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Experimental Study on Characterization of Bituminous Mixes Containing Recycled Asphalt Pavement Materials for the Construction of Surface Course in Flexible Pavements.

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Abstract: ***In India majority of the road network has a bituminous top surface made of naturally accessible road materials and bitumen. This process has resulted in a faster depletion of road aggregates as well as an increase in gas emissions into the atmosphere, resulting in pollution.***
The most promising approach for achieving sustainability in road building will be to use low emission bitumen, re-use aggregates obtained from milling, and material reclaimed from the old distressed pavement to create or rehabilitate new roads. In this regard, the current study seeks to evaluate and compare the physical and engineering features of bituminous mixes including RAP material in various percentages for the construction of the surface course in flexible pavements through thorough laboratory investigations.
According to the results of laboratory experimental tests, a bituminous mix containing recycled asphaltic pavement (RAP) material exhibits better Marshall Properties, performance properties, and volumetric properties, and meets all of the requirements of the bituminous concrete (BC) layer as per standard specifications. According to the findings of the study, it is possible to create an acceptable grade bituminous mix with a high RAP component that meets the needed volumetric characteristics and performance parameters for the construction of flexible pavements under current traffic and environmental circumstances.
Keywords: RAP, Sustainable roads, Volumetric properties, Marshall Properties, ITS.

I. INTRODUCTION

In India majority of the road network has a bituminous surface at the top and is constructed using naturally available road aggregates and bitumen. Effective, timely, and rapid maintenance is the only method to protect the massive capital investments linked to the road network, therefore proper road network strengthening and maintenance are crucial for long-term infrastructure growth. Maintenance of flexible pavement under current traffic and environmental circumstances is one of the biggest issues for highway engineers.

With the constant increase in traffic, pavement discomfort or road deterioration increases. Construction of new pavement has become less time demanding and cost-effective in recent years than maintaining or rehabilitating distressed pavement. One of the most common methods for restoring distressed pavements had been and continues to be bituminous overlaying over distressed pavements with virgin courses.

The continuous application of overlays increases the pavement thickness thereby leading to a major drainage crisis, especially in urban localities. The use of conventional techniques leads to global energy consumption, fossil fuel burning across the world, and global air pollution by emitting greenhouse gasses [1]. The construction industry may face a scarcity of resources over time due to the continuous use of virgin construction materials. Hence use of marginal or alternative materials in road construction is the need of the hour. In this regard, the present study attempts to ascertain the optimum proportion of Reclaimed Asphalt Pavement (RAP) material to be used in the surface course of flexible pavements. With the development of RAP technology, the various ecological and economic advantages which contributed to the enhancement of recycling processes across the world are a decrease in pavement thickness, preservation of existing pavement geometrics, reduced cost of transportation, conservation of aggregates and binders, conservation energy and labor, preservation of environment [2].

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II. STUDY OUTLINE

A. Objectives and Study Approach

The study aims at determining the optimum proportion of RAP material to be used in the design mix by evaluating the properties of bituminous mixes containing RAP material in various percentages through laboratory investigations. The objectives of the study are summarized as follows:

1) Characterization of pavement construction materials through laboratory investigation.
2) Evaluation of physical, engineering, volumetric, and rheological properties of construction materials through laboratory investigation.
3) Bituminous mix design by Marshall method.
4) Determination of the optimum proportion of RAP material to be used in the design mix which replaces virgin aggregates.

B. Materials and methodology

1) *Aggregate:* The virgin aggregates for this investigation were obtained from a quarry near Hosakote, Bangalore. The laboratory investigations and test results are reported in Table I. Physical properties as such Flakiness and elongation index, Abrasion value, specific gravity, Impact value, Water absorption, etc were evaluated at the laboratory.

