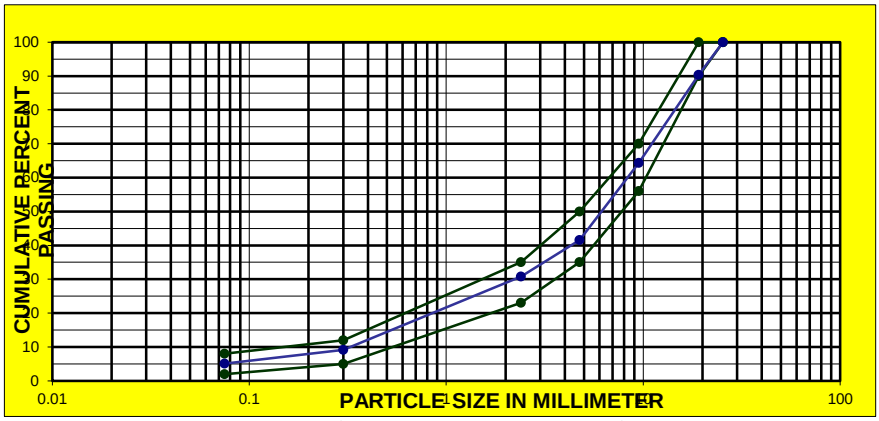


Fig. 3. Blend Curve of 50% RAP aggregates and 50% fresh aggregates

IV. RESULTS

i. Asphalt mix containing 100% fresh aggregates

Table. 8

Bitumen content (%)	Stability	Flow	Unit weight	% Air voids	%VMA	%VFA
2.5%	2093	5.46	2.297	11.27	14.192	20.59
3.0%	2154	6.36	2.313	9.929	14.037	29.27
3.5%	2309.3	7.867	2.339	8.2	13.519	39.34
4.0%	1852	10.267	2.384	5.69	12.312	54
4.5%	1512.3	11.13	2.411	3.867	11.781	67.17
5.0%	1226.3	12.06	2.359	5.184	15.136	63.32

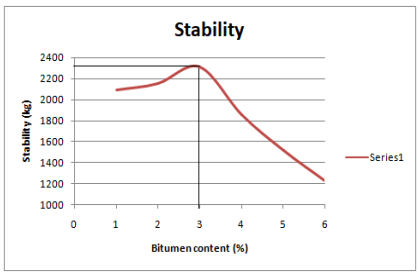
ii. Asphalt mix containing 50% RAP and 50% fresh aggregates

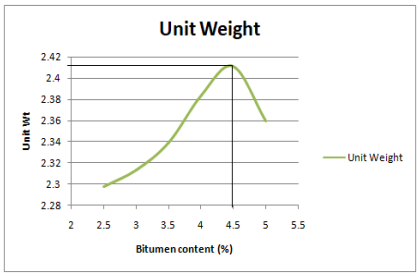
Table. 9

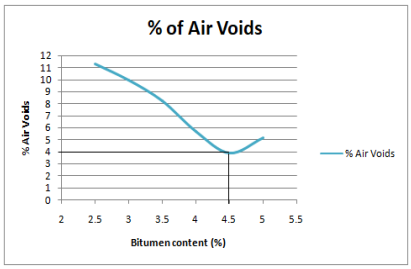
Bitumen content (%)	Stability	Flow	Unit weight	% Air voids	%VMA	%VFA
1.0%	3661	6.36	2.275	12.68	12.82	1.09
1.5%	3999.6	7.53	2.334	11.58	12.84	9.81
2.0%	3033.3	9.06	2.405	8.54	11.03	22.57
2.5%	2704	11.33	2.413	5.0	8.795	43.14
3.0%	2175	12.73	2.404	3.97	8.96	55.69
3.5%	1885	13.33	2.264	3.56	9.76	63.52

iii. Optimum Bitumen Content (OBC)

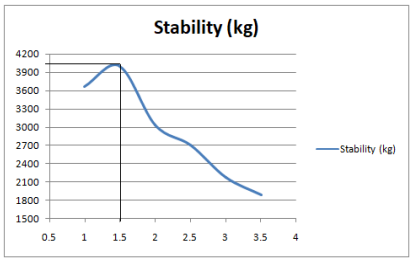
OBC (%) = 4.0% in case of Asphalt mix containing 100% fresh aggregates

