Experimental Investigation on HMA by using RAP Material (BC Roads)

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Abstract - *Reclaimed Asphalt Pavement (RAP) is an innovating technique in India, and the use of RAP is gradually increasing popularity. Using RAP does not only help in minimizing the budget of project but also ensures proper utilization of material. The objective of this study is to understand the vitality of using RAP for the construction of bituminous pavements. Reclaimed asphalt pavement (RAP) materials are resulted from milling process. In this study samples of Reclaimed asphalt pavement (RAP) materials were collected and analysed for suitability of their usage in flexible pavements. Their characteristics including gradation, Aggregate Impact value, Aggregate Crushing value, Specific gravity, Flakiness & Elongation Index, Loss Angles Abrasion value, and Water absorption were determined and compared to the MORTH specifications. Form the study it was found that the RAP materials can be effectively used in the soil sub-grade, sub-base and base of the flexible pavements resulting in reduction of the construction cost. The Marshall mix design method was adopted in this study to determine the optimum binder content (OBC) for the asphalt mixes containing five aggregate combination with RAP contents of 0%, 10%, 20%, 30% & 40% was found to be 5.63%, 5.8%, 5.6%, 5.6%, 5% respectively. The volumetric properties of mixes at OBC satisfy design requirements. The addition of 40% RAP may result in approximately 41% saving quantity of binder. Results obtained from the Marshall Stability test in terms of stability and flow value is to satisfy the requirement of MORTH specifications.*

Key Words: *Bituminous mixes; Marshall mix design; Reclaimed asphalt pavement; Hot mix asphalt.*

1. INTRODUCTION

Recycled asphalt pavement (RAP) is a removed and reprocessed pavement material containing asphalt binder and aggregates. RAP is obtained either by milling or by a full depth recovery method. Large quantities of Reclaimed asphalt pavement (RAP) materials are produced during highway maintenance and construction. The properties of RAP materials can be improved by blending of aggregates and by addition of chemical stabilizers. In recent years there was a gradual increase in construction and demolition wastes. It has resulted in waste disposal problem due to shortage of available landfills. Reuse of these materials after proper recycling can be the right solution for the same. There will be a reduction in cost about 25 to 30% by reusing the recycled road aggregate generated at same site. The most used recycled materials are Reclaimed asphalt pavement (RAP) materials and recycled concrete aggregate (RCA). The generation of RAP and RCA result in an aggregate of high quality and grading. Due to coating of asphalt on the aggregate of RAP it reduces the water absorption in aggregates.

1.1 RECLAIMED ASPHALT PAVEMENT

Reclaimed asphalt pavement materials are removed and/or reprocessed pavement materials containing asphalt-coated aggregates. These materials are generated when asphalt pavement is removed for reconstruction, resurfacing, or to obtain access to buried utilities. When properly crushed and screened, RAP consists of high-quality, well-graded aggregates coated with aged asphalt. Large quantities of Reclaimed asphalt pavement (RAP) materials are produced during highway maintenance and construction.

Sources of RAP: The various possible sources of RAP are as follows

1. Generation from milling of HMA layer
2. Full depth pavement removal
3. Waste from HMA generated at plant

Milling is the process of scraping and removing any distressed upper layers of existing pavement to a specified depth.

The process includes grinding by machine and loading of RAP into a truck for transportation.

Fig – 1 Various Stockpiles of larger size RAP materials

1.2 ADVANTAGES

1. Reuse and conservation of non-renewable energy sources.

2. Preservation of the environment and reduction in land filling.
3. Energy conservation and improved pavement smoothness.
4. Improved pavement physical properties by modification of existing aggregate gradation and asphalt binder properties.
5. Using different sized RAP stockpiles provides greater flexibility in developing mix designs.

1.3 SCOPE AND OBJECTIVES OF STUDY

Design of The overall objective of the present study was to design and evaluate laboratory performance of bituminous mixes containing different percentages of RAP. Specifically, the objectives of the present study were to:

1. Determine the Physical properties of Conventional aggregates and RAP aggregates and the constituent mixtures.
2. Determine the optimum bitumen content for bituminous mix samples.
3. Bituminous concrete (BC) with different percentage of RAP (i.e., 0%, 10%, 20%, 30% and 40%) using Marshall Mix design method.
4. Examine the effects of using RAP in bituminous mixtures in terms of stability and flow value by using Marshall Mix design method.
5. Compare the test results with the performance of the traditional control conventional asphalt mixes in laboratory with addition of RAP material and without addition of RAP material (conventional modified mixes).