TABLE I
PROPERTIES OF VIRGIN AGGREGATE

Description	Specification	Aggregates test results	Permissible limits as per MORTH table-500-8
Combined Flakiness and Elongation Index (%)	IS-2386 Part- 1	22.50	35% maximum
Water Absorption (%)	IS-2386 Part- 3	0.18	1% maximum
Specific gravity	IS-2386 Part- 3	2.52	2.5-2.9
Aggregate Impact Value (%)	IS-2386 Part- 4	13.14	27% maximum
Aggregate Crushing Value (%)	IS-2386 Part- 4	21.50	30% maximum (as per IS:383-1970)
Aggregate Abrasion Value (%)	IS-2386 Part- 4	14.15	35% maximum

2) *RAP Material:* Milled material (Fig. 1) was acquired from the site near Sirsi Circle Flyover in Bangalore, where milling was being done for overlaying purposes. Before being used in the construction process, the obtained RAP material was mechanically processed with the use of equipment (Fig.2) designed by M/s KK Waste Plastic Management Pvt. Ltd. Bengaluru.



Fig. 1 Milled material obtained from the site



Fig. 2 RAP material processing equipment

The bitumen extraction test was carried out in accordance with IRC: SP 11 –1988 (Appendix – 5), and the findings are listed in Table II. Table III shows the physical parameters of the RAP material.

TABLE III
Bitumen extraction test by centrifuge method results

Description	Sample 1	Sample 2	Sample 3
Weight of RAP material in grams (A)	500	500	500
Weight of RAP material after extraction in grams (B)	482	479	481
Percentage of Bitumen contents in RAP material = $\frac{(A-B)}{B} \times 100$	3.73	4.38	3.9
Average Bitumen contents in RAP material	4.0 %		

TABLE IIIII
Properties of RAP Material

Description	Specification	RAP Aggregates test results	Permissible limits as per MORTH table-500-8
Specific gravity	-	2.46	2.5-2.9
Water Absorption (%)	IS-2386 Part-3	0.15	1% maximum
Aggregate Crushing Value (%)	IS-2386 Part-4	24.50	30% maximum
Aggregate Impact Value (%)	IS-2386 Part-4	12.10	27% maximum

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3) *Virgin binder:* VG-30 Bitumen and CRMB-55 binder materials were utilized to create the appropriate bituminous mix to test the behavior of a mix incorporating RAP and various binder materials. Table IV lists the features of both the VG-30 and CRMB-55 binder.

TABLE IVV
PHYSICAL PROPERTIES OF VG-30 AND CRMB-55 BINDER MATERIALS

Sl.No.	Property	Test method	VG-30	Permissible Limit	CRMB-55	Permissible Limit
1	Penetration at 25°C, 5seconds	IS-1203	64.33	60-70	56	60 max
2	Softening point,°C	IS-1205	48.00	45-55	56	55 min
3	Flash point, °C	IS: 1448 [P:69]	276.00	175 min	310	220 min
4	Ductility at 25°C,	IS-1208	96.00	75 min	>100	50 min
5	Specific gravity	IS-1202	0.995	0.99 min	1.02	-
6	Viscosity at 135°C in centistokes (cSt)	IS-1206 (Part 3)	380	350 min	-	-

4) *Mix design:* The basic goal of mix design is to reduce material requirements and produce a mix that performs better, and the developed mix must have the desired volumetric characteristics. The Ministry of Road Transport and Highways (MoRTH) section:507 specification was used to calculate the material requirements for the Bituminous Concrete (BC) grade-II mix. Different amounts of mineral aggregate combinations in terms of specific sieve sizes are provided by laboratory mix designs. In this study, the combined grading of coarse aggregate, fine aggregate, and filler material for BC grade-II was studied in accordance with the mid gradation values stated in MoRTH specification Table: 500-17. For practical on-site operational needs, however, a blend of two or more aggregate sizes (each size containing a range of separate sieve sizes) should be considered. The weight percent of coarse aggregate, fine aggregate, and filler required to achieve the final aggregate gradation is calculated using this mix ratio (MoRTH Section:511.2.3). Table V shows the gradation of materials that were considered for the design.

