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LABORATORY STUDIES OF DENSE BITUMINOUS MIXES-II WITH RECLAIMED PAVEMENT MATERIALS

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ABSTRACT

The present study addresses the issue of growing demand on our nation's roadways over that past couple of decades, decreasing budgetary funds, and the need to provide a safe, efficient, and cost effective roadway system has led to a dramatic increase in the need to rehabilitate our existing pavements and the issue of building sustainable road infrastructure in India. With these emergency of the mentioned needs and this are today's burning issue and has become the purpose of the study. In the present study, the samples of existing bituminous layer materials were collected from NH-48(Devahalli to Hassan) site.The mixtures were designed by Marshall method as per Asphalt institute (MS-II) at 20% and 30% RAP. RAP material was blended with virgin aggregate such that all specimens tested for the DBM-II gradation as per MoRT&H(4^{TH} revision). Mixtures containing RAP showed significant variability and the variability increased with the increase in RAP content.The finding of the study will help in development of sustainable road infrastructure for recycling in India.

KEYWORDS: RAP, Marshall Stability, MS-II, Material Testing

INTRODUCTION

Road Transport in India accounts for 80% of passenger movement and 65% of freight movement. With 3.34 million km of roads, India has the second largest road network in the world. Only 50% of the roads are paved, even the paved length has inadequate pavement thickness, substandard pavement composition and poor geometrics. In terms of developing the road infrastructure to boost productive potential of the economy in Karnataka, the Vision 2020 targets the development of a core network of 40000 kms to serve its industrial, agriculture and tourism industries. In an effort to address the increasing traffic intensities and the persistent regional disparities in the accessibility to good quality roads, the vision targets increasing the road density from the current 1.09 km per sq km to 1.50 km per sq km and up gradation of existing road network to increase the share of roads with carriage width of 2 lane and above from the current 10.32% to 55%. This is based on the assumption that all NH and SH will have a carriage width of 2 lane and above while 30% of MDGs will be 2 laned by 2020(Vision 2020,Report for Mission Group on Infrastructure Development, Karnataka).

These mega road modernization projects throws up 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. Recycling of existing bituminous mixes results in substantial savings through the reuse of aggregates and bitumen. Use of the recycled materials in the road construction has been favored over virgin 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 (A.Verraragavan et al., 2012).

When RAP is reused in a new mixture, it is necessary to properly account for the old material in the new design.

The aggregate from the RAP has to be included with the new aggregate, and that blend of aggregate has to meet certain physical properties and gradation. In the current study the Marshall method of mix design as per Asphalt institute (MS-II) was used for the performance evaluation of asphalt mixtures containing various RAP ratios. The binder course mixtures with 20 and 30% RAP content were made and compare the results with the Virgin mixes (No RAP content).

BACKGROUND

Based on the process adopted in recycling of bituminous mixes, the technique can be broadly classified as central plant recycling and in-situ recycling (Mallick et al.2010). if the recycled material is modified at the plant, away from construction site, then the process is known as central plant recycling. In the in-situ recycling process, the recycled material is modified in-place. In cold mix recycling, existing pavement are stabilized without application of heat. The classification system for recycling is presented schematically in the Figure 1.

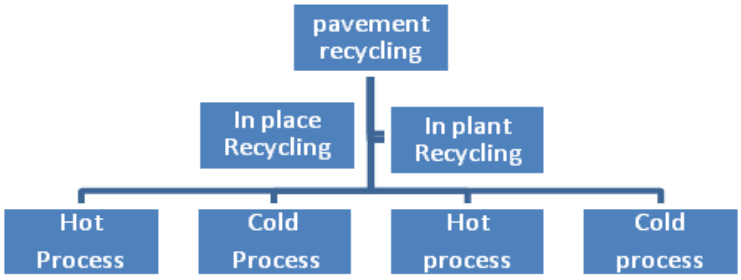

Figure 1: Classification of Recycling Process

Al-Qadi et al., (2007) found that recycling of existing bituminous mixes result in substantial savings through the reuse of aggregates and bitumen. Use of the recycled materials in road construction has been favored over virgin 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 costs alone, it is estimated that using recycled materials, savings ranging from 14 to 34% can be achieved. Mallick et al. (2010) found that 100% recycling can be made use without affecting the performance of bituminous mixes. Aravind and das, (2007) obtained around 12 to 55% savings in cost was obtained using recycled materials in bituminous mixes when compared to virgin bituminous mixes.