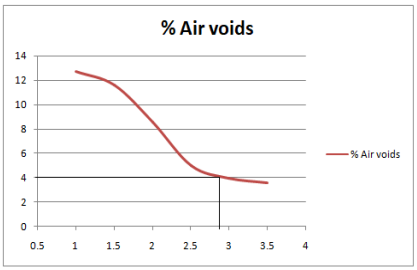






OBC (%) = 2.5% in case of Asphalt mix containing 50% RAP and 50% fresh aggregates

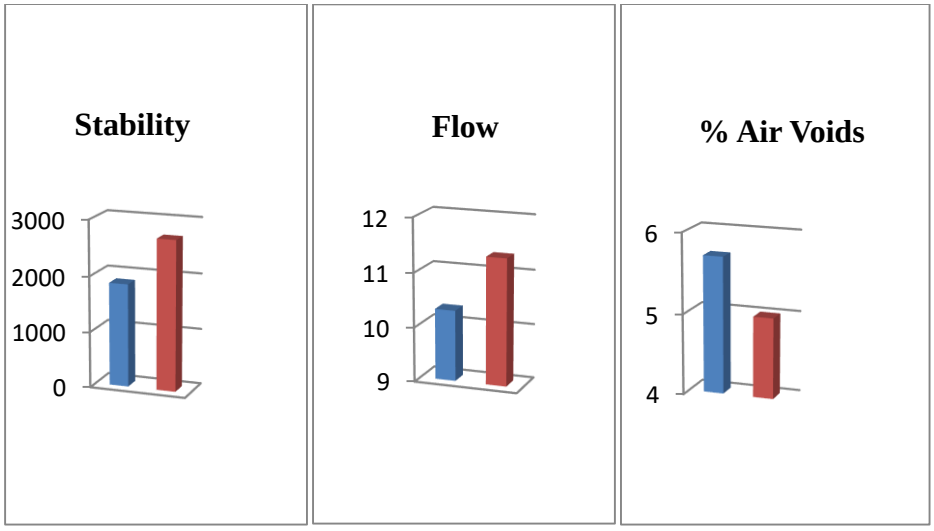




iv. Properties at Optimum bitumen contents

Table. 10

Property	@ OBC (100% fresh aggregates)	@ OBC (50% RAP & 50% fresh aggregates)	Marshal Specifications
Stability	1850	2700	1000 min.
Flow	10.3	11.3	8 – 14
Unit weight	2.384	2.413	-
% Air voids	5.7	5.0	5 – 9
% VMA	13	8.8	12 min.
% VFA	55	43	55 - 65



1. @ OBC (4%) of Asphalt mix containing 100% Fresh Aggregates
2. @ OBC (2.5%) of Asphalt mix containing 50% RAP & 50% Fresh Aggregates

V. CONCLUSION

From the results shown above, it can be concluded that the Reclaimed asphalt pavement (RAP) can be suitably used by 50% in wearing course (surface course) of the flexible pavements. Almost all the properties required comes in specified ranges i.e: Stability, flow, % air voids etc, even with an increased stability by 46% at optimum which shows safe use of RAP in wearing course.

On the other side, the technique found economical and sustainable also. The optimum bitumen content is reduced to 2.5% by making use of 50% RAP in Asphalt mix which was earlier 4.0% in case of asphalt mix containing no RAP in it. The fresh bitumen is reduced by 37.5% at the optimum, fresh aggregated are also saved by 50% which leads to reduction in cost of overall projects making the project economical and sustainable.

VI. RECOMMENDATIONS

- The Reclaimed Asphalt pavement (RAP) should be clean and clear free from dust as much as possible.
- The RAP percentage covered in this research is 50% which was almost the threshold percentage in our case of study in terms of its gradation. Percentage of RAP greater than 50% is not recommended.
- Depending upon the RAP gradation, which is not always same for all cases, so if gradation permits you to use RAP greater than 50%, it is recommended to use RAP in higher percentage to evaluate stability because in our research, stability at OBC was increased by use of 50% RAP.

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