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TO STUDY THE EFFECT OF RAP ADDITION IN FRESH DENSE BITUMINOUS MIX WITH THE HELP OF MARSHALL STABILITY TEST

Viranta Sharma[1], Robin Babit[2], Ajay K. Duggal[3]

[1]*Asst. Prof., Dept. of Civil Engineering, ICFAI University, Baddi, Himachal Pradesh, India*
[2]*Asst. Prof., Dept. of Civil Engineering, SUS Engineering College, Tangori, Punjab, India*
[3]*Associate Professor, Dept. of Civil Engineering, NITTTR, Chandigarh, India*

Abstract

Road network in India aggregates to about 4.2 million kilometers, which is second largest in the world only after USA. National Highways (NH) constitute about 70,934 kilometers which is only 2 percent of the total road network. State Highways (SH) and Major District Roads (MDR) together constitute the secondary system of road transportation which contributes significantly to the development of the rural economy and industrial growth of the country. Hence, construction of roads has led to increase the pressure on natural resources. For sustainable development, it is therefore desirable to implement the reuse and recycling techniques in road construction. Using Reclaimed Asphalt Pavement (RAP) in bituminous mixes is one such technique. This paper presents the effect of addition of RAP on Dense Bituminous Macadam on the basis of Marshall Stability Test. The mix having RAP percentage of 25% and 30% showed better results when compared to control mix.

Keywords: *Dense Bituminous Macadam, RAP, Marshall Stability Test, Flow Value.*

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1. INTRODUCTION

Infrastructure is the backbone of a developing nation and to fulfill this indispensable demand, construction industry is growing rapidly across the globe. New construction, maintenance of old structures, reconstruction by demolishing old structures, etcetera are inevitable for the growth of the infrastructure in the world. If we agree to World Bank reports (2012), the solid waste generated in cities is about 1.3 billion tons and it will increase upto 2.2 billion tons by the year 2025. As per Technology Information Forecasting and Assessment Council (TIFAC) reports, Construction and Demolition (C&D) waste generated in India by buildings in the year 2013 amounts to a humungous 530 MT. The above data by TIFAC does not include the waste generated through infrastructure projects like dams and roads which are one of the major contributors of waste generation. Moreover, to dump the generated waste we require large piece of lands which otherwise can be used for the development of the nation. The best way to reduce the C&D waste is to reuse it in new constructions. Thus, recycling will lead to many benefits like:-

1) Reduction in existing waste materials,
2) Preservation of environment,
3) Conservation of aggregate and binder,
4) Preservation of existing pavement,
5) Conservation of energy,
6) Reduction in the cost of construction.

1.1 Reclaimed Asphalt Pavement

The materials present in old bituminous pavements certainly have some value even when pavements have reached the ends of their service life. The use of reclaimed asphalt pavement (RAP) in constructing new pavements is increasing day by day. RAP can serve as an alternative to virgin materials as it decreases the use of new aggregates and the quantity of virgin bitumen binder in the production of Hot Mix Asphalt (HMA), thereby it also decreases the amount of old pavement's waste.

1.2 Objectives of the Study

The objectives of the study are given below:-

1. To determine the optimum quantity of RAP for Dense Bituminous Macadam (DBM).
2. To study the effects of addition of different percentages of RAP on Marshall Flow values, Marshall Stability and density in bituminous mixes.

1.3 Study Methodology

This study was divided into following stages:

i) Collection of suitable RAP.
ii) To source various suitable materials, as per MORTH (5th revision) guidelines.
iii) Preparing Job mix formula for DBM (control mix) using Marshall Stability test method.
iv) Preparing Job mix formula by part substitution of virgin materials with RAP, using trial percentage 25%, 30%, 35% and 40%.

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v) Analysing the results obtained from the Marshall Stability test and optimizing percentage addition of RAP.

2. MATERIAL DESCRIPTION

The materials required to conduct this study are RAP, Bitumen and fresh aggregates.

1. RAP: The RAP was collected from New Chandigarh Airport road. The specific gravity of RAP was determined to be 2.586 and the bitumen content was 4.5%.
2. Aggregates: The sizes of aggregates used were 37.5mm down, 25mm, 13.2mm and stone dust. Physical properties of aggregate were evaluated through certain tests and results are shown in table I.
3. Binder used: VG30 bitumen was used having specific gravity 1.0 and certain tests were conducted on bitumen whose results are given in table II.

