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An Experimental Study on Reclaimed Asphalt Pavement In Bituminous Concrete

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Abstract- This paper presents the optimization of the use of RAP in surface courses such as Bituminous Concrete. From the past research papers it has been observed that there is no specific optimum percentage for using RAP as it varies from project to project. Optimum percentage of RAP depends upon many factors such as RAP materials, binder content, and availability of RAP, viscosity of binder and extent of deterioration. In this study various properties like Marshall Stability, Flow value and Density of bituminous mixes using RAP with varying % age 25 to 40% were compared to that of fresh bituminous mix. One virgin bituminous mix and four different percentages of RAP were selected and samples were prepared at four different percentages of bitumen at each bitumen percentage preparing 3 samples. Total 60 samples were prepared and tested. Test results showed that mix prepared with 35% RAP gave nearly same physical and strength parameters as virgin bituminous mix.

Keywords: - *RAP, Bituminous concrete, Marshall Stability, Flow value, Density, etc.*

I. INTRODUCTION

RAP (Reclaimed Asphalt Pavement) is a latest technology in the field of construction of bituminous pavements. RAP is being widely adopted all over the world as it has several benefits over virgin mixes. By using RAP the cost of project is marginally reduced and it also has a favorable effect on environmental impact. RAP also leads to optimization of resources. Old road pavements due to repeated overlays being placed over the years, result in the increase of the road levels compare to adjacent built up areas, so RAP becomes a necessity is some cases. Over a period of time the technological improvements have resulted in reclaiming the bituminous pavement in usable condition. Earlier the old pavements were excavated using excavators which resulted in availability of bituminous mix in form of chunks .In modern times, the scarifying process using diamond cutters result in removal of pavement in sizes nearly aggregate size. The results given by RAP mixes are either similar or better than virgin mixes. Hence the use of RAP is justified. An attempt has been made in this paper to find the various parameters obtained by Marshall Stability test of different bituminous mixes using different percentages of RAP.

II. OBJECTIVES AND EXPERIMENTAL PROGRAM

The objectives of this study are mentioned below: -

1. To evaluate the engineering characteristics of RAP for example aging, grading, residual binder content etc
2. To ascertain strength of bituminous mix for use as bituminous concrete using different percentages of RAP.

For this study, the aggregate were obtained from a hot mix plant nearly Chandigarh. A blend using

these aggregates were prepared and samples prepared at different binder content and tested to determine the optimum binder content. Thereafter the same aggregate blend was used and part of it was replaced by RAP percentage of 25%, 30%, 35% and 40% were selected and used samples prepared of Bituminous Concrete. Various parameters like Marshall Stability, flow value and density were studied at four different percentages of bitumen 5.4 %, 5.6%, 5.8% and 6% three samples by preparing at each bitumen percentage. Total 60 samples were prepared.

III. DETAILS OF MATERIALS USED

Materials Used

For this study, aggregates of 20mm, 10mm, 6.7mm and Stone Dust were used. Along with RAP material was collected from the vicinity of sec. 27 Chandigarh. where the old road is being reconstructed. RAP here comprise of mix of old surface course and bituminous base course. The aggregates needed to be separated slightly. The removal of RAP was done using excavator. The material is 3 year old. RAP being mix of base and old surface layer, the binder content found in RAP was 4.8% and the original percentage at the time of construction was 5.5%

3.1 Properties of Aggregates:-

The physical and engineering properties of the aggregates used are given in table 1

Table 1-Physical properties of aggregates

Physical Properties	20mm	10 mm	Required Values as per MORTH 5th revision
Sp. Gravity	2.60	2.71	**2.6-2.8**
Elongation Index, %	11.74	14.82	**Combined Elongation and Flakiness Max 30%**
Flakiness index, %	14.28	12.86	
Impact value, %	16.1	16.3	**24% Max**
Water absorption	0.24%	0.32%	**2 % Max**
Stripping	< 2%	< 2%	**< 5 %**

Bitumen: binder of VG-30 was used for this study; following are the properties of binder.

