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An Experimental Study on Reclaimed Asphalt Pavement in Dense Bituminous Macadam

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Abstract- This paper shows the optimization of the use of RAP in binder courses such as Dense Bituminous Macadam. This paper presents a comparison between bituminous mixes using different percentages of RAP and conventional method of bituminous mix design. It has been observed from various research papers that there is no defined optimal percentage of RAP that should be used in the construction of bituminous pavements, as the optimal percentage of RAP depends upon many parameters e.g. age of RAP materials, binder content, availability of RAP, viscosity of binder, extent of deterioration etc which vary from one pavement to another. In this study properties like Marshall Stability, Flow value and Density of bituminous mixes using RAP 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 3 samples were prepared. Total 60 samples were prepared and tested. Test results showed that mix prepared with 30% RAP performed nearly same as virgin bituminous mix and best amongst other RAP mixes.

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

I. INTRODUCTION

Reclaimed Asphalt Pavement (RAP) is a method used for the construction of bituminous pavements. Construction of pavements using RAP method is being used world widely. Using materials from RAP does not only help in minimizing the cost of project but also supports sustainable development. Over a period of time, the technical improvements have resulted in reclaiming the bituminous pavements in readily usable condition. Earlier the old pavements were scarified using excavators which resulted in availability of bituminous mix in form of chunks. In modern times, the scarifying process using diamond cutter results in removal of pavement of nearly aggregate size. The need for using RAP becomes more important with the increase in the restrictions on the dumping of reusable materials. With the passage of time and wear tear, pavement deteriorates resulting in poor driving conditions. To take precautionary or restoration (of Riding Quality) measures resurfacing of pavement is practiced, but continued resurfacing results in increased road levels which may not be acceptable in many cases. This is particularly true for city roads where drainage problem may arise due to higher road levels. To overcome this problem the older surface layer of pavement should be scarified and the materials should be reused.

II. OBJECTIVES AND EXPERIMENTS

The objectives of this study are mentioned below: -

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

For this study aggregates were obtained from a hot mix plant nearby Chandigarh. A blend using these aggregates was prepared and samples were 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 with RAP. RAP of percentages 25%, 30%, 35% and 40% were selected and were used as Dense Bituminous Macadam. Various parameters like Marshall Stability, flow value and density were studied at four different percentages of bitumen 4.5 %, 4.65, 4.85 and 5% by preparing three samples at each bitumen percentage. Total 60 samples were prepared.

III. DETAILS OF MATERIALS USED

Different materials used in this study are RAP and virgin aggregates and binder of grade VG 30. Aggregates used in this study were 20mm, 10mm, 6.7mm, stone dust and RAP. The specific gravities of 20mm, 10mm, 6.75mm, stone dust and RAP are 2.60, 2.71, 2.6, 2.61 and 2.51 respectively. RAP material is collected from the vicinity of PEC sec 11, Chandigarh, where the old road is being reconstructed. RAP 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 5 year old. RAP being mix of old base and surface layer, the binder content value found in RAP is 2.4 % , it is within the expected range as the original value was

3.1 Properties of Aggregates Used:-

The physical properties of 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%**

3.2 Properties of Bitumen Used:-

Bitumen: An attempt was made to use binder from RAP, but it was unsuccessful. Bitumen of VG-30 grade was used. Following are the properties of binder.

Table 2-Physical properties of bitumen used

Properties	VG-30 grade		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" by MORTH 5th revesion, 2012. The individual desired grading was then calculated by trial and error method using Microsoft excel, grading is represented below in table 3

4.1 Job Mix Formula for DBM Virgin Mix

Following is the grading table depicting the gradation of various aggregates and filler used namely 20mm, 10mm, 6.7mm, stone dust

Table 3-Gradation table for virgin mix

IS Sieve size	% passing (required)	% passing 20mm	% passing 10mm	Grit passing 6.7mm	% passing stone dust	Grading of mix
37.5mm	100	100	100	100	100	**100.00**
26.5mm	90-100	100	100	100	100	**100.00**
19mm	71-95	74.2	100	100	100	**92.26**
13.2mm	56-80	2.2	100	99.4	100	**70.55**
4.75mm	38-54	1	0.6	41.7	99.3	**37.72**
2.36mm	28-42	0	0	5.8	90.2	**28.10**
300µ	7-21	0	0	1.9	36.8	**11.38**
75µ	2-8	0	0	1.7	10.4	**3.42**
Ratio		0.30	0.22	0.18	0.30	

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 and RAP mixes 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 2.4% bitumen.