2. MATERIALS USED

2.1 Aggregates

The amount of aggregate in asphalt concrete mixtures is generally 90 to 95 per cent by weight and 75 to 85 per cent by volume. Aggregates are primarily responsible for the load supporting capacity of a pavement. Aggregate has been defined as any inert mineral material used for mixing in graduated particles or fragments. It includes sand, gravel, crushed stone, slag, screenings, and mineral filler. Aggregates are collected from Mitti Malkapur stone crushing plant near Yaragera. Sizes of aggregates collected are 6mm, 10mm, 20mm, stone dust from same quarry. Which are used for mix design by performing varies tests to determine its strength of aggregates.

2.2 Binder

Asphalt is a constituent of petroleum with most crude petroleum containing some asphalt. Crude petroleum from oil wells is separated into its fractions in a refinery by a process called distillation. Viscosity grade VG 30 bitumen sample was collected from bitumen plant situated near Mitti Malkapur village Raichur. The VG-30 grade binder is generally used for construction of flexible pavements in India.

2.3 Filler Material

Lime is preferred as filler in asphalt mixes. In addition, lime works as an anti-stripping agent and enhances moisture damage potential of asphalt mixes. Generally 2% of lime by weight of total aggregates is used in preparation of a mix. The lime taken from BRITE CEM lime which is product of Raghavendra enterprise Raichur.

2.4 Recycled Asphalt Pavement (RAP)

RAP is collected from road which is a link between Raichur to Mantralayam. The top layer of the pavement was removed for the construction of existing new roads. By making some transportation arrangement, these RAP material have been brought to the lab by using some hand tools, we crushed that RAP materials into small pieces.

Fig No – 02 Materials Used

3. TESTS ON MATERIALS USED

3.1 Aggregates Properties

The aggregates were evaluated for various physical properties in accordance with the Indian Standard specifications and The following Table No 01 presents the test results of physical characteristics of aggregates used in the present work.

3.2 Binder

Bitumen grade (VG -30) was used as binder in the mixture design of Bituminous Mix throughout the work. The test results are tabulated in Table No 2.

Table No 01 Physical Characteristics of Aggregates-Test Results

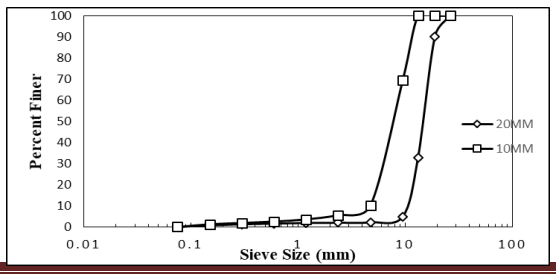
Sl No	Aggregate Test	Result	Limits as per MoRTH Specifications	Test Method
1	Aggregate impact value	15.17%	24%	IS:2386-part-4
2	Aggregate crushing value	19.07 %	30%	IS:2386-part-4
3	Combined flakiness and Elongation index	37.56%	40%	IS:2386-part-1
4	Specific gravity	2.643	2.5-2.8	IS:2386-part-1
5	Water absorption	0.8754 %	2 % max	IS:2386-part-3

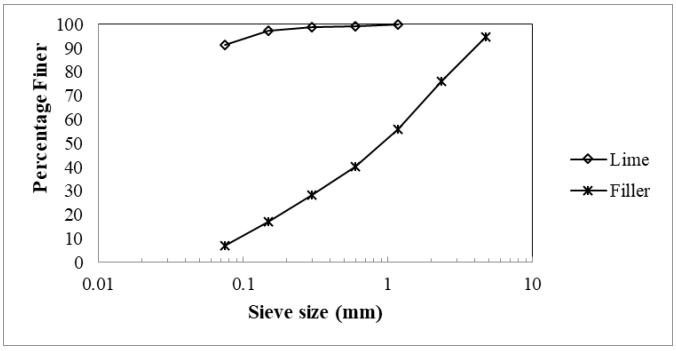
Table No 2 Bitumen Test Result

Sl No	Test	Method	Results	Requirement as per MoRTH
1	Penetration at 25°C (mm)	IS 1203	64	60-70
2	Softening Point (°C)	IS 1205	47	45-55
3	Ductility at 27 °C	IS 1208	79	Min 70
4	Specific Gravity	IS 1202	1.00	0.92-1.02