TABLE 2-Physical properties of Bitumen used

Properties	VG-30		Test Method
	Calculated	Required	
Penetration	55	50-70	**IS:1203:1978**
Softening Point	48.3	47 Min	**IS:1205:1978**
Ductility	78	40 Min	**IS:1208:1978**
Specific Gravity	1.00	0.99	**IS:1202:1978**

IV. JOB MIX FORMULA & RESULTS

The design mix was performed using job mix formula according to table 500-17 as given in "SPECIFICATIONS FOR ROAD AND BRIDGE WORKS", MORTH (fifth revision), 2012. Following

is the grading table-depicting the gradation of various aggregates and filler used for bituminous concrete (fresh materials) of sizes 20 mm, 10 mm, 6.7 mm and stone dust.

4.1 Job Mix Formula For BC virgin mix

Table 3- Gradation table for virgin mix

Sieve size	% passing (required)	% passing IS 19mm	% passing 13.2mm	% passing 6.7mm	% passing stone dust	Cement	Grading of mix
19mm	100	98.6	100	100	100	100	99.86
13.2mm	79-100	10.2	100	100	100	100	91.02
9.5mm	70-88	1	87	99.4	100	100	86.87
4.75mm	53-71	0	1	42.4	99.3	100	55.55
2.36mm	42-58	0	0	6.4	90.3	100	44.78
1.18mm	34-48	0	0	2.2	68.9	100	34.40
600µ	26-38	0	0	2.2	51.3	100	26.48
300µ	18-28	0	0	2.2	37.1	100	20.09
150 µ	12-20	0	0	1.7	19.6	100	12.12
75µ	4-10	0	0	1.7	10.5	100	8.03
Ratio		0.1	0.24	0.18	0.45	0.03	

4.2 Required Values for Bituminous Mixes-

Various values that are required for bituminous mixes are as specified in table 500-11 in "SPECIFICATIONS FOR ROAD AND BRIDGE WORKS", MORTH (fifth revision), published by Indian Roads Congress

4.3 Experimental Results (average) of Marshall Stability Test

The experimental results (average) of different parameters of Marshall Stability Test for Virgin mix at optimum binder content are given in table 5

4.4 Proportion of Bitumen Present in RAP

Percentage of bitumen was determined using centrifugation method. It was found that the RAP contained 4.8% bitumen.

4.5 Job Mix Formula For BC Using RAP- 25 %, 30%, 35% and 40%

Table 3- Table for grading of bituminous mix using RAP 25%, 30%, 35%, 40%

IS Sieve size	% passing (required)	Grading of mix with RAP 25%	Grading of mix with RAP 30%	Grading of mix with RAP 35%	Grading of mix with RAP 40%
19mm	100	**97.96**	97.58	97.21	96.84
13.2mm	79-100	**83.25**	81.88	80.51	80.03
9.5mm	70-88	**77.00**	74.94	72.85	72.08
4.75mm	53-71	**56.96**	56.07	55.18	56.12
2.36mm	42-58	**55.25**	46.34	46.07	46.84
1.18mm	34-48	**36.07**	35.97	35.86	36.48
600µ	26-38	**27.96**	27.91	27.87	28.39
300µ	18-28	**21.40**	21.41	21.42	21.84

150 µ	12-20	**13.05**	13.1	13.14	13.41
75µ	4-10	**8.34**	8.55	8.57	8.72
Ratio		**6%,8%,15%, 43%, 25% and 3%**	**5%,7%,13%,42%, 30% and 3%**	**4%, 6 %, 11%, 41%, 35% and 3%**	**2%, 3%, 11%, 41%, 40% and 3%**

NOTE**:** %ages of 20mm,10mm,6.7mm,stone dust, cement and RAP respectively.

4.6 Experimental Results (average) of Marshall Stability Test For DBM containing RAP- 25 %, 30%, 35% and 40%

The experimental results (average) of different parameters of Marshall Stability Test for DBM containing RAP 25%, 30%, 35% and 40% at optimum binder content are given in table 5

Table 5-Average results of different parameters of Marshall Stability test at optimum binder content for bituminous mix containing different percentages of RAP

