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Characterization of Reclaimed Asphalt Pavement

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Abstract*—Reclaimed asphalt pavement (RAP) is one of the most effective and innovative technique throughout many places in the world. Now-a-day the use of RAP is gradually increasing popularity and becomes emerging technique in India. RAP is removed and/or reprocessed pavement materials containing bitumen coated aggregates. These materials are generated when bituminous pavement is removed for resurfacing, reconstruction, or to obtain access to buried utilities. It consists of high-quality, well-graded aggregates coated with asphalt cement, when crushed and screened properly. RAP materials are a useful alternative for use in pavement construction which not only help in reducing the cost of project but it also ensures the proper utilization of resources and reduce the use of fresh materials required for the construction of new road. The main objectives of this study are to evaluate the characteristics of reclaimed asphalt pavement (RAP) material and properties of fresh materials and fresh bitumen, preparation of several Marshall mixes samples using different percentage of RAP materials with fresh materials to achieve optimum binder content by using Marshall method. Also, to investigate the performance of bituminous mixes, performance evaluation test has been carried out for tensile strength ratio. Pavement design as per Indian Roads Congress (IRC) method to calculate the economical benefits in utilization of RAP material in terms of quantity and fresh materials saving

Keywords*— Hot Mix Asphalt (HMA),Reclaimed Asphalt pavement (RAP), Milling, Dense Bituminous macadam (DBM), Gradation, Stability, Optimum Bitumen Content, Tensile Strength Ratio (TSR)

I. INTRODUCTION

The road network is a backbone of rapid growth of economy, industry trade and tourism of country. It connects and links to remote areas for various economic activity and also integrating people of different place and culture. Road plays an important role in transport infrastructural development, through links with airports, railway stations, and ports. It was noted that population growth and economic development have resulted in an extensive network of bituminous surface road in the last 50 to 70 years. In India most of the roads are constructed with bituminous pavement and these roads need periodically maintenance action due to heavy traffic loads and environmental conditions. Now-a-day thousands of kilometers (miles) new road construction has a number of implication for the environment, consuming large amount of materials and energy. To conserve diminishing supply of construction materials and to reduce the cost of preserving existing pavement, the pavement recycling is only a logical and practical way. In the asphalt pavement industry, pavement recycling process was done approximately 73 million tons of materials annually, which is more than twice the combined total for recycle paper, glass, plastic, and aluminum.

Over 60% of Indian highway the majority of roads were constructed with Hot Mix Asphalt (HMA). As the Indian infrastructure ages, these highways and roads were maintained and established. The material can be reused to repair, reconstruct and to maintain the original highway. When the materials are removed from the existing flexible pavement, during resurfacing or reconstruction operations, then the removed materials are known as Reclaimed Asphalt Material. With increasing the demand of fresh aggregate and asphalt supply, Reclaimed Asphalt Pavement is a valuable material for Hot Mix Asphalt. Therefore, increase the amount of Reclaimed asphalt pavement in bituminous concrete. Recycled asphalt Material is useful to reduce the use of fresh aggregate and the amount of fresh asphalt binder in production of hot mix asphalt.

RAP was used for the first time in 1973, however, with low percentages due to the lack of understanding of its effect on the performance of asphalt mixes. The most recycled materials in the United States is asphalt pavement materials. Currently, higher percentages (e.g. >50%) are being utilized to reduce costs and natural resources and make use of demolished old asphalt pavements. In some urban area recycling can be more profitable than in rural areas. In rural areas recycling can be expensive and impractical due to high transportation cost and the lack of nearby materials. On the other hand, if materials are available, reuse of materials that otherwise have to be transported can be very cost effective. Overall, there is a critical need to understand the use of recycling of existing damaged asphalt pavement materials to produce new pavement with considerable saving in material, energy and cost in the Indian context. In addition, aggregates and binders from old asphalt pavements are still valuable even though the damaged pavement has reached the end of their service lives.