To summarize, the above studies have clearly evade the utilization of recycled materials towards the sustainable and economic development of infrastructure.

OBJECTIVES

The main objective of the research is to evaluate the effects of partial replacement of aggregates by RAP on the mechanical response of dense bituminous mixtures, Grade-II, are as fallows.

- To determine the basic engineering properties of the Virgin bitumen and Virgin aggregate and the basic engineering properties of Reclaimed Aggregate and binder after extraction and Recovery.
- To carry out the blending of RAP and Virgin aggregates for 20% and 30% RAP content as per Asphalt Institute (MS-II), according DBM-II gradation as per MoRT&H(4^{th} revision).
- To carry out the mix design for 20% and 30% recycled mixes with virgin mixes as per Asphalt Institute (MS-II) and compared with Marshall Properties.
- To workout the economics of recycling of bituminous pavement materials, comparing with conventional virgin mixes.

EXPERIMENTAL INVESTIGATION

Around 200 kg of milled RAP samples was collected from the NH-48(Devahalli to Hassan stretch), the collected samples were labeled appropriately for the further investigation (Figure 2).Random samples were considered from the field samples for the laboratory tests. The RAP materials were subjected to solvent (benzene) extraction method by centrifuge extractor (Figure 3) and the average bitumen content were found to be 3.2%.

Figure 2: Stock Piled Milled RAP Materials Figure 3: Extraction of Bituminous Mix

Furtherly, sieve analysis was carried out on the extracted aggregates. It was found that the aggregate lies in the band of specified limits for dense bitumen macadam grade-II as per MoRT&H, (4^{th} revision). The solvent obtained after the extraction taken for distillation to recover the binder for further studies.

Evaluation of Binder in RAP

The binder extracted from RAP was tested for its penetration value and it was found to be 19mm, which satisfies the minimum criteria of 15mm.Furtherly the same evaluated after rejuvenation using virgin 60/70 binder and found to be 48mm which also satisfies the minimum criteria as per MoRT&H, Clause 517.2.6.

Virgin and Recycled Aggregate Properties

The aggregate properties were measured from the extracted sample (table-1) and tested for its suitability. Recycled aggregate were found to satisfy the requirements as per MORTH, table 500-8.

Table 1: Properties of Recycled and Virgin Aggregates

Properties	Virgin	RAP	Permissible Limit
Impact value(AIV),%	19.62	17.12	27 max.
Crushing value,%	22.7	-	24 max.
Abrasion value,%	21.5	-	35 max.
Specific Gravity,%	2.65	2.7	2 .5-3.0
Combined index,%	24.30	26	30 max.

Virgin Bitumen Properties

For the study, Bitumen 60/70 grade was considered and their properties were tested for its suitability for the study (Table-2). The bitumen properties were found to satisfy the requirements.

Table 2: Properties of Virgin bitumen (60/70)

Properties	60/70	Permissible Limit	Specification
Penetration at 25°c,5sec	64	60-70	IS -1203:1978
Softening point(R&B),°C	49	45-55	IS -1205:1978
Flash point, °C	295	175 min.	IS -1448:1969
Ductility at 25°C,cm	82	75 min.	IS -1208:1978
Specific gravity	1.01	0.99 min.	IS -1202:1978
Viscosity-60°C,poise,0.3 RPM	1730	1000 min.	ASTM-D 4402

Table 2: Contd.,

Viscosity-135ºC,poise,100 RPM	3.6	-	ASTM-D 4402
After RTFO, Loss in weight, %	0.40	1 max.	-
Reduction in Penetration of residue at 25°c,%	10.93	48 max.	-
Increase in Softening point, °c	1.27	-	-

Mix Design

The mix design was carried out for virgin aggregate and rap material for different percentages i.e 0%, 20 % and 30% Detailed calculation showing gradation of RAP and required percentages of virgin Aggregates of different Percentages for 20%, 30% as per MS-II (Table-3).