RAP percentage	Fresh mix	RAP 25%	RAP 30%	RAP 35%	RAP 40%
Density (g/cc)	2.369	2.357	2.361	2.364	2.358
Volume of Bitumen, V_b%	13.74	13.671	3.1	83.254	13676
Volume of aggregates $V_{A\%}$	81.86	82.61	17.099	13.711	83.273
Voids in mineral aggregate (VMA)%	16.27	17.11	80.086	17.129	17.442
Voids filled with bitumen(VFB) %	84.47	79.90	82.953	80.048	78.413
Measured stability,(kN)	1461	1189	1376	1431	1308
Flow value (mm)	2.9	3.8	4.43	3	3.5
Marshall quotient (Stability/Flow)	5.03	3.12	13.694	4.77	3.73
S.G of mix, S_T	2.726	2.687	2.681	2.675	2.667

V. DISCUSSIONS:

All the prepared samples were tested for Marshall Stability test and with the help of graphs the observations are explained further.

5.1 Density:

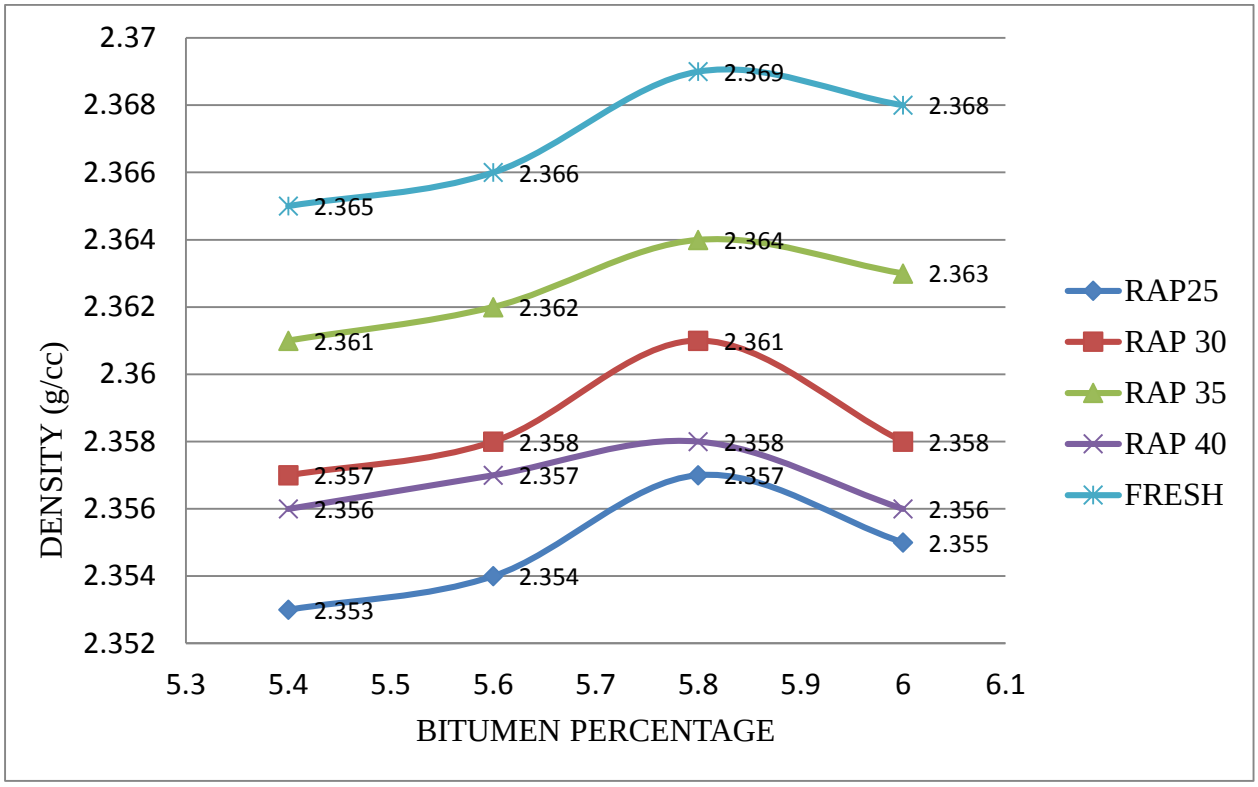

Fig 5.1 Density v/s Bituminous percentage

Note: It is observed that fresh bituminous mix has the maximum density of all RAP percentages at all bitumen percentages. It is also seen that the Optimum Binder Content was not changed in any of RAP mixes and remains the same as fresh bituminous mix i.e at 5.8%. This indicates that the binder in RAP materials perfectly blended with fresh binder. At 5.8% binder content density of fresh bituminous mix is found to be 2.365 as compared to 2.364 which is maximum value determined corresponding to content 30% this difference is negligible . the overall variation of max. density is between 2.357 to 2.364 which is again minimal. Slightly more than density of RAP 30 % by 0.21%.