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

Following is the grading table depicting the gradation of various RAP percentages

Table 4-Table for grading of bituminous mix using RAP 25%, 30%, 35%, 40%

IS Sieve size	% passing (required)	Grading of mix using RAP 25%	Grading of mix using RAP 30%	Grading of mix using RAP 35%	Grading of mix using RAP 40%
37.5mm	100	**100**	**100**	**100**	**100**
26.5mm	90-100	**100**	**100**	**100**	**100**
19mm	71-95	**93.66**	**93.52**	**93.39**	**93.78**
13.2mm	56-80	**71.93**	**70.66**	**57.37**	**70.04**
4.75mm	38-54	**40.70**	**40.40**	**38.94**	**38.88**
2.36mm	28-42	**31.69**	**32.28**	**31.18**	**31.05**
300µ	7-21	**13.40**	**13.77**	**13.43**	**13.49**
75µ	2-8	**4.13**	**4.23**	**4.16**	**4.21**
Ratio*		**17%, 14%, 14%, 30% and 25%**	**16%, 13%, 11%, 30%, and 30 %**	**15%, 12%, 10%, 28% and 35%**	**12%, 11%, 10%, 27% and 40%**

Note: * percentages of 20mm, 10mm, 6.7mm, stone dust and RAP respectively.

4.6 Experimental Results (average) of Marshall Stability Test for fresh mix and mix 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)	2.346	2.333	2.336	2.33	2.33
Volume of Bitumen, V_b%	11.37	11.31	11.33	11.30	11.29
Volume of aggregates $V_{A\%}$	83.42	83.94	84.23	84.20	84.35
Voids in mineral aggregate (VMA)%	15.02	15.24	15.1	15.28	15.28
Voids filled with bitumen(VFB) %	75.70	74.24	75.02	73.95	73.91
Measured stability,(kN)	14.68	13.61	14.31	3.6	11.65
Flow value (mm)	3	3.4	3.2	12.41	3.9
Marshall quotient (Stability/Flow)	4.89	4	4.47	3.44	2.98
S.G of mix, S_T	2.676	2.644	2.639	2.633	2.627

V. DISCUSSIONS

5.1 Marshall Stability

All the prepared samples were tested for Marshall Stability test and with the help of fig 5.1 the results are explained below.

