LABORATORY INVESTIGATION ON HOT MIX ASPHALT USING RECLAIMED ASPHALT PAVEMENT (RAP) FOR BITUMINOUS CONCRETE MIX

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Abstract

Recycled Asphalt Pavements (RAP) obtained from damaged or abandoned pavement used in hot mix asphalt mixtures has evolved into a regular practice in many countries around the world. Use of these materials in the past has not only proved to be economical but also environmentally sound. Incorporating RAP in fresh materials has been favoured over fresh materials in the light of the increasing cost of asphalt, scarcity of quality aggregate, scarcity of asphalt and pressuring need to preserve the environment. The use of reclaimed asphalt pavement is effective in improving the performance which is equally or better than the fresh mixtures. Unfortunately, asphalt pavement recycling is yet to takeoff in India despite the current ambitious road building program underway. The purpose of this study is to examine the performance between Fresh and various RAP mixtures i.e. 20%, 30% and 40% of Bituminous Concrete (BC) obtained from standardized laboratory tests. Firstly, the quantity of RAP and new aggregates are to be blended in such a way that the resultant gradation of aggregates conforms to the BC as per MoRT&H and the total quantity of asphalt binder are adjusted to satisfy the desired or optimal quantity of the target mix using the soft grade bitumen without using any rejuvenator. Then RAP to new aggregate ratio has been adopted and bituminous mixtures with recycled materials are assessed for their sustainability under mechanical behaviour and compared with the fresh mix. The laboratory study concludes that the all the Marshall Property values are within limit; the Optimum Binder Content was reduced by increasing the percentage of RAP content and the recommended percentage of RAP Mix is 20%.

Keywords: *Reclaimed Asphalt Pavement, Bituminous concrete, Gradation, Stability, Optimum Bitumen Content*

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1. INTRODUCTION

The mega road modernization exposes challenges of various concerns pertaining to depletion of resources like good soil and aggregates, long lead to get good quality aggregates and increase in fuel consumption etc,. Furthermore, the supply of Bitumen, whose cost keeps on increasing, is dependent on foreign sources, and energy that is needed for processing new materials is becoming costlier every day. The Recycling of existing bituminous mixes are the only alternatives, through the reuse of aggregates and bitumen. Use of the recycled materials in the road construction has been favoured over fresh materials in the light of increasing cost of bitumen, scarcity of good quality aggregates and the priority towards preservation of the environment. Considering the material and construction cost alone, it is estimated that using recycled materials, saving ranging from 14 to 34% can be achieved**.** It is universally recognized that an important benefit of asphalt as a pavement construction material is its ability to be recycled. This factor is becoming more relevant as the use of RAP in asphalt mixtures could produce important benefits in terms of performance and economics.

1.1 Reclaimed Asphalt Pavement (RAP)

Reclaimed asphalt pavement (RAP) is the term given to removed and/or reprocessed pavement materials containing asphalt and aggregates. These materials are generated when asphalt pavements are 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 by asphalt cement.

1.2 The Benefits of Asphalt Recycling

The following points suggest the generalized benefits:

- Reuse and Conservation of non-renewable energy sources
- Preservation of the environment and reduction in land filling
- Energy conservation and improved pavement smoothness
- Cost saving over traditional rehabilitation methods
- Improved pavement physical properties by modification of existing aggregate gradation, and asphalt binder properties

2. LITERATURE

The literatures have indicated that the structural performance of recycled mixes is equal and in some instances better than that of the conventional mixes. The use of RAP in asphalt mixtures could produce important benefits in terms of performance and economics. The change in specifications since 2007 allowed addition of higher percentages of RAP with no change in the fresh performance graded binders [5]. Xiao and Amirkhanian 2009 [4] used Crumb rubber with RAP as per AASHTO specifications to know the mechanical behavior.

The studies indicate that the use of RAP will increase the stiffness of asphalt binder, RAP has a superior aging index compared with the original asphalt, and mixture containing RAP has higher modulus [13]. The use of RAP containing HMA in the surface course of airfield pavements shows good resistance to rutting while environmental distresses such as block cracking and ravelling were the primary type of distresses observed and the addition of 20% RAP to a mix increased the life of a pavement [2].

Widyatmoko [6], used three different levels of addition of RAP (10%, 30% and 50%). Rigorous control of the grading of the source materials (i.e. RAP and virgin aggregate) is required, as small variations in grading could result in the target recycled mixture having a combined aggregate grading outside the specification hence a graph necessitates to study the composition of aggregate and binder in the target mixes weather for wearing course or base course. The results suggested that rejuvenated binders properties show similar results of 60/70 bitumen properties.