II. RECLAIMED ASPHALT PAVEMENT

In recent years there has been a large amount of construction and demolition waste. Disposal of such waste has been always a problem due to shortage of available landfills. Moreover, the cost of the materials required for construction has been increased due to unavailability of material in nearby location. Using reclaimed asphalt pavement in bituminous roads addresses both of the above problems thus helping in construction of a sustainable pavement. Recycling of existing pavement can reduce the usage of fresh materials results in considerable saving of material, money, and energy. However, there are multiple benefits of using reclaimed asphalt pavement. Some of the advantages are listed in the following sections:

- Less user delays
- Conservation of energy
- Preservation of environment
- Reduced construction cost
- Conservation of fresh aggregate and binder
- Preservation of existing pavement geometrics

Reclaimed asphalt pavement may be obtained from several sources. The performance of a RAP mix depends on the source from which it is extracted and the method of extraction. The various possible sources of RAP are as follows:

- Generation from milling from pavement layer
- Pavement demolition
- Full depth reclamations (FDR)
- Waste from HMA generated at plant

The following types of investigation on the existing pavement are required:

- Pavement condition
- Pavement composition and history
- Structural evaluation
- Existing pavement material properties

The following aspects of recycling process for an existing pavement are as follows:

- Hot in-place recycling (HIR)
- Cold in-place recycling (CIR)
- Hot in-plant recycling (HIP)
- Cold in-plant recycling (CIP)
- Full depth reclamation (FDR)

A. Hot in-place recycling (HIR)

In HIR, 100 percent of the reclaimed material is utilized. However, its limitation is that no more than 50 mm thick bituminous layer can be satisfactorily recycled (maximum 75mm if softer binder was used in original construction). This process is a series of equipment's that have the ability to perform different functions such as infrared heating of pavement surface to soften it, milling the softened hot pavement surface, transferring the milled materials into pug mill mixer of recycling equipment's through a belt conveyer, adding fresh mix/binder/rejuvenator as per requirements of design into the pug mill, discharging the remixed materials into integrated paving screeds for paving the remixed output, rolling and compaction of the paved material. If the pavement needs to be overlaid from structural consideration, a seconder of Hot mix overlay may have to be done on top of the recycled surface and in such situations (also called repaving), HIR has to be done in two layers (or multiple layer).

B. Cold in-plant recycling (CIR)

In this process, milling and mixing are simultaneously processes accomplished by a single equipment or a train of equipment capable of milling and conveying the milled material to be fed to a pug mill, with parallel supply line for feeding fresh aggregate also, and separate feeding lines to pug mill for bitumen emulsion, and rejuvenator. Where foam bitumen is to be used, there has to be separated feeding line for hot bitumen and water to produce the foam bitumen and then feed into the pug mill. The mixed material is discharged into the paver hopper closely following the recycling equipment or train of equipment, then paved and compacted. This type of recycling is considered suitable for depth up to 150 mm and the use of reclaimed material is also in same order (typically 30 to 50%) as in HIP. Another variant of cold in-place recycling is (CIR) Full Depth Reclamation, where the thickness of pavement to be recycled is greater than typically 150 mm.

C. Hot in-plant recycling (HIP)

This process involves production and laying of hot mix materials but not with virgin aggregate and binder but with a combination of reclaimed stockpiled aggregate already coated with binder and additional virgin aggregate and fresh binder to meet the requirements of the design. Usually, some rejuvenator is used to soften the old hardened binder in the reclaimed aggregates. Heating the reclaimed binder coated aggregates may release unacceptable fumes while feeding them cold directly into the pug mill may reduce the mixing temperature. Therefore, the hot mix production process, has to be suitably modified. It is suggested that not more than 50% of the reclaimed material is to be used, though a widely accepted percentage is only 30% and thickness is 100 mm.

D. Cold in-plant recycling (CIP)

This process involves production of the mix in a plant using either emulsion or foam bitumen and laying and compaction in usual manner. Rejuvenator is to be added in the mixing process to soften the hard binder in the reclaimed material. Depth of recycling and use of reclaimed materials is same as for cold in-place recycling.

E. Full depth reclamation (FDR)

In Full depth reclamation (FDR) all the reclaimed materials of the pavement, with or without fresh material, is stabilized in-situ with suitable stabilizers to produce the base course of the pavement to be overlaid by bituminous course. The thickness varies between 100 to 300 mm. It produces "granular" pavement layer which can be used as is, can have additional granular materials placed over it, or can be enhanced with the addition of an additive. FDR equipment consist of a reclaimer unit, stabilizing additive unit, motor grader and rollers

III. LABORATORY INVESTIGATION

To check the suitability of materials to be used in bituminous mixes, it is necessary to carry out physical test on materials. In the present research different materials used are RAP materials, fresh materials and Bitumen of grade VG 40. The purpose of this research is to examine the performance between Fresh materials and various RAP materials mixture i.e. 15%, 20%, 25%, 30%, 35%, and 40% of Dense Bituminous macadam grade-II obtained from standardized laboratory tests.