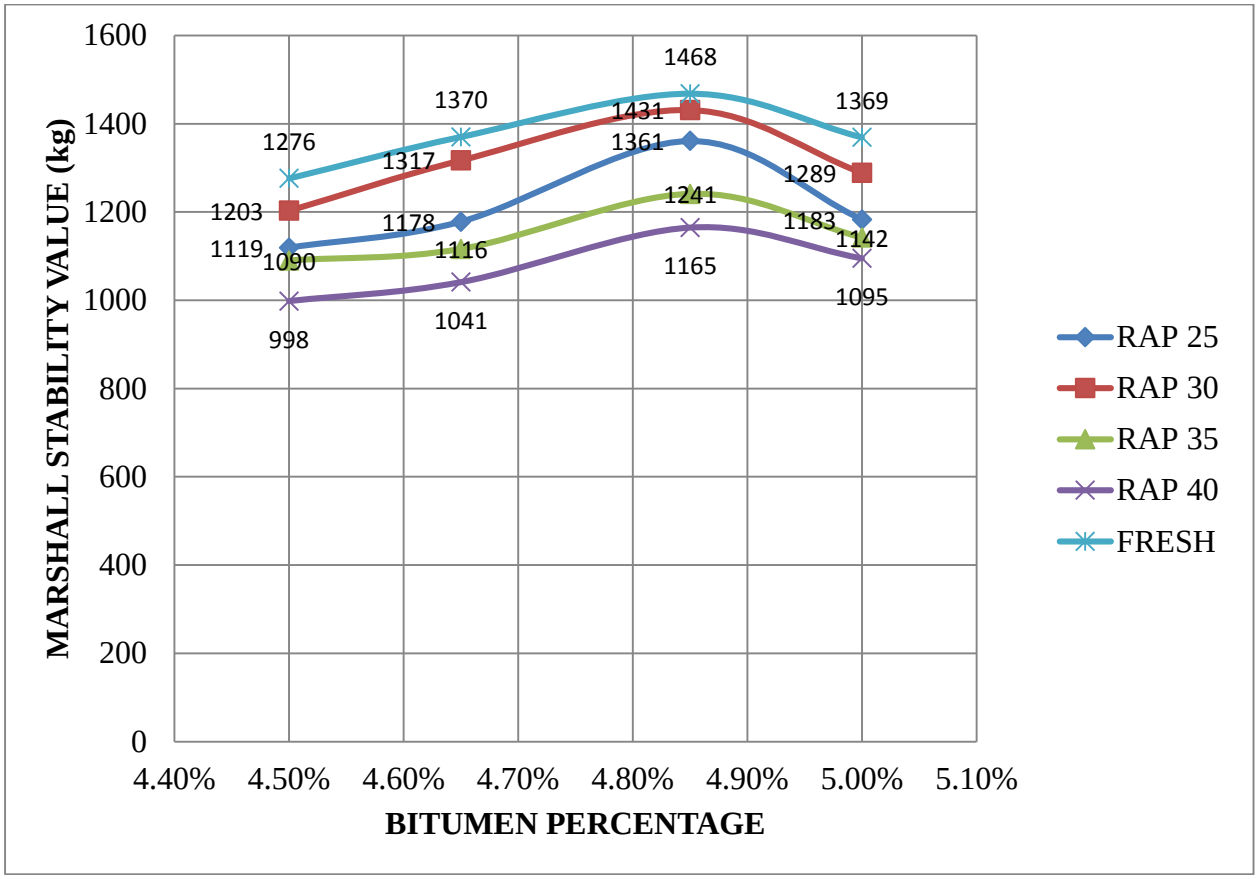


Fig 5.1 Marshall Stability value v/s Bitumen percentage

Note. It was observed that Marshall Stability values of all RAP percentage were below virgin mix. RAP 30 gave maximum Marshall Stability value 1431 kg at 4.85 % bitumen percentage. It was observed that the optimum binder content of RAP mixes and fresh bituminous mix were same which is 4.85%. This indicates that the binder present in RAP materials perfectly blended with fresh binder. At 4.85% binder content the Marshall Stability value of fresh bituminous mix was found to be 1468 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 1165 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

5.2 Flow Value

All the results of flow value of the prepared samples are explained below with the help of fig 5.2