Alex K. Apeagyei et al, 2012 [1] studied on the production of high-RAP mixes (i.e., mixes with more than 20% for surface and intermediate, and 25% for base mixes) to evaluate the stiffness characteristics of asphalt-concrete mixtures containing different RAP amounts to achieve a better understanding of how high RAP (>20%) affects the mixture performance properties that are important for more durable and cost-effective asphalt. The use of higher RAP percentages with locally available binders was adopted as an approach to reduce the demand, on specialty more expensive Fresh binder and Fresh aggregates in Virginia.

Recent researches [1–10], have established that RAP replacement at proportions above 50% is feasible to produce new HMA mixtures, obtaining satisfactory results in the mechanical properties. It is universally recognized that an important benefit of asphalt as a pavement construction material is its ability to be recycled. This factor is becoming more relevant as the use of RAP in asphalt mixtures could produce important benefits in terms of performance and economics.

The properties of the recycled mixture are believed to be mainly influenced by the aged reclaimed asphalt pavement (RAP) binder properties and the amount of RAP in the mixture. A literature showed that mixtures prepared from the recycled binder blends generally age at a slower rate than fresh mixtures. This may be due to the fact that the RAP binder has already undergone oxidation which tends to retard the rate of hardening and the recycled mixtures withstands the action of water better than the Fresh mixtures.

The above studies have clearly evaded the utilization of recycled materials towards the sustainable and economic development of infrastructure. The gaps in the studies were explored; hence an attempt has been made to study the performance of RAP.

3. LABORATORY INVESTIGATION

In the present study the RAP sample was collected from NICE Road (Bangalore to Mysore stretch) in Karnataka, India. RAP materials were put into the various tests and checked for its suitability for the further investigation. First the RAP materials were subjected to solvent (benzene) extraction method by centrifuge extractor. The percentage bitumen content in the sample was observed to be 4.8%. The Recycled Aggregate properties were measured from the extracted aggregate sample and tested for its suitability according to IS: 2386-1963 – Part VI (Mechanical properties of Aggregate). The test results have been presented in Table 1 Recycled aggregate were found to satisfy the requirements as per Ministry of Roads, Transport and Highways (4th revision) for BC-I clause 509.2.2, Table 500-17.

Table -1: Recycled Aggregate Properties

Sl. No	Description	Values
1	Specific Gravity of Aggregates	2.70
2	Impact Strength, %	15.12
3	Combined EI+FI, %	26

3.1 Mix Design

Bituminous Concrete (Grade I) layer has been selected in the present study for bituminous mix. The Combined Gradation of fresh Aggregates and different percentage for RAP [0%, 20%, 30%, 40%] meeting the desired specification requirement is calculated fulfilling the BC-I Gradation as per Ministry of Roads, Transport, and Highways (4th revision), Table 500-18 as per MS-II by blending process, which is shown in the Table 2 and the typical S-curve for BC mix gradation for different RAP mix is shown in Figure 1.

Table -2: Combined Gradation for RAP Material and Fresh Aggregate in BC Mix

IS sieves (mm)	Cumulative % weight of total aggregate passing the IS sieves	Avg. limit	Obtained Gradation for RAP mixes			
			0% RAP	20% RAP	30% RAP	40% RAP
26.5	100	100	100	100	100	100
19	100 – 79	89.5	87.33	87.32	87.03	88.82
13.2	79 – 59	69	78.18	73.33	70.42	71.07
9.5	72 – 52	62	63.3	62.36	59.63	60
4.75	55 – 35	45	44.73	46.21	44.44	44.59
2.36	44 – 28	36	34.29	33.86	33.34	33.42
1.18	34 – 20	27	26.71	26.56	26.43	26.65
0.6	27 – 15	21	19.88	20.14	20.19	20.49

0.3	20 – 10	15	10.97	11.83	12.09	12.56
0.15	13 – 5	9	8.14	8.22	8.16	8.23
0.075	8 – 2	5	4.74	4.52	4.35	4.26

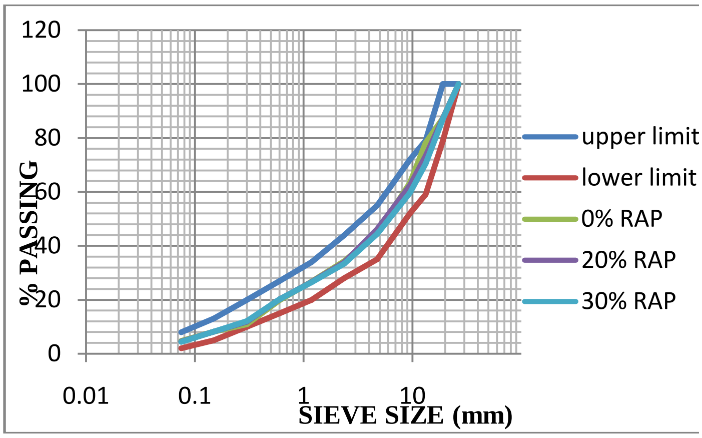


Fig – 1: S-Curve for Combined Gradation of RAP Material and Fresh Aggregates for BC Mix