This study compares Marshall test parameter such as Marshall Stability, Flow value and Density of bituminous mixes using RAP materials to that of fresh bituminous mix. One set of fresh bituminous materials mix and six different set of percentages of RAP materials mix were selected and samples were prepared at six different percentages of bitumen, at each bitumen percentage 3 samples were prepared. Total 189 samples were prepared and tested.

A. *Properties of RAP Material*

RAP sample was collected from stockpile at Jahagirpura in Surat. RAP material was obtained by the milling operation done on several roads in urban area at Surat district of Gujarat state, India. Figure 1 shows the milling process on several roads in urban area at Surat and Figure 2 shows the RAP material stockpiled at Jahangirpura in Surat.

Figure 1 : Milling Process at Surat Urban Area, Gujarat

Figure 2: Material Stockpiled at Surat

The physical properties of RAP material were obtained as shown in Table 1. The result fulfils the requirement of MORTH 5th revision specification. The binder content in RAP material was determined by centrifuge extraction test method according ASTM D 2172. Binder content was calculated from difference in weight of aggregates before and after extraction of bitumen. The binder content was determined from average of different sample in RAP material was found to be 2.4%.

Table 1 : Test Result of RAP Material

Property of RAP materials	Test Method	Test Results				MORTH 2013 5th Revision Specification
		30-20 mm	20-12 mm	12-6 mm	6 mm Down	
Specific Gravity	IS 2386 (Part III)	2.734	2.649	2.606	2.652	2.6 to 2.9
Water Absorption	IS 2386 (Part III)	1.30	1.33	0.88	0.77	Max. 2%

After the extraction of binder, the aggregates were recovered and kept for oven drying for 24 hours. After oven drying the gradation of recovered aggregate was performed and it falls in nearly to lower limit of DBM (Grading-II) which is shown in Table 2 and Figure 3 shows the gradation of recovered aggregate from RAP material.

Table 2 : Gradation of RAP Materials

Sieve Size (mm)	Job Mix Formula	Specification Limit as per MORTH 5th revision
37.5	100	100
26.5	100	90-100
19.0	92.57	71-95
13.2	55.56	56-80
4.75	34.21	38-54
2.36	27.4	28-42
0.30	2.5	7-21
0.075	1.6	2-8

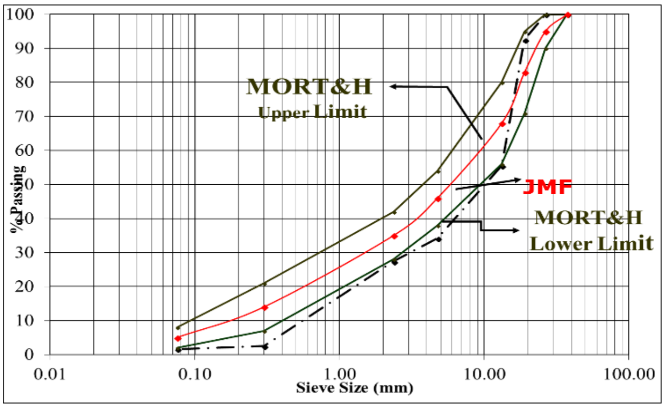

Figure 3: Gradation of RAP Materials

B. Properties of Fresh Material

The Fresh aggregates used in this research were local aggregates obtained from a quarry at Sevaliya. These aggregates tested to check their suitability for the design of Dense Bituminous Macadam (DBM) Grade II for various physical properties for design mix. All the tests were carried out in Laboratory and IS Test procedure followed. The test result summary of fresh aggregate and limit according to MORTH 5th revision specification as given in Table 3.

Table 3 : Physical Properties for DBM Mix

Property of Aggregates	Test Method	Test Results				MORTH 2013 5th Revision Specification
		30-20 mm	20-12 mm	12-6 mm	6 mm Down	
Aggregate Impact Value	IS:2386(Part IV)	18.11%	-	-	-	Maximum. 27%
Aggregate Abrasion Value	IS:2386(Part IV)	16.97%	-	-	-	Maximum. 35%
Combined (EI+FI) index	IS:2386(Part I)	21.51%	-	-	-	Maximum. 35%
Specific Gravity	IS:2386(Part III)	2.69	2.687	2.676	2.652	2.6 to 2.9
Water Absorption	IS:2386(Part III)	0.24	0.34	0.54	0.77	Maximum. 2%

C. Properties of Bituminous materials

In this present study bitumen was collected from a hot mix plant at site of RKC Infrabuilt Pvt. Ltd. (Mehsana-Himatnagar) road project. In this research VG-40 grade of bitumen was used in the control design of DBM grade II. Tests were conducted to check their suitability for binding of bituminous mix. All properties of VG-40 bitumen was checked in controlled condition in laboratory as per test procedure in relevant IS codal provision. Table 4 shows the test results and criteria according to MORTH 5th revision specification, with test method.