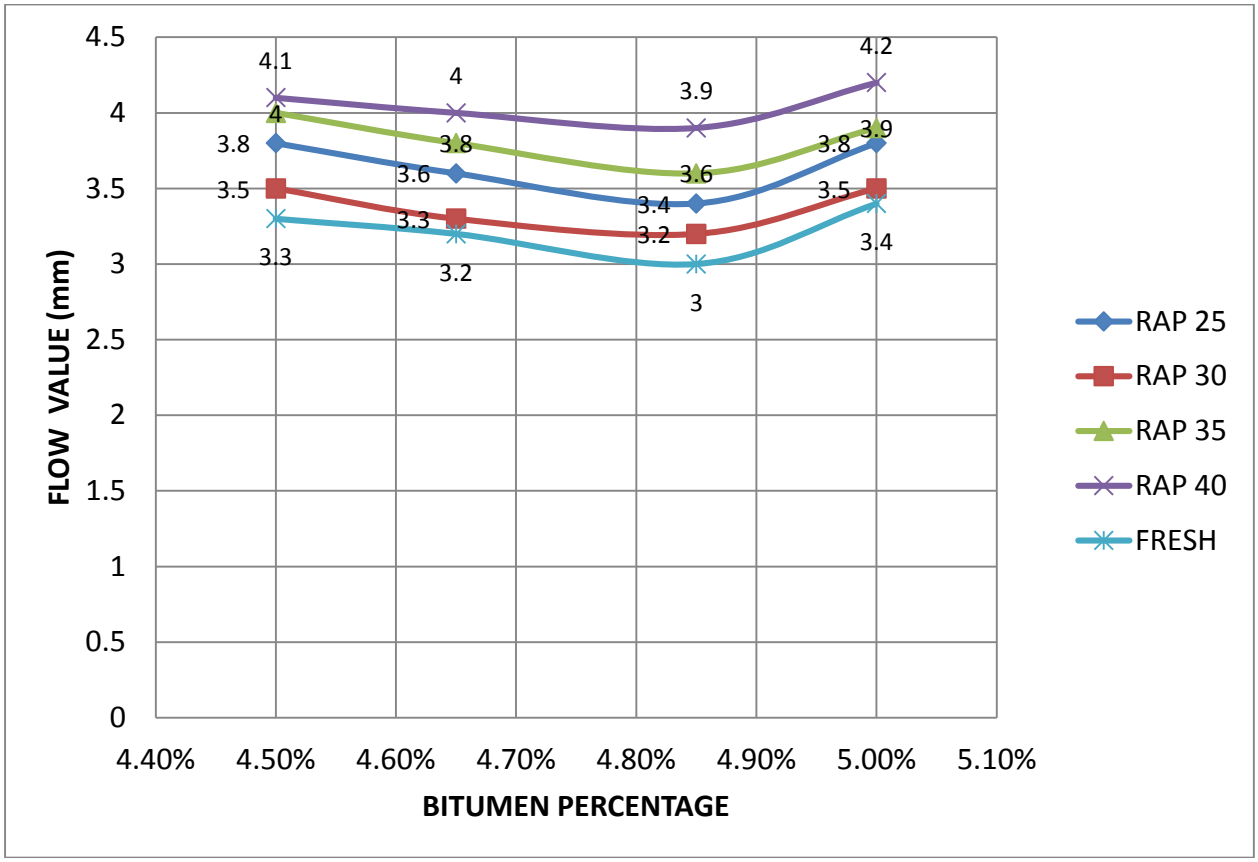
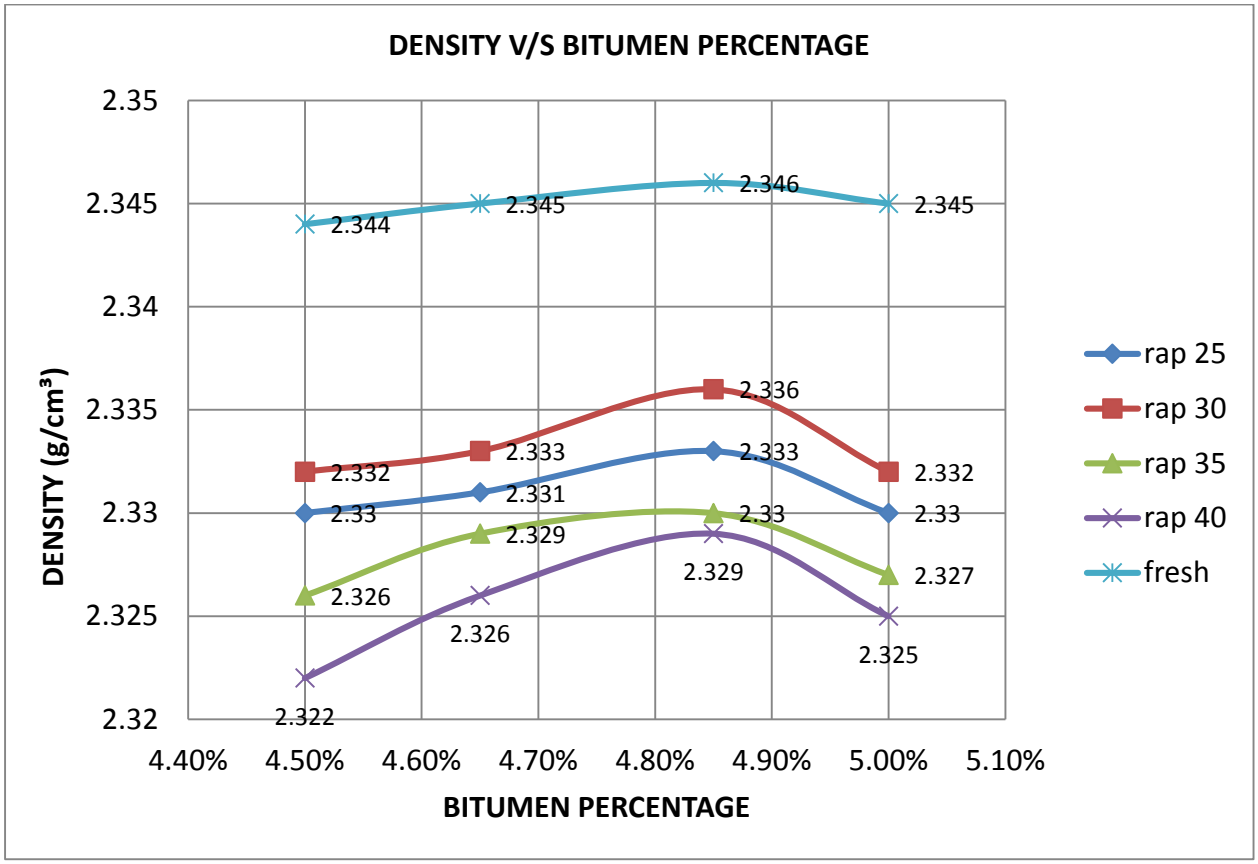