3.2 Actual Percent of Fresh Binder

The quantity of new asphalt to be added to the mix of recycled mixture, expressed as percentage by weight of total mix is calculated by using the following formula and results were tabulated in Table 3.

$$P_{nb} = \frac{(100^2 - r\, Psb)Pb}{100(100 - Psb)} - \frac{(100 - r)Psb}{(100 - Psb)}$$

Where,
P_b – Asphalt content of mix in Recycled mix, %
P_{sb} – Asphalt content in the salvaged mix (RAP), %
r - Percent new aggregate materials to total aggregates in the Recycled mix, %
P_{nb} – Percent of new asphalt in recycled mix, %

Table -3: Actual Fresh Binder Content

Percentage of Actual Virgin Bitumen by Weight of Total Mix						
20% RAP	**R**	**P_{sb}**	**P_b**			
	80	4.8	4.5	5.0	5.5	6.0
	P_{nb}, %		3.5	4.0	4.5	5.1
30% RAP	**R**	**Psb**	**P_b, %**			
	70	4.8	4.5	5.0	5.5	6
	P_{nb}, %		3.1	3.6	4.1	4.6
40% RAP	**R**	**P_{sb}**	**P_b, %**			
	60	4.8	4.5	5.0	5.5	6
	P_{nb}, %		2.6	3.1	3.6	4.1

3.3 Marshall Properties

Marshall Stability test of a mix is defined as maximum load carried by a compacted specimen at a standard test temperature of 55 or 60 degree Celsius. The flow value is the deformation of specimen that under goes during the loading up to the maximum load in 0.25 mm units. The Marshall Stability test is applicable for hot mix design using bitumen and aggregates.

The Marshall Stability tests were conducted on HMA mixes with varying the bitumen content at mixing temperature of 155° C as per Asphalt Institute (MS-II).Two types of mixes were prepared, which includes.

- BC-I (Fresh): Mixes prepared by using Fresh materials (0% RAP).
- BC-I (RAP): Mixes prepared by using RAP (20%, 30%, and 40%) material.

Properties like stability, flow, bulk density, volume of voids and voids filled with bitumen are found for different percentage of RAP content. The graphs were plotted for bitumen content with Marshall Stability, Bulk Density and Air voids. The bitumen content corresponding to Maximum Stability, Maximum Bulk Density and 4.0% Air voids were obtained from these graphs. (The Maximum permissible air voids as per specification is 4% according to MORTH). The bitumen or binder content has taken to be an average value from the three plotted graphs and it is treated as optimum bitumen content (OBC). The Marshall Test results and OBC values for BC with different RAP content is tabulated in Table 4.

Table -4: Comparison of Marshall Properties

Properties	**Fresh Mix (0% RAP)**	**RAP**			**Criteria as per MORT &H**
		20%	**30%**	**40%**	
OBC, %	5.42	5.3	5.09	4.99	--
Stability KN	16.8	14.6	12.9	10.3	9
Flow, mm	3.82	3.82	3.4	2.85	2 to 4
Air Voids, %	3.4	3.08	3.82	3.8	3 to 6
Bulk Density, Kg/m^3	2281.42	2305.71	2278.72	2288.62	--
VMA, %	15.55	15.12	15.2	15.1	12.5
VFB, %	74.43	78.9	74.6	74	65 – 75

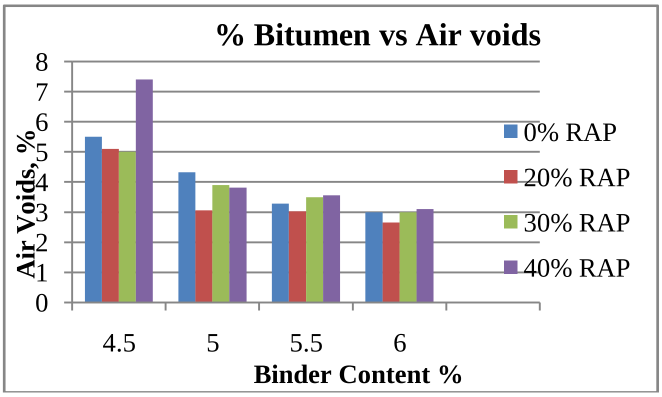


Fig – 2: Comparison of Air Voids values for different percentage of RAP Mixes for varying Binder Content