5.2 Marshall Stability:

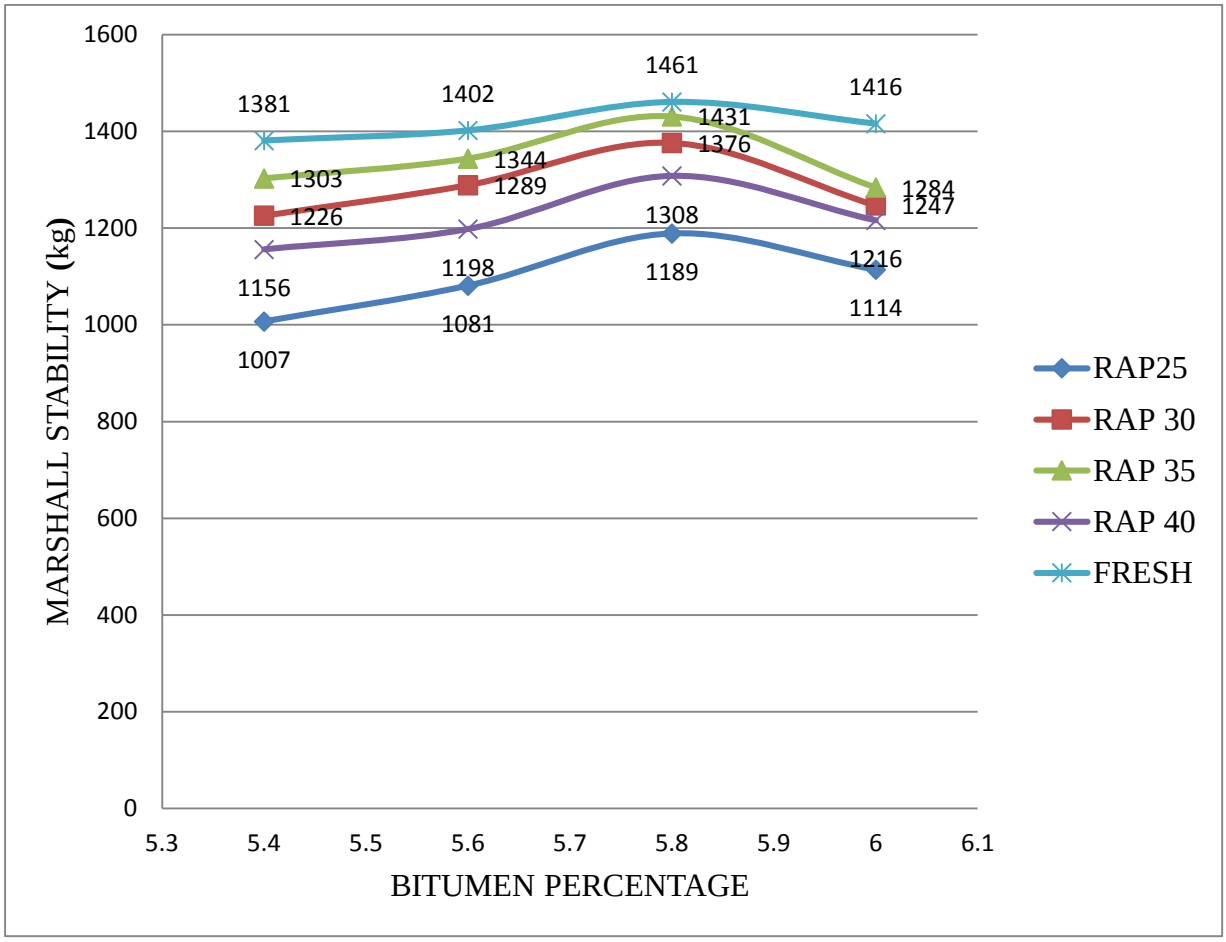

Fig. 5.2 Marshal Stability v/s bitumen content

Note**:** It is observed that the Marshall Stability values for virgin bituminous mix are more than any of RAP mixes. RAP 35% has values nearly equal to that of fresh bituminous mix and has best density values amongst other RAP mixes. At 5.8% binder content the Marshall Stability value of fresh bituminous mix was found to be 1461 kg as compared to 1431 kg which was the maximum value determined correspondingly to RAP content 30%. This difference is negligible. The overall variation of maximum stability was between 1189 kg to 1431 kg, which again is not a huge difference. Also all the stability values of RAP mixes and fresh bituminous mix were above the minimum required range (minimum 9kN) which is specified in table 500-11 in "SPECIFICATIONS FOR ROAD AND BRIDGE WORKS", MORTH (fifth revision), published by Indian Roads Congress

