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Comparative Study on Design of Bituminous Mixes Containing Recycled Asphalt Pavement Materials

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***Abstract*: RAP is a deteriorated bituminous mix that contains aged bitumen and aggregate. Hence its performance is comparatively poorer than virgin mix. Performance of RAP can be enhanced by adding virgin bitumen, virgin aggregates & rejuvenators (such as waste plastic) in suitable proportions. Recycling of Reclaimed Material from a deteriorated pavement to reuse partially or fully to produce new pavement materials results in considerable savings of material, money & energy.**

Recycling is one such alternative that reduces use of new materials, conserves natural resources & most importantly reduces carbon foot prints there by earning carbon credits for India.

Present work focuses on evaluation and comparison of physical and engineering properties of bituminous mixes containing RAP material in various percentages through extensive laboratory tests for the construction of surface course in flexible pavements.

Keywords: RAP, Bituminous Mixes.

I INTRODUCTION:

Effective, timely and speedy maintenance is the only way to protect the huge capital investments which are linked to the road system. The proper strengthening and maintenance of the road network is required. Where deteriorating of roads increase with the steady increase in traffic. Overlaying the distressed pavements with virgin courses had been adopted and continues to be the preferred method for restoration of aged pavements. The continuous application of overlays increases the pavement thickness and approaches the curb line. The conventional methods are responsible for 22 percent of the global energy consumption and 25 percent of fossil fuel burning across the world and 30 percent of global air pollution and greenhouse gasses. The availability and efficient recycling technology favored the adoption of Reclaimed Asphalt Pavements (RAP) Technology in many countries. Recycling, in place of conventional method of overlaying of asphalt pavements has made a rapid advancement in the developed countries. This method of strengthening and repairing of roads was based on their durability rather than their initial cost. The concept of RAP lies in restoring the physio-chemical properties of the aged bitumen to its original and at the same time it enhances the mechanical properties and strength of the aged binder. With the development of RAP technology, asphalt pavement rehabilitation costs would significantly decrease. The various ecological and economic advantages which contributed to enhancement of recycling processes throughout the world are conservation of aggregates and binders, decrease in pavement thickness, reduced cost of transportation, conservation energy and labour, preservation of existing pavement geometrics, preservation of environment. The ability to mill and remove old, distressed pavements allows for more effective rehabilitation techniques which create RAP may have substantial engineering benefits. Severely cracked or rutted layers can be removed so that their damage is not reflected through a new surface layer. The effective use of RAP solves a large societal problem because it does not occupy landfill space.

II OBJECTIVE OF THE STUDY

The objectives of the present study are as follows,

1. To study about the Reclaimed Asphalt Pavement (RAP) technology as a renewable resource.
2. To study Mix design approach for hot recycled RAP.
3. Extraction of bitumen from RAP materials is done using centrifuge method and the bitumen content to be determined.
4. To determine the physical properties of virgin aggregate which includes aggregate specific gravity, Impact value, Abrasion value, Water absorption, Flakiness and elongation index.
5. To determine optimum virgin bitumen content for different percentage of RAP material by Marshall Method of mix design.
6. To workout the economics of recycling of bituminous pavement material.

III METHODOLOGY

The present investigation aimed at the laboratory evaluation of bituminous mix containing RAP material which replaces virgin aggregates by various percentages. For the present study virgin aggregates are obtained from

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Hosakote quarry and VG-30 and CRMB-55 type binders are used to ascertain the characteristic of bituminous mixes containing various percentage of RAP material with normal and modified binders.

RAP Materials

i. Milled RAP: Milled material is obtained from the site near shirsi circle flyover, Bangalore where the milling process was in progress for overlaying purpose.

ii. Processed RAP: Bituminous pavement material for reuse, which is obtained by processing reclaimed (full depth) asphalt material in a exclusively developed equipment (as shown in Fig:) developed by M/S K K Waste Plastic Management Pvt. Ltd. Bangalore. Reclaimed material for processing is obtained from Hosakote – Gownipalli via Chintamani road (SH-82) which is presently under reconstruction.

Fig: 1 Equipment Developed by M/S K K Plastic Waste Management Pvt Ltd. Bangalore, for processing Reclaimed Asphalt Pavement material.

Virgin aggregates, RAP material and bitumen binder are subjected to standard laboratory investigations to know its physical and engineering properties.

This study investigates the effect of utilization of recycled materials on Marshall Stability of bituminous course mixes. BC grading II of MORTH (IV revision) was considered for the study.