TABLE V
MoRTH Specifications for bc grade-ii layer

Sieve sizes (mm)	BC Grade II Specifications as per MoRTH	Desired Mid Gradation
19	100	100
13.2	79-100	89.5
9.5	70-88	79
4.75	53-71	62
2.36	42-58	50
1.18	34-48	41
0.6	26-38	32
0.3	18-28	23
0.15	12-20	16
0.075	4-10	7

III.RESULTS AND DISCUSSIONS

Marshall's method of mix design was adopted to evaluate the properties of bituminous mix containing RAP material in various proportions with VG-30 and CRMB-55 grade binders. This method evaluates bituminous mix based on various parameters to arrive at optimum binder content. RAP materials having aged bitumen binder 3.9%, which is extracted from the centrifuge method were used to replace virgin aggregates in various proportions (35%, 40%, 50%, 60%, and 100%). From the desired optimum binder content, the percentage of existing/aged bitumen was deducted and the only remaining percentage of virgin bitumen grade VG30 was considered in the design mix and laboratory studies were performed on the specimens prepared using the design mix as per standard specifications. Results of the same are tabulated in Table. VI.

TABLE VI
MARSHALL TEST RESULTS

Sl. No.	Binder	Percentage RAP	Marshall Stability (Kg)	Flow (mm)
1	VG-30	0	1141.28	3.20
2		35	1084.24	3.45
3		40	1148.1	4.6
4		50	1228.05	4.00
5		60	1262.32	5.58
6		100	1019.64	6.94
7	CRMB-55	0	1530.80	3.19
8		35	1267.21	3.45
9		40	1318.24	3.68
10		50	1495.65	4.10
11		60	1374.23	3.7
12		100	1600.52	6.74

Marshall Mix design for control mix and the mixes with processed RAP material fulfill the minimum stability criteria of 900Kg and also satisfy VMA and VFA requirements. It can be observed from the results that Marshall Stability increases linearly with an increase in RAP content. The flow values for all mixes fall within the permissible limits of 2mm to 4mm except for the mixes containing RAP material greater than 50%. Hence from the test results, it can be evident that the ideal percentage of RAP materials that can be used in the design is 50%.

Further, to ascertain moisture susceptibility of the bituminous mix containing RAP material and various binders Indirect Tensile Strength (ITS) test was carried out and the test results are as follows:

TABLE VII
ITS TEST RESULTS

Description	No. of blows	Average Failure Load (N)		Average Tensile Strength in'St'(Kpa)		Tensile Strength Ratio (TSR) (%)
		Unconditioned	Conditioned	Unconditioned	Conditioned	
Bituminous mix with virgin materials & VG-30 Binder	75	2135.33	1821.4	195.1	166.4	85.28
	35	2083	1360.33	194.4	120.3	61.9
Bituminous mix with 50% RAP materials & VG-30 Binder	75	2347.87	1726.57	211.5	155.5	73.5
	35	2246.50	1242.63	206.2	116.3	56.4
Bituminous mix with virgin materials & CRMB-55 Binder	75	4100.58	3580.65	371.13	325.63	87.74
	35	3891.30	3001.86	357.41	268.05	75
Bituminous mix with 50% RAP materials & CRMB-55 Binder	75	4005.75	3116.31	359.24	279.44	77.79
	35	3646.05	2429.61	330.01	222.01	67.28

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From the Tensile Strength Ratio Test, the moisture susceptibility of the mix is nearly satisfying as per AASHTO T 283 standards. Also, test results of specimens containing RAP material imply that the bitumen content in the mix is insufficient to resist moisture susceptibility. The variation in the attributes of the mix is attributable to variations in the RAP material, such as aggregate size and shape, percent fines, percent aged bitumen content, etc. which normally increases as the RAP percentage increases.

IV. CONCLUSIONS

Based on the laboratory test results it can be deduced that:

1) The physical and engineering properties of construction materials i.e., virgin aggregates, RAP, and binder materials considered for the study are well within the permissible limits as per standard specifications.

2) A bituminous mix containing RAP is designed using Marshall Method and from the laboratory investigations, it is observed that compared the performance of the mix is the same or even better than the control mix.

3) Marshall Stability values increase with the increase in RAP content up to a certain percentage (50%) and it follows the normal distribution.