3.3 Aggregate Gradation

Aggregate gradation is one of the most basic laboratory test done which aims to determine the percentages of different size of aggregates to be used in the mix. After the basic tests, the aggregates are further used in the determination of the proper blend to give a good mix consisting of different size of aggregates. The gradation of different sizes of aggregates (20 mm, 10 mm, stone dust, and lime as a filler) used in this study are presented in the graph No 1 and graph No 2 shows the plot of gradations.





Graph No 1&2: Aggregate Gradation & Gradations of Lime Filler and Stone Dust

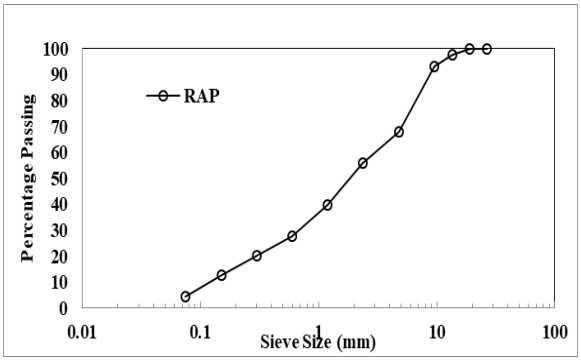
3.4 Asphalt Content in RAP

The asphalt content in collected RAP material was determined using two different methods: chemical extraction using centrifuge device and ignition oven. The asphalt content in RAP determined from chemical extraction using centrifuge device and ignition oven was found to be 4.96% and 5.40%, respectively. The reported results are the average of five samples. The ignition oven predicted AC on higher side compared to centrifuge extraction method. It might be because the high temperature (i.e. 540°C) in ignition oven may burn fine aggregates in RAP, resulting in high AC content. In this study, average of both the methods, 5.2%, is considered for design of mixes containing different percentages of RAP. The AC content is RAP is relatively high, indicating that the RAP is rich in asphalt content and hence a significant cost saving can be expected. The AC content in RAP helps to determine quantity of neat binder to be added in the mix. Bitumen content in RAP is shown in Table 3.

Table No 3 Asphalt Content in Rap

Test Method	Bitumen Content (%) Average of 5 Samples	Standard Deviation (%)	Average Bitumen Content (%)
Centrifuge Extraction	4.96	0.11	5.2
Ignition Oven	5.40	0.19	

3.5 Sieve Analysis of RAP Aggregates



Graph 03: Gradation Curve of RAP Aggregates

The gradation of RAP aggregates in presented in Table 4 and in graph 03 The RAP aggregates had approximately 4.3% and 67.8% passing from 0.075 mm and 4.75 mm sieves.

Table No 04: Reclaimed Asphalt Pavement (RAP) Aggregates Gradation

IS sieve size in mm	Passing (%)
45	100
37.5	100
26.5	100
19	100
13.2	97.6
9.5	93.0
4.75	67.8
2.36	56.0
1.18	39.8
0.6	27.8
0.3	20.1
0.15	12.8
0.075	4.3

3.6 Marshall Stability Test: Sample Preparation

First approximately 1200 gm of different sizes of aggregates and filler (lime) as per the blended design gradation are taken, and heated at the temperature 170-190°C. The bitumen was then heated at 150°C. A fixed amount of bitumen quantity was then added in aggregates. The aggregate and binder are mixed at mixing temperature ranging from 130°C-160°. Thereafter, the mix is compacted by giving 75 blows on either side at compaction temperature ranging from 170°C-190°C.A compacted specimen of thickness 63.5 ± 3 mm and diameter 100 mm are prepared. The above procedure is repeated for other bitumen contents. Test Matrix for Sample Preparation for Marshall Mix Design for HMA shown in Table 05 and Figure 01.