The aggregates are collected from the crusher at Hosur about 45 km from Bangalore. Virgin aggregates, RAP material and bitumen binder as described above are tested for basic properties to check for their suitability. The virgin aggregate will be blended with RAP materials for RAP mixes to meet the requirement of desired layer gradation as per MORT&H- IV revision. For the present study mid gradation values are adopted as shown in figure 2 and Table 3.The most common and convenient method to determine optimum binder content of bituminous mixes is Marshall Method. Standard Marshall Specimens were prepared with trial percentages of bitumen to determine optimum binder content. The parameters viz., stability, density, voids in mineral aggregate, voids filled with bitumen and air voids etc. will be evaluated to arrive at optimum bitumen content. The test results so obtained for both VG-30 binder and CRMB-55 binder for various percentages of RAP materials were compared to deduce present work.

The virgin aggregates are tested for physical properties as per table 500-14 of MORTH (IV revision) as indicated below:

1) Crushing test.
2) Aggregate Impact value test.
3) Los Angeles Abrasion value test.
4) Combined flakiness and elongation test.
5) Specific gravity and Water Absorption test.

Following tests were carried out on bitumen binders:

1) Specific gravity test.
2) Softening point test.
3) Penetration test.
4) Ductility test.
5) Flash point test.

To assess the content of bitumen in the RAP material, bitumen extraction test is carried out with the help of centrifuge bitumen extractor as per standard specifications.

IV LABORATARY EVALUATION

Table: 1 Test Results on Basic Properties of Aggregates and RAP.

SL NO	TESTS	AGGREGATES	RAP MILLED	RAP PROCESSED	PERMISSIBLE LIMIT (as per table 500-14 of MORTH)
1	Crushing Value (%)	21.5	25.5	24.35	24.0 max
2	Impact Value (%)	13.14	11.5	12.1	27.0 max
3	Abrasion Value (%)	14.15	-	-	35.0 max
4	Combined Index (%)	22.5	-	-	30.0 max
5	Specific gravity	2.52	2.46	2.48	2.5-3.0max
6	Water Absorption (%)	0.18	0.12	0.15	2.0 max

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Table: 2 Test Results on Basic Properties of Bitumen

SL NO	TESTS	VG-30	PERMISSIBLE LIMIT	CRMB-55	PERMISSIBLE LIMIT
1	Penetration at 25°C, 5sec	64.33	60-70	56	60 max
2	Softening point, °C	48.00	45-55	56	55 min
3	Flash point, °C	276.00	175 min	310	220 min
4	Ductility at 25°C,	96.00	75 min	60	50 min
5	Specific gravity	0.995	0.99 min	-	-

Table: 3 MORTH Specifications for gradation of BC layer.

MORTH SPECIFICATION FOR BC LAYER				
Sieve sizes(mm)	Grade II	Upper limit	Lower limit	Mid Gradation
19	100	100	100	100
13.2	79-100	100	79	89.5
9.5	70-88	88	70	79
4.75	53-71	71	53	62
2.36	42-58	58	42	50
1.18	34-48	48	34	41
0.6	26-38	38	26	32
0.3	18-28	28	18	23
0.15	12-20	20	12	16
0.075	4-10	10	4	7

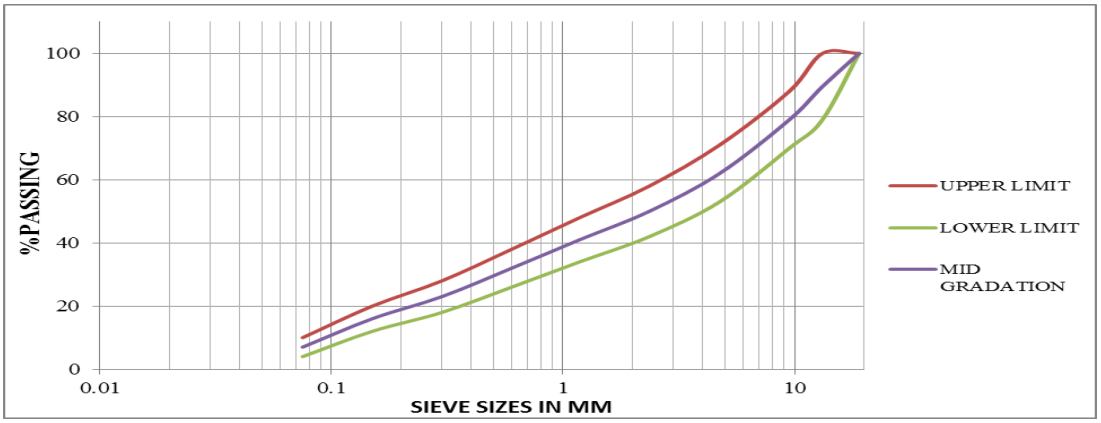

Fig: 2 Graph showing gradation curves.