Table 4 : Test Result of Bituminous Material

Property of Bitumen	Test Method	Test Result	MORTH Specification
Specific Gravity at 27℃	-	1.03	-
Penetration(1/10mm) at 25℃, 5sec., 100g	IS 1203:1978	46	Min. 35
Ductility at 25℃, Cm, Min	IS 1208:1978	95	Min. 25
Kinematic Viscosity, 135℃, cSt	IS 1206(Part-3):1978	529.78	Min. 400
Absolute Viscosity, 60℃, Poises, Min	IS 1206(Part-2):1978	3702.32	3200-4800
Softening Point ℃	IS 1205:1978	52.75	Min. 50

IV. BITUMINOUS MIX DESIGN

A. Job Mix Formula for DBM Fresh Mix

Mix design was performed for job mix formula for fresh material according to Table 500-10 as given in MORTH 5th revision. The calculation of individual gradation was done by trial and error methods and final blend of gradation for aggregate used in the research is shown in Table 5.

Table 5 : Blending of Average of Sample for DBM Grade-II for Fresh Material

IS Sieve mm	Individual % Passing				Individual % Blending				JMF limitCombined 100.0% Passing	Specified Limits
	HB-4	HB-3	HB-2	HB-1	HB-4	HB-3	HB-2	HB-1		
					16.0%	19.0%	23.0%	42.0%		
	30 - 20 mm	20 - 12 mm	12 - 6 mm	6 mm Down	30 - 20 mm	20 -12 mm	12 - 6 mm	6 mm Down		MoRTH Limit
37.5	100	100	100	100	16.00	19.00	23.00	42.00	100	100
26.5	82.87	100	100	100	13.26	19.00	23.00	42.00	97.3	90-100
19.0	3.85	92.05	100	100	0.62	17.49	23.00	42.00	83.1	71-95
13.2	0.65	21.66	97.35	100	0.10	4.12	22.39	42.00	68.6	56-80
4.75	0	2.41	22.75	91.78	0.00	0.46	5.23	38.55	44.2	38-54
2.36	0	0	2.59	78.91	0.00	0.00	0.60	33.14	33.7	28-42
0.300	0	0	0	34.52	0.00	0.00	0.00	14.50	14.5	7-21
0.075	0	0	0	8.82	0.00	0.00	0.00	3.70	3.7	2-8

B. Job Mix Formula for DBM using Fresh material + RAP material

Mix design was performed with and without RAP mixture i.e. 15%, 20%, 25%, 30%, 35%, and 40% of DBM grade-II as per MORTH specified limit. The combined gradation of RAP and fresh aggregates were obtained by blending RAP material and fresh material in the proportion i.e. 15% of RAP materials + 85% fresh materials shown Table 6 which meet the specific requirement as per MORTH 5th revision specification. And the graph according to the blending of RAP and fresh material.Also, JMF for mix design is in specific limit and the combined percentage for each of the different sizes of sieve should fulfil requirement and none of fall outside the range of upper and lower limit of gradation specification limit for DBM grade II as indicate in Figure 4.

Table 6 : Obtained Gradation of RAP Mixes with Fresh Mixes

IS Sieve mm	Specification limits	Average limit	Freshmaterial	RAPGradation	Obtained gradation for RAP mixes					
					15% RAP	20% RAP	25% RAP	30% RAP	35% RAP	40% RAP
37.5	100	100	100.00	100	100	100	100.0	100	100	100
26.5	90-100	95	97.30	100	97.71	97.84	9.98	98.11	98.25	98.38
19.0	71-95	82.5	83.10	92.57	84.52	84.99	85.47	85.94	86.41	86.89
13.2	56-80	68	68.60	55.56	66.64	65.99	65.34	64.68	64.04	63.38
4.75	38-54	46	44.20	34.21	42.70	42.20	41.70	41.20	40.70	40.20
2.36	28-42	35	33.70	27.4	32.76	32.44	32.13	31.81	31.50	31.18
0.300	7-21	14	14.50	2.5	12.70	12.1	11.50	10.9	10.30	9.70
0.075	2-8	5	3.70	1.6	3.39	3.28	3.18	3.07	2.97	2.86