Certain tests conducted on aggregates, to satisfy the requirements set by MoRTH (5th revision) and results of the tests are shown in the table below:-

Table -1: Physical Properties of Aggregates

Physical properties	37.5mm down	25mm	Required Values as per MoRTH (5th revision)
Specific Gravity	2.665	2.683	2.6-2.8
Elongation index (%)	13.38	13.57	Combined Max. 30%
Flakiness Index (%)	14.98	16.36	
Impact Value (%)	17.0	17.2	Max. 24%
Water Absorption (%)	0.26%	0.34%	Max. 2%
Stripping Value (%)	< 3	<3	< 5%

Table -2: Physical Properties of Binder Used

Properties	VG-30 Grade		Test Method
	Determined	Required	
Penetration	63	50-70	IS:1203:1978
Softening Point	45min.	47 min.	IS:1205:1978
Ductility	38min	40 min.	IS:1208:1978
Specific Gravity	1.0	0.99	IS:1202:1978

3. JOB MIX FORMULA FOR DENSE BITUMINOUS MACADAM

For preparing the mixes, grading of various aggregates and RAP were done which is shown in the table below:

Table -3: Grading of control mix, with 25% RAP and 30% RAP

IS Sieve Size	% passing (required)	Grading of mix obtained		
		Control Mix	25% RAP	30% RAP
37.5mm	100	100	100	100
26.5mm	90-100	100	95.04	95.04
19mm	71-95	100	91.54	91.46
13.2mm	56-80	98.85	79.04	78.14
4.75mm	38-54	60.00	50.2	50.39
2.36mm	28-42	34.59	33.73	33.59
300µ	07-21	15.33	14.44	14.52
75µ	02-08	7.14	7.98	7.94
Ratio of Blending		15:23:28:34	8:12:24:31:25	8:13:20:29:30

Table -4: Grading of mix with 35% RAP and 40% RAP

IS Sieve Size	% passing (required)	Grading of mix obtained	
		35% RAP	40% RAP
37.5mm	100	100	100
26.5mm	90-100	95.04	95.04
19mm	71-95	91.38	91.46
13.2mm	56-80	77.19	78.19
4.75mm	38-54	49.84	51.47
2.36mm	28-42	32.98	32.89
300µ	07-21	14.26	14.34
75µ	02-08	7.69	7.66
Ratio of Blending		8:14:17:26:35	8:13:15:24:40

3.1 Quantity of Aggregate Used

From above table, ratio is decided as per the requirement of the grading. With this ratio quantity of different aggregates were determined. Hence, the quantity shown in table 5 of aggregates will be used in the preparation of samples.

Table -5: Quantities of Aggregates

Size of Aggregate	Weight of Aggregate in grams				
	Control Mix	RAP 25%	RAP 30%	RAP 35%	RAP 40%
37.5mm down	180	96	96	96	96
25mm	276	144	156	168	156
13.2mm	336	288	240	204	180
Stone Dust	408	372	348	312	288
RAP	00	300	360	420	480

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3.2 Quantity of Bitumen Used

For virgin mix four percentages of bitumen was selected and its quantities were calculated. The quantity of bitumen to be added in the mixes with RAP was determined by subtracting the required quantity of bitumen with the quantity of bitumen available in RAP. The quantities of bitumen determined are given below in table 6:-

Table -6: Percentage and Quantities of Aggregates

Percentage of Bitumen	Weight of Bitumen in grams				
	Control Mix	RAP 25%	RAP 30%	RAP 35%	RAP 40%
4.50%	56	43.9	39.6	36.7	34
4.60%	58	45.9	41.6	38.7	36
4.75%	60	47.9	43.6	40.7	38
5.00%	63	50.9	46.6	43.7	41

3.3 Marshall Stability Test Results for Mixes

The results obtained from Marshall Test for control mix are as given below in the table:

Table -7: Marshall Test Results

Property/Mix	Control Mix	RAP 25%	RAP 30%	RAP 35%	RAP 40%
Binder Content	4.75%	4.75 %	4.75 %	4.75 %	4.75 %
Specific Gravity of Bitumen	1.000	1.000	1.000	1.000	1.000
Density, gm/cc	2.386	2.382	2.38	2.383	2.389
Volume of Bitumen, V_b (%)	11.33	11.32	11.31	11.32	11.35
Volume of Aggregate, V_a(%)	84.204	84.690	84.714	84.884	85.194
Voids in Mineral Aggregate, VMA (%)	15.796	15.310	15.286	15.116	14.806
Voids Filled with Bitumen, VFB (%)	71.749	73.904	73.957	74.884	76.641
Air voids, %	4.463	3.995	3.981	3.796	3.459
Marshall Stability, kg	1780	2552	2862	2879	2514
Flow Value, mm	3.5	3.85	3.8	3.3	4.3
Marshal Quotient	5.086	6.630	7.532	8.724	5.848
Specific Gravity of mix	2.699	2.679	2.67	2.674	2.67
			6		1

4. EXPERIMENTAL DATA

The experimental data obtained shows variations in various properties with respect to change in binder content. To analyse the results, some graphs are plotted between density-bitumen content, stability- bitumen content and flow-bitumen content.

4.1 Density-Bitumen Content

The density for the five mixes discussed above had shown same pattern i.e. density increases with the increase in bitumen content up to 4.75% and after it density starts to decrease as the bitumen content increases. The maximum densities for all five mixes are obtained at 4.75% bitumen content. The density of mixes with 25%, 30% and 35% RAP are less than the density of control mix. The maximum density of mix with 25% RAP and 30% RAP are approximately equal to 2.38. While comparing all the mixes the maximum density, 2.386, is recorded in the mix having 40% of RAP at 4.75% bitumen content.

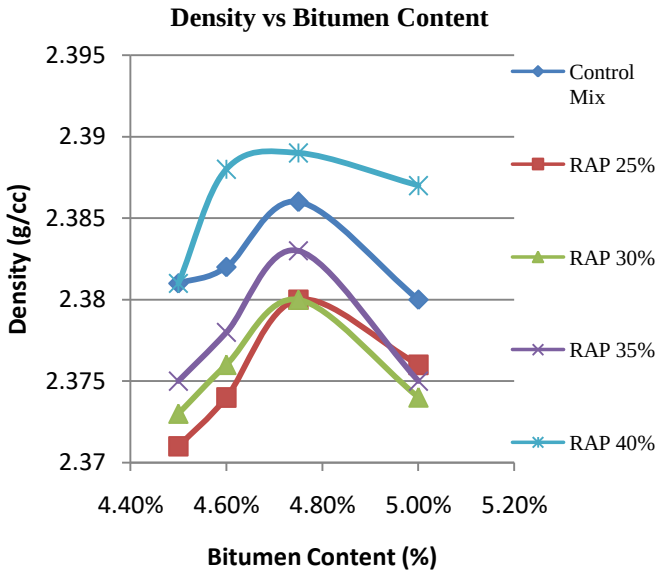

Chart -1: Relationship between density of mix and bitumen content.

4.2 Stability-Bitumen Content

As the quantity of RAP is increased the stability values are also increased but reduction in stability value is observed at 40% RAP. Here control mix is showing least value for stability i.e. 1780 kg at 4.75% bitumen content. The maximum stability is obtained in the Mix with RAP 35% i.e. 2879 kg at 4.75% bitumen content. The stability values with RAP 30% is 2862 kg, RAP 25% is. 2552.4 kg and RAP 40% is 2514.6 kg.

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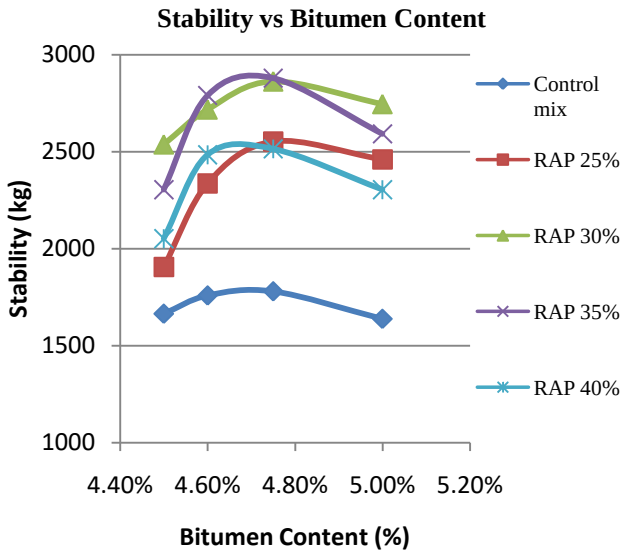

Chart -2: Relationship between Stability of mix and Bitumen Content.