Table: 4 Marshall Mix Design for All Mixtures

Milled Material					Processed RAP			
Sl. No.	Binder	Percentage RAP	Marshall Stability (Kg)	Flow (mm)	Binder	Percentage RAP	Marshall Stability(Kg)	Flow (mm)
1	VG-30	35	1139.05	3.4	VG-30	35	1084.24	3.45
2		40	1071.93	3.5		40	1148.1	4.6
3		50	1306.37	2.97		50	1228.05	4.41
4		60	1059.69	3.63		60	1262.32	5.58
5		100	1285.23	4.63		100	1019.64	6.94
6	CRMB-55	35	1501.06	3.4	CRMB-55	35	1267.21	3.45
7		40	1438.39	4.18		40	1318.24	3.68
8		50	1422.89	4.1		50	1495.65	4.34
9		60	1465.09	3.68		60	1374.23	3.7
10		100	1267.21	4.13		100	1600.52	6.74

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Table: 5 Comparison of Milled RAP with Processed RAP (VG-30)

SL NO	RAP PERCENTAGE	Stability (in Kg) (Milled Material)	Flow (in mm) (Milled Material)	Stability (in Kg) (Processed Material)	Flow (in mm) (Processed Material)
1	35	1139.05	3.4	1084.24	3.45
2	40	1071.93	3.5	1148.1	4.46
3	50	1306.37	2.97	1228.05	4.41
4	60	1059.69	3.63	1262.32	5.58
5	100	1285.23	4.63	1019.64	6.94

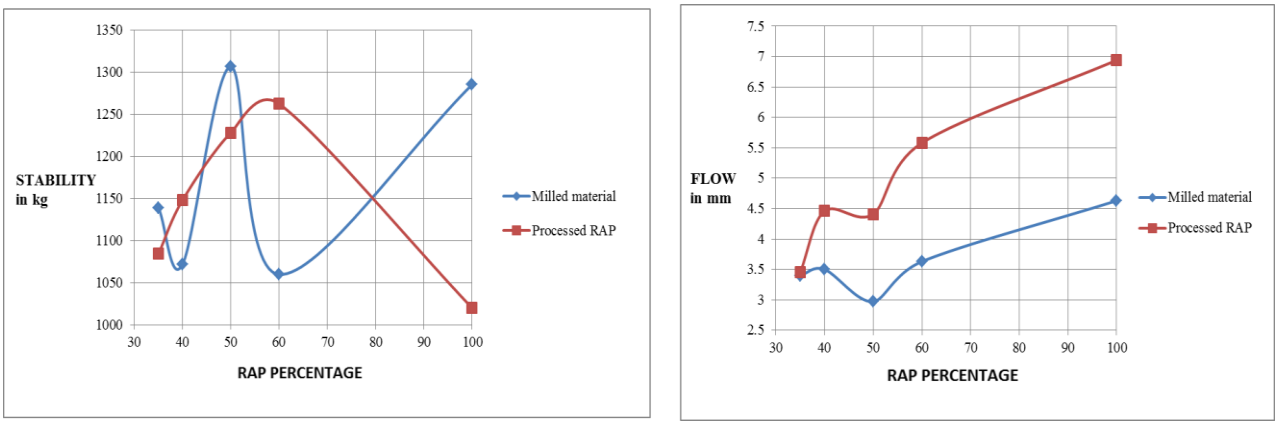

Fig: 3 Variation of Stability and Flow of Mix (VG 30) with respect to Percentage of RAP.

Table: 6 Comparison of Milled RAP with Processed RAP (CRMB-55)

SL NO	RAP PERCENTAGE	Stability (in Kg) (Milled Material)	Flow (in mm) (Milled Material)	Stability (in Kg) (Processed Material)	Flow (in mm) (Processed Material)
1	35	1501.06	3.67	1267.21	3.45
2	40	1438.39	4.18	1318.24	3.68
3	50	1422.89	4.1	1495.65	4.34
4	60	1465.09	3.68	1374.23	3.7
5	100	1355.54	4.13	1600.52	6.74