Fig 5.2 Flow value v/s Bitumen percentage

Note. It was observed that fresh bituminous mix had least flow values. Flow value of fresh bituminous mix started decreasing from 3.3 mm to 3 mm at bitumen percentage from 4.5% to 4.85%. At 4.85% binder content the flow value of fresh bituminous was found to be 3 mm as compared to 3.2 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

5.3 Density

All the densities of the prepared samples are explained below with the help of fig 5.3



5.3 Density v/s Bitumen percentage

Note. It was observed that fresh bituminous mix had densities slightly higher than that of any RAP mixes followed by RAP 30, RAP 25, RAP 35 and RAP 40. At Optimum Binder Content (4.85%) fresh bituminous mix had density greater than RAP 30 by 0.42%. At 4.85% binder content the density of fresh bituminous mix was found to be 2.346 g/cc as compared to 2.336 g/cc, which was the maximum value determined correspondingly to RAP content 30%. This difference is negligible. The overall variation of maximum stability was between 2.329 kg to 2.336 kg, which again is not a big difference.

5.4 Cost Comparison

Following analysis shows a cost comparison between a fresh bituminous mix and mix prepared with RAP 30% for DBM

- Cost of laying fresh Dense Bituminous Macadam (DBM) = Rs 9000 /m³
- Reduction in cost by aggregates by using 30 % RAP = Rs 100 /m³
- Reduction in cost by bitumen since RAP contained 2.4% bitumen = Rs 2523 /m³
- Total reduction in cost = Rs 2523 /m³ + Rs 100 /m³ = Rs 2623 /m³
- Cost of laying DBM using 30 % RAP = Rs 9000 /m³ - Rs 2623 /m³ = Rs 6377 /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 certain specifications which are specified in table 500-11 in "SPECIFICATIONS FOR ROAD AND BRIDGE WORKS", MORTH (fifth revision), published by Indian Roads

Congress it was found that the optimum binder content for Virgin Mix was at 4.85% bitumen percent. It was 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.
- At optimum binder content the density of virgin mix was 2.346 g/cc which is slightly higher than that of RAP 30% which had density 2.336 g/cc by 0.42% followed by RAP 25% (2.333 g/cc), RAP 35% (2.33 g/cc) and RAP 40% (2.329g/cc).
- At optimum binder content the Marshall Stability value of virgin mix (1468 kg) was found to be greater than RAP 30% (1431 kg) followed by RAP 25% (1361 kg), RAP 35% (1241 kg) and RAP 40% (1165).
- At optimum binder content flow value of RAP mixes were greater than virgin mixes. Flow value of RAP 30% was found to be greater than virgin bituminous mix by 7.6%. However 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
- VMA values of RAP mixes were higher than those of virgin mix. VMA values were observed maximum for RAP 40% (15.28%) and RAP 35% (15.28%) followed by RAP 25% (15.24%) and RAP 30% (15.1%).
- VFB values of virgin bituminous mix were greater than those of RAP mixes. RAP 30% (75.02%) showed maximum VFB values followed by RAP 25% (74.24%), RAP 35% (73.95%) and RAP 40% (73.91%). All of these are within permissible limit or slightly higher (75% of mix) which is negligible.
- Volume of bitumen V_b was observed more for virgin mix than RAP mixes. In RAP mixes RAP 30% had greater values (11.33%) than RAP 25% (11.31%) followed by RAP 35% (11.30%) and RAP 40% (11.29%). RAP 35 % and RAP 40% had equal values.
- It is observed that using 30 % RAP reduces the cost of project by 21 %.
- 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 30 % showed results similar to that of virgin bituminous mix and best performance amongst other RAP percentages. Also RAP 30 % showed a reduction in cost of project by 21 %

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