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Preparation of Cold Mix Asphalt using Reclaimed Asphalt Pavement

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Abstract - With increasing urban development and traffic growth, the demand for road construction materials has increased significantly, leading to depletion of natural aggregates and increased environmental pollution due to conventional Hot Mix Asphalt production. Cold Mix Asphalt prepared using bitumen emulsion at ambient temperature provides a sustainable alternative as it reduces energy consumption, fuel usage, and greenhouse gas emissions. Reclaimed Asphalt Pavement, obtained from milling of existing pavements, contains valuable aggregates and aged bitumen binder, and its reuse helps in resource conservation and waste reduction. This study focuses on the utilization of RAP in cold mix asphalt by partially replacing virgin aggregates with RAP at different proportions. Bitumen emulsion and rejuvenator are used to improve the performance of the recycled mix. Laboratory tests such as Marshall Stability and Indirect Tensile Strength are conducted to evaluate the performance of the mix. The study also examines the suitability of RAP-based cold mix asphalt for pavement maintenance works such as pothole patching, micro-surfacing, thin overlays, and repair of distressed pavement sections. The results indicate that RAP cold mix asphalt can be used as a sustainable and economical material for road maintenance applications.

Key Words: Cold mix, Recycling Asphalt Pavement

1. INTRODUCTION

The increasing demand for transportation of goods and passengers has resulted in higher traffic volumes and increased axle loads, which require pavements to withstand heavier loads and more frequent traffic repetitions. At the same time, there is a need to develop better performing pavements and to encourage the reuse of existing pavement materials through recycling techniques. Recent developments in asphalt pavement research have led to the development of improved mix design procedures and various recycling methods, including cold bitumen stabilized mixes using bitumen emulsion.

In India, road transport carries more than 60% of freight traffic and more than 80% of passenger traffic, making road infrastructure very important for economic development. Large quantities of aggregates are required for highway construction, and old pavement materials are often removed and dumped as waste. These materials can be effectively reused through recycling techniques such as Cold In-Place Recycling (CIR), in which the existing pavement is milled, mixed with bitumen emulsion and additives, and compacted to form a new stabilized layer. Therefore, this study focuses on the design and performance evaluation of cold bitumen stabilized mixes prepared using reclaimed asphalt pavement materials and bitumen emulsion for sustainable and economical pavement maintenance and rehabilitation works.

2. NEED FOR THE STUDY

Highway construction requires a large quantity of aggregates. It is estimated that about 15,000 tonnes of aggregates are required per kilometer of highway construction, and a typical 60 km highway project requires nearly 20 lakh tonnes of materials. This high demand leads to depletion of natural resources and increases construction cost. During pavement maintenance and rehabilitation works, old pavement materials obtained from milling are often dumped as waste, even though they contain reusable aggregates and bitumen. Recycling these materials using cold mix asphalt and cold in- place recycling methods can reduce material wastage, lower construction cost, conserve natural resources, and provide a sustainable solution for pavement maintenance and rehabilitation.

3. OBJECTIVES OF THE STUDY

- To Study the properties of Recycled Asphalt Pavement (RAP).
- To Study the properties of Cold Bitumen Stabilized Mix using Bitumen Emulsion.
- To suggest various conditions under which Cold Bitumen mix for recycling of flexible pavements be used for Indian Condition.

4. METHODOLOGY

The working methodology of the project involves collection of Recycled Asphalt Pavement (RAP) samples from the work site either by milling or core cutting. From the collected samples of RAP determine the various characteristic of RAP such as Bitumen content, Gradation of RAP aggregates by conducting test in the laboratory. Then from the gradation of RAP aggregates obtained in the lab establish whether virgin aggregate is needed to add in the mix. Next specific percent of slow setting emulsion is added with the mix as a recycling agent. The specimens are then prepared using Marshall method for different bitumen emulsion content and compacted using modified Marshall compaction method. Then the specimens are cured for 48 hours in dry air oven. Finally, Marshall specimens are tested in indirect tensile strength test apparatus to find the load at failure and the result value is compared with the other values. The mixture for Marshall Specimens are prepared at 0.5% increments of emulsion and three specimens are compacted at each emulsion content. Specimens are compacted with the Marshall hammer applying 50 blows per face and are cured in the mould for 6 hours at 60°C and at room temperature for about twelve hours. Specimens are tested for bulk specific gravity, maximum specific gravity, stability and flow at 60°C, so that the optimum emulsion content can be determined. Additional specimens are prepared at the optimum emulsion content and at other total water contents such as 2.0,2.5,3.0,3.5 and 4.0%.the recommended design parameters include air void contents between 9 and 14%.