5.3 Flow Value:

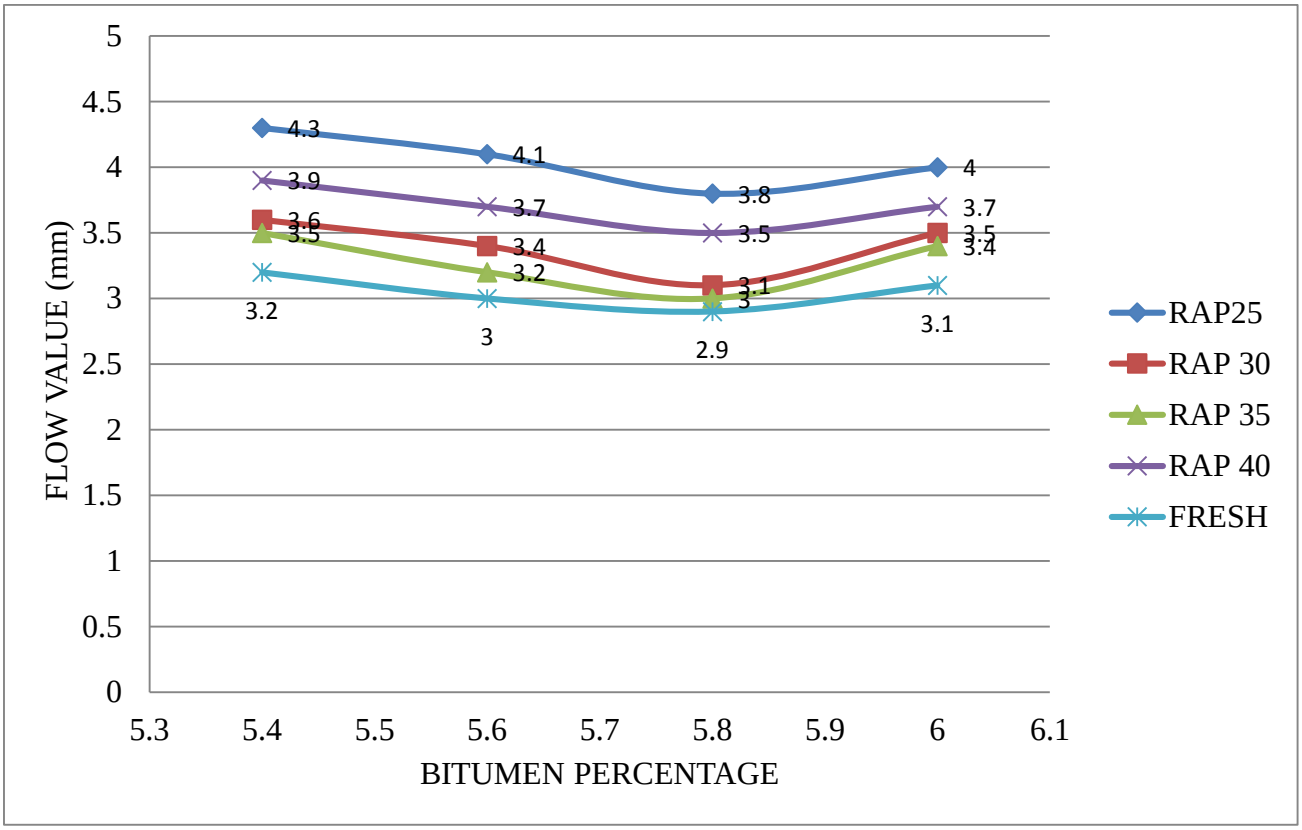

Fig. 5.3 Flow Value V/S Bitumen percentage

Note: it is observed that RAP 25 % had the maximum flow values followed by RAP 40%, RAP 30%, RAP 35 % and fresh bituminous mix. Fresh bituminous mix had minimum values out of all mixes. At 5.8% binder content the flow value of fresh bituminous was found to be 2.9 mm as compared to 3 mm which was the minimum value determined correspondingly to RAP content 30%. This difference is very less. Also all the flow values of fresh bituminous mix and RAP mixes except for RAP 40 were within the required range (2mm - 4mm) as specified in table 500-11 in "SPECIFICATIONS FOR ROAD AND BRIDGE WORKS", MORTH (fifth revision), published by Indian Roads Congress

5.4 Cost Comparison

Following analysis shows a cost comparison between a fresh bituminous mix and mix prepared with RAP 35% for BC

- Cost of laying fresh Bituminous Concrete (BC) = Rs 10,500 /m³
- Reduction in cost by aggregates by using 35 % RAP = Rs 200 /m³
- Reduction in cost by bitumen since RAP contained 4.8 % bitumen = Rs 5106 /m³
- Total reduction in cost = Rs 5106 /m³ + Rs 200 /m³ = Rs 5306 /m³
- Cost of laying BC using 30 % RAP = Rs 10,500 /m³ - Rs 5306 /m³ = Rs 5194 /m³

From the above analysis it can be understood that using RAP makes the project more economical.

VI. CONCLUSIONS

Following are the outcomes of experiment conducted for the comparison of RAP mixes and Virgin bituminous mix:

- By comparing specifications which are specified in table 500-11 in "SPECIFICATIONS FOR ROAD AND BRIDGE WORKS", MORTH 5th (2012) revision it is found that the optimum binder content for Virgin Mix was at 5.8% bitumen percent. It is also observed that the optimum binder content for RAP mixes was same as that of virgin samples. This clearly indicates that there is no change in optimum binder content for RAP Mixes.