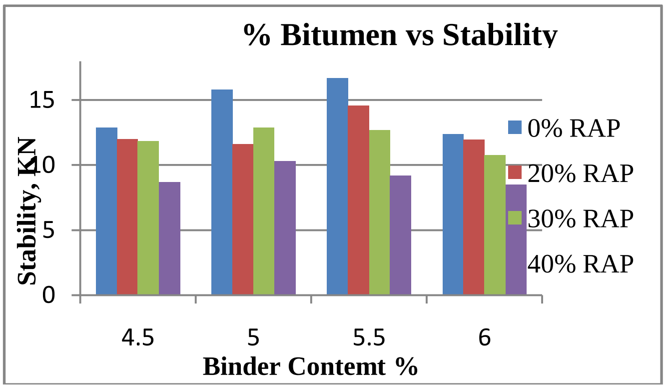
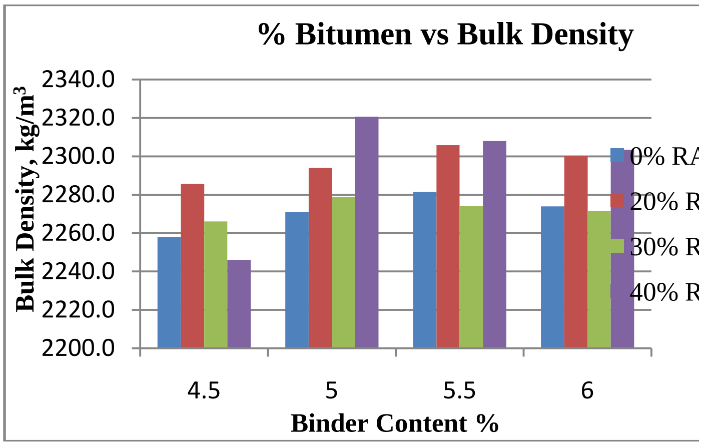


Fig – 3: Comparison of Marshall Stability values for different percentage of RAP Mixes for varying Binder Content



Fig– 4: Comparison of Bulk Density values for different percentage of RAP Mixes for varying Binder Content

4. ANALYSIS OF RESULTS

From Table 4 the Marshall Properties values for the HMA specimen of BC Grade-I vary with the variation in percentage of RAP content. The stability value for the HMA mix at 0% RAP was 16.8KN, 20%RAP was 14.6KN, 30% RAP was 12.9KN and for 40% RAP was 10.3KN this shows the stability values of the mixes are within limit. Due to the addition of RAP content Stability values goes on decreasing. To minimise the fresh material addition of 20% RAP is suggested, as *Figure 3* shows next best stability value, compared to fresh mix. The requirement for the durability of the transport way seems to out lay the 40% RAP mix even though factors are within the limit as per specifications.

Initially the increase in the binder content increased the Bulk Density but further increase in bitumen content decreases the bulk density for both fresh aggregate and RAP mixes. The bulk density for the 0% RAP was 2281.42 kg/m³, 20% RAP was 2305.71 Kg/m³, 30% RAP was 2278.72 Kg/m³ and for 40% were 2288.62 Kg/m³ respectively.

The percent of Air voids decreases with the increase in the Binder content (Figure 2). It is found that 20% RAP addition causes lower air voids in all the different percent of Binder content which is even better than the fresh mix or 0% RAP. Air voids show higher percent for 40% RAP mix generally infeasible for the practical applications. The voids filled with asphalt (VFA) and (VMA) is increased with increase in the binder content for both the mixes.

The optimum bitumen content obtained for RAP mix and fresh mix for BC grade-I was different at different percentage of RAP content.

5. CONCLUDING REMARKS

The following conclusions were determined based upon the experimental results obtained from a laboratory investigation of various HMA mixtures which contain both RAP and Fresh Material on Bituminous Concrete Grade-I.

- Based on the Bitumen Centrifuge Extractor Test Bitumen Content in RAP material was 4.8% which indicates that binder content in RAP was in higher percentage and based on recycled aggregate properties result it shows all test result are within specification limits and it can be used for further tests.
- From Table 3, the actual Fresh Binder content for RAP mixes value indicates that by using RAP material we can save up to 2 % to 3% of Fresh Bitumen in mix.
- The Marshall Stability Values of HMA for the BC-I mixes prepared with RAP material of 0%, 20%, 30% and 40% at 155°C shows all the Marshall Test values of the mixes are well and within the specified limit.
- It has also seen that there was very less difference in the Marshall Properties values of different percentage of RAP mixes. The Laboratory prepared mixtures containing RAP tend to have slightly lower Stability than those from control mixtures without RAP.
- Specimen prepared with Fresh Mix (0% of RAP) sample has less Air Void value than specimen prepared with RAP mixes it indicates that Air Voids value goes on increased while increasing the RAP content.
- Based on the Marshall properties, the BC-I mixes prepared with RAP materials of 40% shows considerable stability and other Marshall properties than the other mixes, whereas OBC decreasing considerably. Hence, RAP mixes of 40% may not be advisable for the construction practice and the RAP percentage may be restricted to 20%.

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