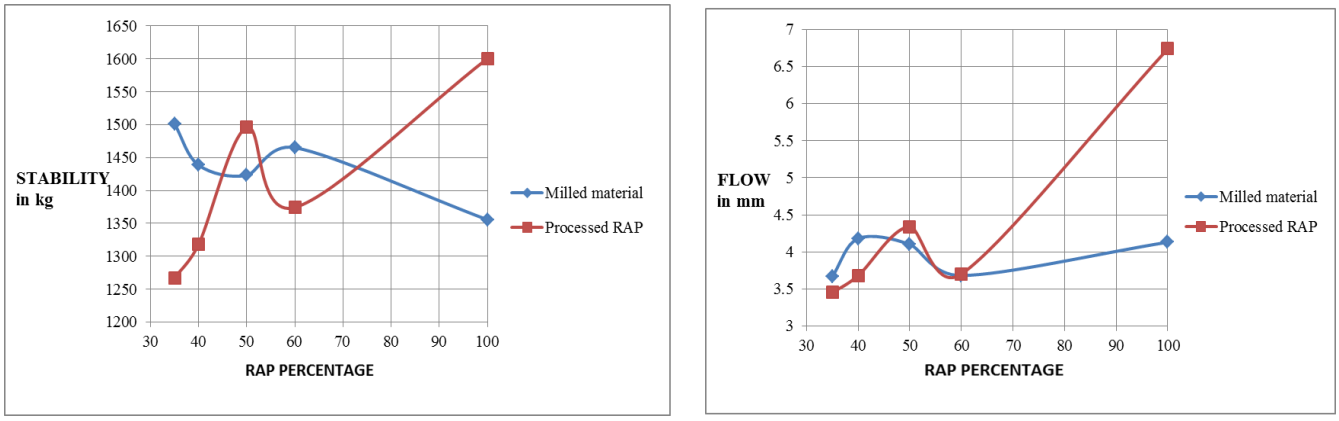

Fig: 4 Variation of Stability and Flow of Mix (CRMB 55) with respect to Percentage of RAP

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V RESULTS

Marshall Mix design for control mix with virgin aggregates and both (milled and processed) type of RAP material in all the mixtures fulfill the minimum stability criteria of 600Kg and also satisfy VMA and VFA requirements. It can be observed from the results that Marshall Stability increases linearly with increase in RAP content. The flow values for all mixes falls within the permissible limits of 2mm to 4mm except for the mixes containing 50% and 100% RAP material.

The variability in the properties of mix is due to variability in the RAP material as such size and shape of the aggregates, %fines, % of aged bitumen content etc., which generally increases with increase in RAP percentage as shown in Fig: 3,4 and Table: 5,6.

VI CONCLUSION

It is observed from the extensive laboratory evaluation of different Marshall Mixtures containing RAP materials that, the blending of virgin and RAP material overall improve the mixture properties by HMA technology. The main conclusions drawn from the present work are as follows:

1. In laboratory, bituminous mixture blended with RAP is designed using Marshall Method and it is observed that bituminous mixes containing RAP material perform same or even better than the conventional mix.
2. Marshall Stability values increases almost linearly with increase in RAP content.
3. The maximum Marshall stability of bituminous mix with VG-30 as binder is 1306.37 Kg which is achieved for blend of virgin aggregates and 50% of Milled RAP corresponding to a flow value of 2.97mm.
4. The maximum Marshall stability of a bituminous mix with VG-30 binder is achieved for mix containing 60% of Processed RAP that is 1262.32 kg and its flow value is 5.58mm which doesn't fall within the permissible limits of 2mm to 4mm.
5. When the Modified binder CRMB-55 is used, maximum stability of 1501.06 Kg is achieved for mixture containing 35% of Milled RAP with a flow value of 3.67mm satisfying minimum requirement of both stability and flow criteria.
6. Maximum stability value of 1495.65 Kg corresponding to a flow value of 4.34mm is yielded for bituminous mix containing 50% of Processed RAP with CRMB-55 binder.
7. It is evident from the present study that properties of bituminous mixture improves with the addition of RAP material, hence use of recycling materials will help in conserving non-renewable resources, reduces carbon foot prints, consumption of fossil fuels and also it reduces the HMA price and improves the performance especially in the areas where aggregate and asphalt are in short of supply or where haul distances to remote locations are exclusively long.

Scope for future study**:**

- A test track may be constructed to study the performance of bituminous mixes containing RAP material under varying traffic and climatic condition.
- Properties of mix containing RAP material in different percentages can be evaluated using various types of binders and modified binders.
- Performance and properties of bituminous mix containing RAP material can be assessed for WMA (warm mix asphalt) technology.

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