4.3 Flow-Bitumen Content

The mix with 35 % RAP showed least value of flow i.e. 3.3mm. Maximum flow value is obtained at 40% RAP i.e. 4.3mm at 4.75% bitumen content. The control mix is having slightly more flow value as compared to mix with 35% RAP i.e. 3.5mm. There is not much difference in the flow values of 25% RAP and 30% RAP i.e. 3.85mm and 3.8mm respectively.

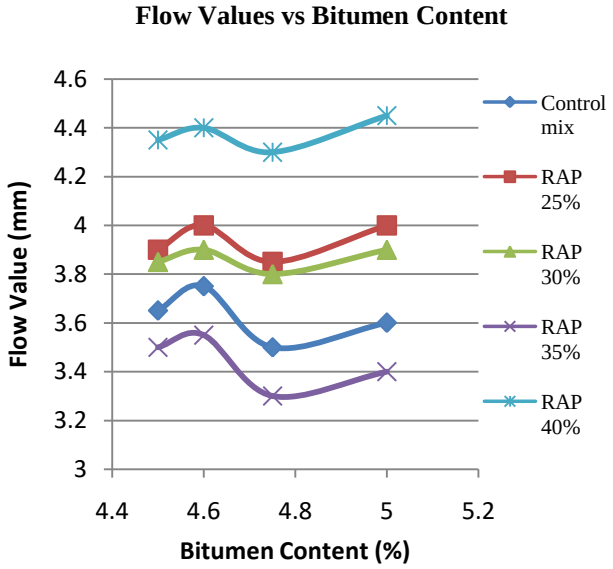

Chart -3: Relationship between flow value and bitumen content

4.4 Air Voids-Bitumen Content

The mix having 4% air voids are expected to give better results. The mix with 25% RAP and 30 % RAP exhibit values very close to it. Though air voids for other mixes are within permissible limits. A value of 3.8 % is obtained for the mix with 35% RAP is also highly acceptable. For mix with 40% RAP, the value determined is higher than the permissible range.

4.5 Other Properties

Other parameters, like VFB and VMA are found to be within specified range for all the mixes except the mix with RAP content of 40 %. From these experiments and results it can be stated that RAP content up to 35 % can be used in the mix for DBM.

5. CONCLUSION

The determination of optimum RAP quantity is not an easy task and it should be determined by studying certain parameters. Some of the parameters obtained in this experiment work are given below:-

i) Density of mix with 40% RAP is highest; density of RAP 35% is nearly same as density of Control mix.

ii) Maximum Stability is observed in the mix with 35% RAP; there is reduction in the stability values at 40% RAP content.

iii) Flow Value is maximum for the mix with 40% RAP i.e. 4.3mm which is higher than the permissible values given in MoRTH (5th revision) i.e. 2- 4 mm. The flow value for other mixes is within the permissible limits. The flow value of control mix and mix with 35% RAP is approximately same i.e. 3.5mm and 3.3mm respectively.

iv) The Marshall Quotient is increasing with the increase in quantity of RAP. However, reduction in Marshall Quotient is observed after RAP 35% i.e. in RAP 40%. Except control mix, no other mix is satisfying the permissible values given in MoRTH (5th revision).

From above results, it can be stated that addition of RAP with 25% to 35% yields mix of acceptable performance except Marshall Quotient. However, results obtained with 35% RAP are closer to the results obtained of Control mix. It may be concluded that optimum values of using RAP in Dense Bituminous Macadam is 35%.

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BIOGRAPHIES

Viranta Sharma is presently working as Assistant Professor in the department of Faculty of Science and Technology in ICFAI University Baddi. She is ME in CTM from NITTTR, Chandigarh. She has more than 3 years of experience in teaching. Her area of interest is in recycling practices in Flexible pavement and Level of service in urban roads.

Er. Robin Babit, Asst. Prof., SUSEC, Tangori, Punjab. Gold Medalist in Masters in CTM (Civil) from Panjab University, Chandigarh. He has published numerous papers in various journals. His area of interest include transportation and pavement design

Er. Ajay K Duggal, Associate Professor, Dept. of Civil Engineering, National Institute of technical Teacher's Training and Research, Panjab University, Chandigarh, India. His area of interest includes Flexible pavement design.