- The fact that Optimum Binder Content remained unchanged even after adding RAP materials indicates that the old binder perfectly blended with fresh binder.
- Densities of virgin mix were slightly higher than that of RAP 35 %(2.364g/cc) by 0.21% followed by RAP 30 %(2.361g/cc), RAP 40% (2.358g/cc) and RAP 25 %(2.357g/cc).
- The Marshall Stability values of virgin mixes were found to be greater than RAP 35% (1431 kg)followed by RAP 30%(1376 kg), RAP 40%(1308 kg) and RAP 25%(1189 kg).
- At optimum binder content it is observed that RAP 25 %(3.8 mm)had the maximum flow values followed by RAP 40%(3.5 mm), RAP 30%(3.1 mm), RAP 35 %(3 mm) and fresh bituminous mix. Fresh bituminous mix had minimum values out of all mixes.
- VMA values of RAP mixes were higher than those of virgin mix. VMA values were observed maximum for RAP 40 %(17.44%) followed by RAP 30 %(17.09%), RAP 25 %(17.11%) and RAP 35 %(17.12%).
- VFB values of virgin bituminous mix were greater than those of RAP mixes. RAP 25% (79.90 %) showed maximum VFB values of RAP 35 %(80.04%) were highest amongst other RAP mixes followed by RAP 30 %(80.08%), RAP 40 %(78.41%) and RAP 25%.
- Volume of bitumen V_b was observed more for virgin mix than RAP mixes. In RAP mixes RAP 35% (13.71%) had greater values than RAP 30 %(13.69) followed by RAP 40 %(13.67%) and lastly RAP 25 %(13.17%). All of these are within permissible limit or slightly higher (75% of mix) which is negligible.
- It is observed that by using 35% RAP the project cost was reduced by 50%.
- Time period for mixing was similar in all the cases.
- An attempt was made to extract the binder from RAP by heating. This was unsuccessful as the binder was in limited quantity, hardened and bound with aggregates.

Overall from this study it was concluded that RAP 35% showed results similar to that of virgin bituminous mix and its performance was best amongst other RAP percentages. Also with the use of RAP 35% the cost of project was reduced by 50 %

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