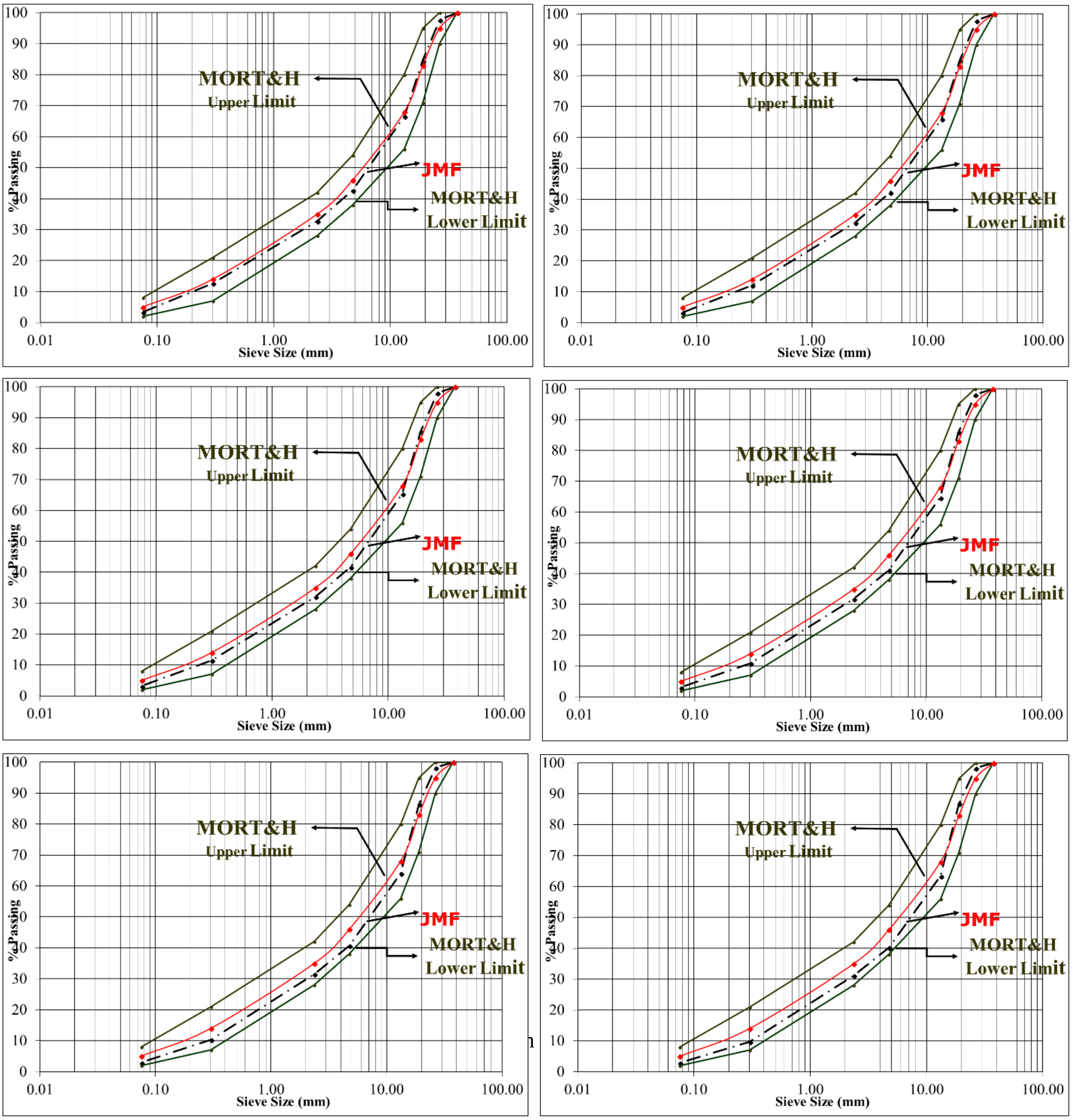

Figure 4: aggregate gradation adoption for fresh + RAP material (15%, 20%, 25%, 30%, 35%, 40%)

C.Marshall Stability Test results for Fresh mix and mix containing RAP

The experimental average results of Marshall Stability test for DBM grade-II fresh mix and mix containing different percentage of RAP material i.e. 15%, 20%, 25%, 30%, 35% and 40% at Optimum binder content workout. Properties of mix like Bulk density, Marshall Stability, Flow value, Air voids, Void filled with bitumen and Void in mineral aggregate are found for different percentage of RAP mixes shown in Table 7.