4) Bituminous mix with optimum RAP material content improves the overall mix property of HMA technology. This implies the use of alternative materials conserves nonrenewable resources and also proves economical, particularly in areas where aggregate and bitumen are in scarce supply or haul lengths to remote sites are very long.

V. ACKNOWLEDGMENT

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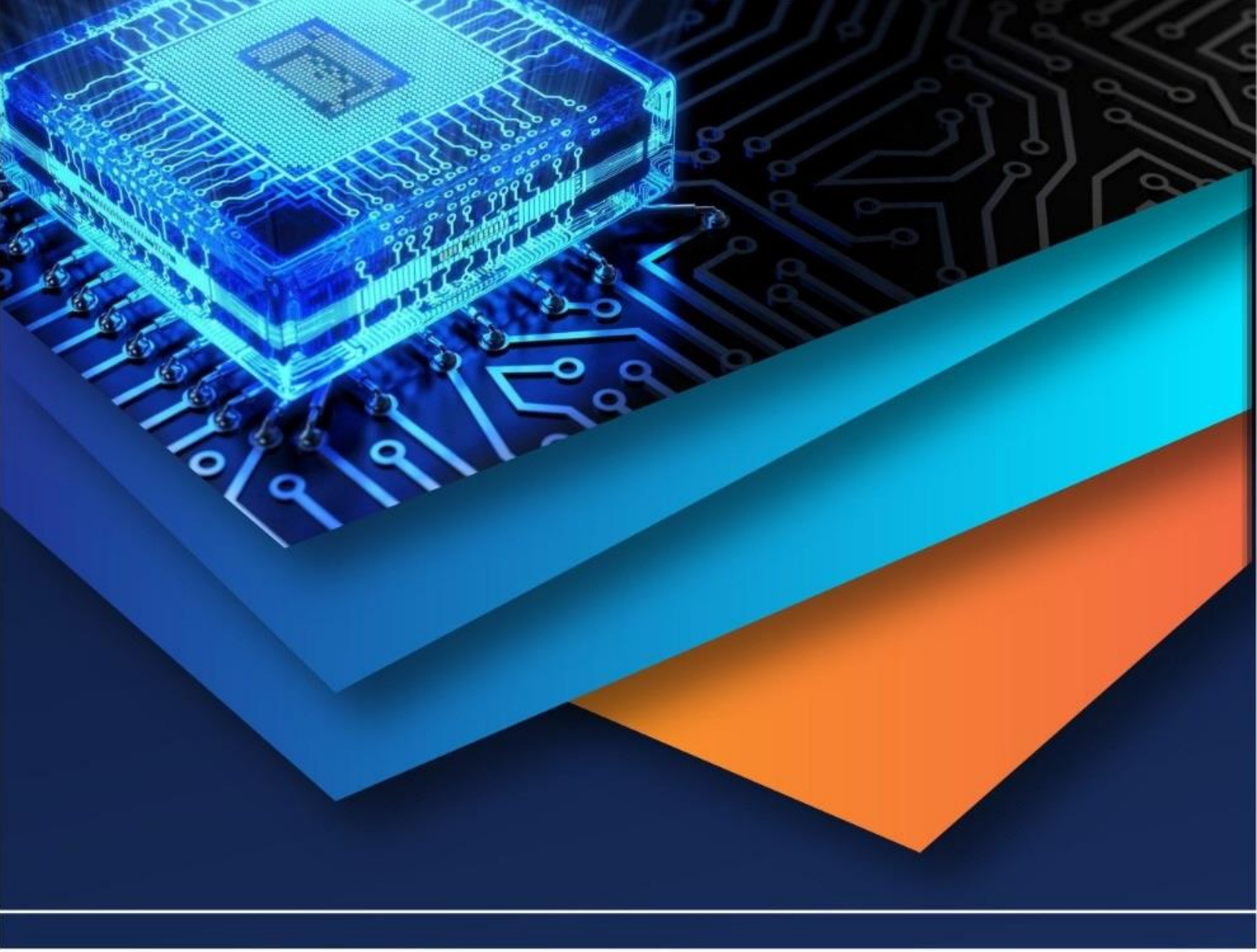
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