Table No 05: Total no of mould prepared for Marshall Stability Test conducted

Percentage of bitumen used	No of moulds for 0% RAP	No of moulds for 30% RAP	No of moulds for 30% RAP	No of moulds for 40% RAP
4%	1	1	1	1
4.5%	1	1	1	1
5%	1	1	1	1
5.5%	1	1	1	1
6%	1	1	1	1
Total	5	5	5	5

Fig: 01 Marshall Stability Test

4.0 TEST RESULTS AND DISCUSSION

4.1 Design of Blended Aggregate Gradations

The bituminous concrete mixes of Grade I with four different percentages of RAP (i.e. 10%, 20%, 30%, and 40%) were designed in the laboratory. Prior to prepare a mix, the blended aggregate gradation was obtained to keep it within the limit of gradation of BC Grade 1 as per MORTH guidelines. Several trials were made while keeping percentages of RAP content fixed for a selected amount. Table 06 shows percentages of different types of materials (i.e., 20 mm, 10 mm, stone dust, filler, and RAP). The percentage of filler (lime) was kept constant as 2% by weight of aggregates. The blended gradation for each combination is shown in Table 07 and graph 04. The design blended aggregate gradation for different percentages of RAP was within the limit of specified BC grade -1 gradation. It can be seen that stone dust reduces significantly with addition of RAP content.

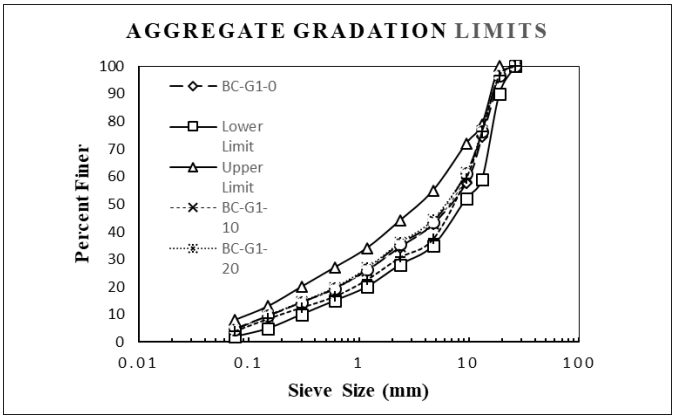
Table No 06: Optimum Percentage of Materials used in BC- Grade-1 Mixes for Different Percentage of RAP

Type of Mixes	Percentage of materials for BC-grade-1					
	Coarse (20 mm)	Fine (10 mm)	Stone Dust	Filler (Lime)	RAP	Total
BC-G1-0	38	20	40	2	0	100
BC-G1-10	35	20	33	2	10	100

BC-G1-20	34	16	28	2	20	100
BC-G1-30	34	14	20	2	30	100
BC-G1-40	34	18	06	2	40	100

Table No 07: Aggregate Gradation of BC-Grade-1 with Different Percentage of RAP

Sieves Size (mm)	Adopted Gradation (Percent Passing)					Specified Limits for BC-grade-1 (MoRTH)		
	0% RAP	10% RAP	20% RAP	30% RAP	40% RAP	LL	UL	MV
26.5	100	100	100	100	100	100	100	100
19	96.3	96.6	96.7	96.7	96.7	90	100	95
13.2	74.5	76.2	76.7	76.4	76.2	59	79	69
9.5	57.7	59.9	61.4	61.3	59.4	52	72	62
4.75	42.8	42.9	44.5	43.5	37.4	35	55	45
2.36	34.3	34.5	36.1	35.5	30.7	28	44	36
1.18	25.8	25.8	26.8	26.3	22.6	20	34	27
0.6	19.3	19.2	19.8	19.3	16.6	15	27	21
0.3	14.2	14.2	14.7	14.4	12.6	10	20	15
0.15	9.3	9.4	9.8	9.6	8.6	5	13	9
0.075	4.7	4.6	4.7	4.5	4.1	2	8	5