Table 7 : Results Shows Marshall Stability Test at Optimum Binder Content

Mix Type	OBC (%)	Bulk Density (gm/cc)	Marshall Stability (KN)	Flow (mm)	Air Voids (VA) %	(VFB) %	(VMA)
Fresh material	4.83	2.394	15.18	3.27	4.08	72.17	14.66
15% RAP material	4.87	2.393	14.68	2.98	4.02	72.15	14.45
20% RAP material	4.77	2.403	14.22	3.43	3.78	73.05	14.01
25% RAP material	4.75	2.387	14.19	3.77	4.43	69.56	14.55
30% RAP material	4.80	2.387	15.02	3.57	4.37	70.06	14.61
35% RAP material	4.70	2.391	11.05	3.87	4.36	69.67	14.38
40% RAP material	4.63	2.414	10.90	3.80	3.52	73.86	13.47
Specified Values as per MORT&H 5th Rev.	-	-	>9	2 - 4	3 - 4	65 - 75	Min13 %

It was observed in results the utilization of RAP materials the stability values were reduce accept in case of 30% of RAP materials. This indicates that the binder present in RAP materials perfectly blended with fresh binder compared to other percentages of RAP material. The best stability value for different percent of RAP mixes for varying binder content compared to fresh mixes. Figure 5 indicates the stability value increases with increasing binder content upto maximum or at

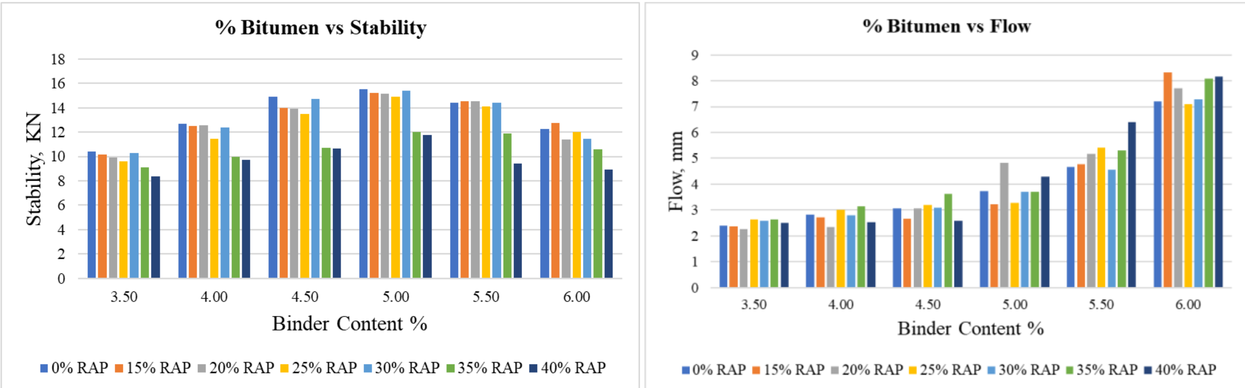

Figure 5: Marshall Stability and Flow Value for Varying Percent of RAP Mixes.

optimum binder content and then after the stability value is decreases while increasing binder content.

From Figure 5 comparison of flow value for different percent of RAP mixes for varying binder content which clearly shows the flow value in consistently increases with increasing with bitumen content.

From Figure 6 initially increasing in binder content the bulk density is also increases but further increases in binder content the bulk density is decreases. The air voids percent steadily reduce with the increasing in bitumen content ultimately approaching a minimum void content as shown in Figure 6.