Table 3: Calculated Required Percentage of Virgin and RAP Aggregates

Sl. No	IS Sieve(mm)	Desired % for DBM Mix	% Available in RAP Material	% Available of RAP Material	Balance 80 % of Virgin Aggregate	% Available of RAP Material	Balance 70 % of Virgin Aggregate
				20%		30%	
1	37.5-26.5	5	0	0	5	0	5
2	26.5-19	12	2.9	0.58	11.42	0.87	11.13
3	19-13.2	15	6.8	1.36	13.64	2.04	12.96
4	13.2-4.75	22	46.25	9.25	12.75	13.875	8.125
5	4.75-2.36	11	14.8	2.96	8.04	4.44	6.56
6	2.36-0.3	21	17.45	3.49	17.51	5.235	15.765
7	0.3-0.075	9	5.5	1.1	7.9	1.65	7.35
8	Below 0.075	5	2.8	0.56	4.44	0.84	4.16
	Total			**19.3**	**80.7**	**28.95**	**71.05**
				100		**100**	

Actual Percentage of Virgin Binder

Detailed calculation showing the actual percentage of bitumen to be added to the mixes considering the bitumen content already present in RAP, As per Asphalt Institute MS-2, (Table-4)

Estimated Percent of virgin Asphalt in Mix - **Pnb = {(1002-rPsb) Pb/100(100-Psb)}-{(100-r)Psb/(100-Psb)}**----------(Asphalt Institute-MS-II)

Where, $\mathbf{P_{nb}}$ = Percent of new asphalt in mix, $\mathbf{P_b}$ = Percent asphalt content of total recycled asphalt mix of asphalt demand (%), **r** = New aggregate expressed as a percent of total aggregate in the recycled mix (%), $\mathbf{P_{sb}}$ = Percent of asphalt content of reclaimed asphalt pavement (%)

Table 4: Calculation Showing the Actual Percentage of Bitumen to be Added

20% RAP	r=80,Psb=3.2	Pb,%				
		3.5	**4**	**4.5**	**5**	**5.5**
	Pnb,%	2.86	3.36	3.86	4.37	4.87
30% RAP	r=70,Psb=3.2	Pb,%				
		3.5	**4**	**4.5**	**5**	**5.5**
	Pnb,%	2.54	3.05	3.55	4.06	4.56

Marshall Properties: Table-5 shows the stability and volumetric properties obtained for 20 and 30% and Virgin mixes.

Table 5: Properties of Recycled and Virgin Mixes

Properties Tested	Recycled Mixes		Virgin Mixes	Criteria as per MoRT&H
	20%	30%		
OBC,%	4.37	4.1	4.63	----
Stability, Kn	23.09	25.43	21.76	9Kn min
Flow, mm	3.3	3.36	3.48	2-4
Air voids,%	5	3.97	4.74	3-6
Unit weight	2.37	2.4	3.54	-----
VMA,%	19.73	18.18	18.14	12.5min
VFB,%	74.59	78.1	73.84	65-75

ECONOMIC ANALYSIS

A typical example for one kilometer length for two lane highway, width of 7m, and depth of 0.1m were considered for cost analysis, additionally milling is considered in case of RAP. The costs are calculated based on the schedule of rates of Govt. of Karnataka. The details of economic analysis are shown in Table-6.

Table 6: Economic Analysis

Particulars	Total Quantity(cum)	Amount(Rs)
Virgin	733	57,43,788
20% RAP	586	46,24,621
30% RAP	513	40,52,593

CONCLUSIONS

Based on the experimental result and after analyzing the results, the following may be concluded.

- DBM-II mixes prepared with RAP materials 20%, 30% shows higher stability of when compared with the conventional virgin mixes and other Marshall properties are within the specified limits.
- The saving can be realized from utilization of recycled materials as per the methodology, the reduction in the total cost is 19%, 30%comparing with the virgin mixes.

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