Graph 04: Gradation Curve for BC grade-1 with Different Percentage of RAP

4.2 Mix Design of HMA-RAP Mixes

The bitumen samples were prepared taking bitumen content in range of 4.5% to 6.5% of an interval of 0.5%. The design blended aggregate gradation was used for this purpose. The additional amount of neat binder was estimated in case of RAP mixes. The Marshall moulds were prepared at each of the bitumen content and their volumetric properties were determined. The bitumen content of a mix was found by taking the average of bitumen content corresponding to maximum stability, maximum unit weight and 4% air voids. The OBC of 0%, 10%, 20%, 30%, and 40% of RAP mixes was found to be 5.63%, 5.8%, 5.6%, 5.6%, 5%, respectively. The volumetric properties of mixes at OBC satisfy design requirements as shown in Table 08. The addition of RAP results in saving of significant amount of binder. For example, addition of 40% RAP may result in approximately 41% saving in quantity of binder. The Marshall stability of a mix increases with addition of RAP. Table 09 and Table 10 show the bitumen and aggregate saving by addition of RAP, respectively.

Table no 08: Marshall Stability and Flow Value for HMA at Optimum Bitumen Content

% RAP	0	10	20	30	40	Limits
Bitumen (%)	5.63	5.8	5.60	5.60	5.0	-
V_v (%)	4.74	4.29	3.59	3.81	3.47	3-5
V_b (%)	13.24	13.70	13.4	13.39	12.00	-
VMA (%)	17.96	17.99	17.0	17.20	16.55	Min 17
VFB (%)	73.7	75.1	74.9	73.8	74.6	65-75
Stability (kN)	15.09	17.38	17.26	17.36	19.70	Min 9
Flow (mm)	3.44	3.97	3.85	3.91	3.67	2-4

Table No 09: Saving of Binder by use of RAP

RAP (%)	OBC (%)	Virgin Binder (%)	Binder (%)	Binder Saving (%)
0	5.63	5.63	-	-
10	5.06	5.06	0.52	9.0
20	4.59	4.59	1.04	18.6
30	4.07	4.07	1.56	27.7
40	2.92	2.92	2.08	41.6

Table No 10: Saving of Aggregate by use of RAP

RAP (%)	Percentage Savings of Aggregate			
	20 mm	10 mm	Stone dust	Total Saving
0	-	-	-	-
10	0.25	4.2	5.6	10
20	0.5	8.6	11.2	20
30	0.75	12.5	15.8	30
40	1	16.6	22.3	40

5.0 SUMMARY AND CONCLUSION

5.1 Summary

The construction of highways with RAP materials is not as popular in India as it expected to be, due to lack of laboratory and field performance data. Furthermore, agencies and contractors are not enough trained and confident on quality of RAP materials and to design mixes containing RAP. Generally it is thought that RAP is a poor grade material which may negatively impact quality of pavements and consequently wastage of significant amount of money. Nonetheless, studies conducted over the years in different parts of the world showed that performance of bituminous mixes containing RAP can be equal and better than the performance of virgin bituminous mix.

The present study was undertaken to design and evaluate performance of bituminous mixes containing different percentages of RAP. For this purpose, RAP was collected from Raichur to Mantralayam road near yaragera. The preliminary laboratory tests on the collected RAP such as aggregate quality, gradation and bitumen content were conducted to ensure its quality. The bituminous concrete (BC) with different percentages of RAP (i.e., 0%, 10%, 20%, 30% and 40%) were design as per the standards and specifications provided by Ministry of Road Surface and Transportation (MoRTH).

5.2 Conclusions

The following conclusions can be drawn from the results and discussion presented in this study.

1. The impact, crushing, and Los Angeles values of selected virgin aggregates in this study were found to be within the limit (i.e., less than 30%), indicating the suitability the aggregates for construction of roads.

2. The penetration softening point, viscosity, and ductility values of collected VG30 binder were found to be within the limit as per IS codes, and hence found to be appropriate to use for construction of pavements.
3. The asphalt content in collected RAP was determined from chemical extraction using centrifuge device and ignition oven was found to be 4.96% and 5.40%, respectively. The average of both the methods, 5.2%, was considered for design of mixes containing different percentages of RAP.

4. The Optimum bitumen content of 0%, 10%, 20%, 30%, and 40% of RAP mixes was found to be 5.63%, 5.8%, 5.6%, 5.6%, 5%, respectively. The volumetric properties of mixes at OBC satisfy design requirements. The addition of 40% RAP may result in approximately 41% saving in quantity of binder. The Marshall stability of a mix increases with addition of RAP.

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