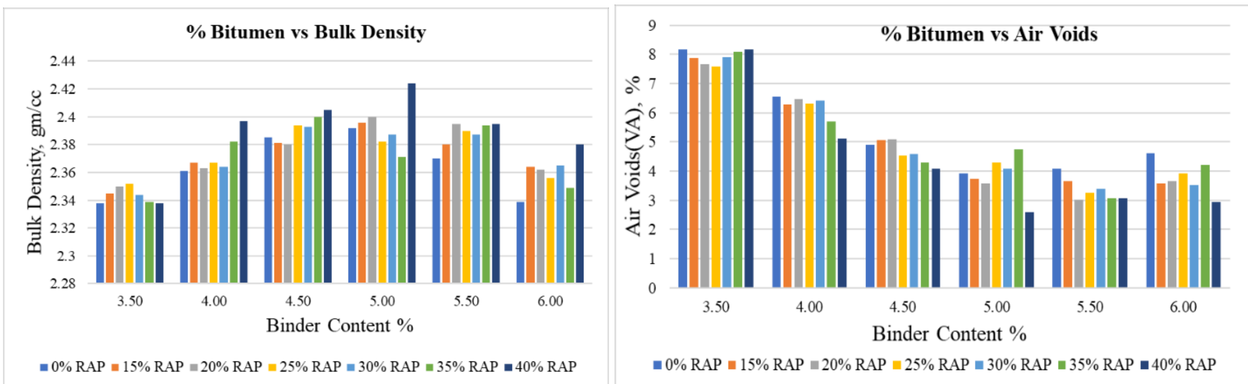

Figure 6: Bulk Density and Air Voids for Varying Percent of RAP Mixes.

V. PERFORMANCE TEST ON BITUMINOUS MIX

The degree of susceptibility to moisture damage is determined by preparing a set of laboratory compacted specimens conforming to job-mix formula. It measures the splitting tensile strength by the application of a diametric compressive force on cylindrical bituminous mix specimen placed with its axis horizontal. Hence, it should be dealt with proper care. The effect of moisture susceptibility on mixture was evaluated using tensile strength ratio test.

A. Tensile Strength Ratio Test

The test was carried out as per ASTM D6931 specification. In this research, two sets of three specimens each, were used to determine the tensile strength ratio. The test specimens were prepared to void levels expected in field, usually at target air voids in 6 - 8 % range. Dry indirect tensile strength (ITS) test specimens were conditioned at 25°C for 4 hours whereas wet ITS test specimen were conditioned maintained at 60°C in water bath for 24 hours and later at 25°C water bath for 2 hours prior to the test as shown in Figure 7 (a), (b) and (c). The specimens are then placed in the loading apparatus and the loading strips are positioned so that they are parallel and centered on the vertical diametrical plane. Vertical compressive load was applied on the specimens until maximum load was reached and the load at failure was recorded as shown in Figure 8 (a) and (b).The tensile strength of specimen (S_t) in Kpa, calculated using Equation 1.

Figure 7 : (a) ITS Specimens In Water Bath (b) ITS Frame (c) Specimen In Frame

$$St = \frac{2000P}{\pi t D} \ldots\ldots\ldots\ldots\ldots.(1)$$

Where,

S_t = tensile strength (in kPa)

P = load (in N)

t = sample height (in mm)

D = diameter of sample (in mm)

The potential of moisture damage is indicated by the ratio of tensile strength of wet condition sample to that of dry condition sample.Tensile strength ratio (TSR) is calculated as given in equation (2)

$$\text{TSR} = \frac{\text{Stm}}{\text{Std}} * 100 \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where,

TSR= Tensile strength ratio, %

S_{tm}= average tensile strength of moisture conditioned sample

S_{td} = average tensile strength of unconditioned sample

Figure 8 : (a)Indirect Tensile Strength Testing In Progress (b) Failure of Specimens In ITS

The TSR values of different mixes, as average of three samples, have been reported in Table 7. Testing results indicate that all the mixes pass the minimum threshold value of 80% as per MORTH 5th revision specification. Also, addition of RAP increases the TSR value for all mixes, thereby improving the moisture susceptibility of mixes containing RAP.

Table 7: Results of Tensile Strength Ratio (TSR) testing

Mix ID	Average tensile strength of conditioned sample, Stm, (kPa)	Average tensile strength of unconditioned sample, Std, (kPa)	Tensile Strength Ratio (TSR), %
Fresh material	458.28	550.60	83.23
15% of RAP material	385.60	431.62	89.34
20% of RAP material	411.06	486.56	84.48
25% of RAP material	405.08	460.26	88.01
30% of RAP material	479.43	496.96	96.47
35% of RAP material	440.36	469.63	93.77
40% of RAP material	412.58	489.75	84.24

VI. DESIGN AND QUANTITY ESTIMATION

A. Pavement Design

For pavement design link road of 1-kilometre length is selected and the design traffic parameters is given in Table 8 in terms of million standard axles should be calculated using the Equation 3 are considered as per IRC: 37-2012 guidelines. The design traffic is N = 115 msa.

$$N = \frac{365 * ((1+r)^{n}-1)}{r} * LDF * VDF * A \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Table 8 : Design Parameter

Lane Distribution factor (LDF)	0.75
Initial Traffic (A)	3076
Vehicle Damage Factor (VDF)	6.31
Traffic growth rate(r)	5%
Design life(n)	15 years
Terrain	Plain
Effective CBR of subgrade	8%

B Quantity Estimation

The thickness of pavement layer obtained from IRC: 37-2012 design guideline and are considered to calculate the quantity of the pavement layer for 1-kilometre length as shown in Table 9. In this study quantity estimation is mainly concern with dense bituminous macadam (DBM) layer of pavement. From Table 9 quantities of DBM layer is 2635m^3 are required for the construction of DBM layer for 1-kilometre of length for fresh materials.

Table 9 : Quantity Estimation of Flexible Pavement For 1 Km Length

Sr. No	Layer type	Length (m)	Width (m)	Thickness (m)	Quantity (m^3)
1	BC/SDBC	1000	17	0.065	1105
2	DBM	1000	17	0.155	2635
3	GB	1000	20	0.250	5000
4	GSB	1000	20	0.200	4000

By adding different percentage of RAP materials to save the fresh material. In this study up to 40% of RAP materials can be mixed with fresh materials for construction of DBM layer as shown Table 10. As the percent of RAP material mix is increased the quantity of fresh material is decreases.

Table 10 : Quantity of Materials and Bitumen Saving by Adding Varying Percent of RAP Materials

Mix type	Total quantity (m^3)	Total quantity (tonne)	Required Bitumen content (tonne)	Bitumen content present in RAP material (tonne)
DBM layer				
Total Fresh material	2635.00	6308.19	304.69	-
15% of RAP	395.25	945.83	46.06	22.70
20% of RAP	527.00	1266.38	60.41	30.39
25% of RAP	658.75	1572.44	74.69	37.74
30% of RAP	790.50	1886.92	90.57	45.29
35% of RAP	922.25	2205.10	103.64	52.92
40% of RAP	1054.00	2544.36	117.80	61.06

By testing the properties of RAP material, it was found that bitumen content of 2.4% was present in RAP aggregates. So, at the time of mix design with varying percent of RAP materials the percentage of fresh bitumen were decreases with increases in RAP materials as indicate in Table 6.

VII. CONCLUSION

Following are the outcomes of experiment conducted in laboratory testing for comparison of RAP mixes and fresh bituminous mix:

- Based on the laboratory testing work the properties of fresh materials and fresh bitumen are as per IS procedure and it was found to be within limit as per the requirement of MORTH 5th revision specification.
- By evaluating the characteristics of RAP materials, bitumen content of 2.4% was obtained by Centrifuge Extraction. Also, gradation of RAP materials was out of range as per DBM grade II gradation limit. But RAP material gradation lies near to lower limit of DBM grade II, so it was acceptable to blend with fresh material to fulfil the required specification limit as per MORTH 5th revision.
- Final blending of material fulfils the job mix formula for mix design. And it was observed up to 40% of RAP material can be blended with RAP material adding of 15%, 20%, 25%, 30%, 35% and 40% shows the Marshall parameter fulfil the requirement of minimum optimum binder content of 4.5%, minimum stability of 9 KN, flow value and air voids were between 2 to 4 & 3 to 4, void filled with bitumen is between 65 to 75% and minimum 13% of void in minerals aggregate are as per MORTH specification limit.

- From the Marshall mixes design, it was clearly found up to 40% of RAP material mix is acceptable. But it was recommended to use RAP material up to 30% due to obtain high stability by comparing other varying percent of RAP material mix.
- Performance testing were carried out with Indirect tensile strength (ITS) & Tensile strength ratio (TSR) on bituminous mixes, both satisfies the minimum requirement of 80% as per MORTH 5^{th} revision specification.
- Based on the design and quantity estimation for DBM layer for 1-kilometre length was found to be 2635 m^3(6308.19 tons) By utilizing of RAP material, it was found saving in materials from 395.2 m^3 (945.83 tons) to 1054 m^3 (2544.36 tons) and considerably saving in bituminous material from 22.70 tons to 61.06 tons.

Moreover, from this study it was concluded the 30% of RAP mix shows the result similar to the fresh material mix. Also, by utilization of 30% of RAP can saving the fresh materials up to 790.5 m^3 (1886.92 tons) and 45.29 tons of bituminous material.

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