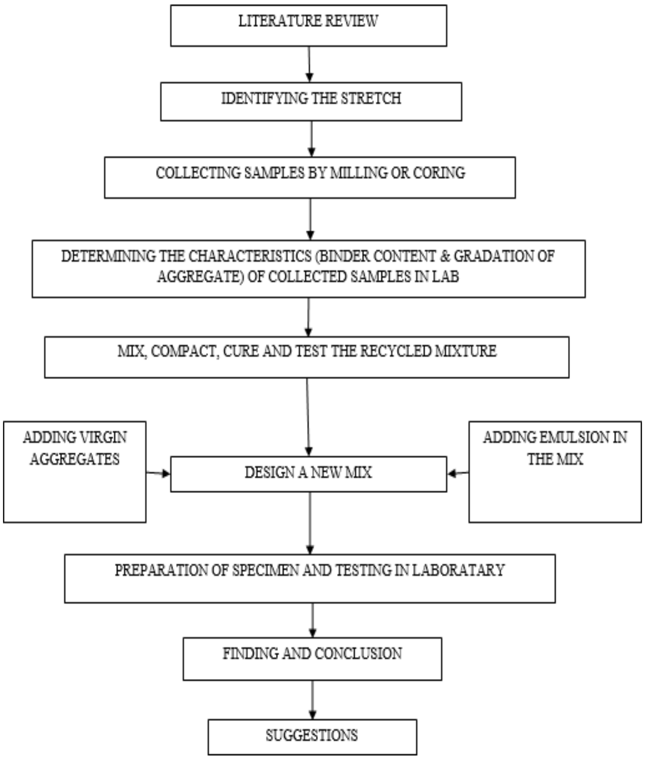

Fig -1:Methodology of the project

5. EXPERIMENTAL RESULTS

This section presents the experimental results obtained from laboratory testing of the recycled mix specimens. The tests conducted include gradation analysis, binder content determination, compaction characteristics, Marshall stability, flow value, density, air voids, and indirect tensile strength. The results are analyzed to evaluate the performance of the recycled mix with the addition of emulsion and virgin aggregates.

5.1 Tests on Aggregates

The aggregates were tested as per Marshall Requirements and gradation of aggregates results shows that the aggregate falls within the allowable limits as the IRC section 500 (MoRT&H) and it can be used for the sample preparation.

Table -1: Aggregate test result

Property	**Test**	**Specification(IS:2386)**	**Test results**
Cleanliness	Grain Size Analysis	< 2% passing 0.075 mm sieve	1%
Particle Shape	Flakiness Index	<12%	10%
	Elongation Index	< 18%	15%
Strength	Los Angeles Abrasion Value	< 25%	22%
	Aggregate Impact Value	< 18%	14.7%
Water Absorption	Water Absorption	< 2%	1.7%
Specific gravity	Specific gravity	-	2.85

5.2 Tests on Rap

The binder content in Recycled Asphalt Pavement materials using centrifuge extractor was found to be 2%.

Fig -2: Centrifugal Extraction

5.3 Gradation on Aggregates

Gradation of aggregates is one of the most important factors for design of mix. To achieve the specified grading, various constituent materials like 9.5 mm nominal size aggregate, crushed stone dust and cement were mixed together with RAP material to get the desired grading . The adopted gradations of mix in the present study is given in table 2.

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Table -2: Gradation for BC Mix

Sieve Size(mm)	Adopted	Limits
19	98	100
13.2	97	79 – 100
9.5	89	70 – 88
4.75	56	53 – 71
2.36	47	42 – 58
1.18	37	34 – 48
0.6	25	26 – 38
0.3	18	18 – 28
0.15	12	12 – 20
0.075	6	4 – 10

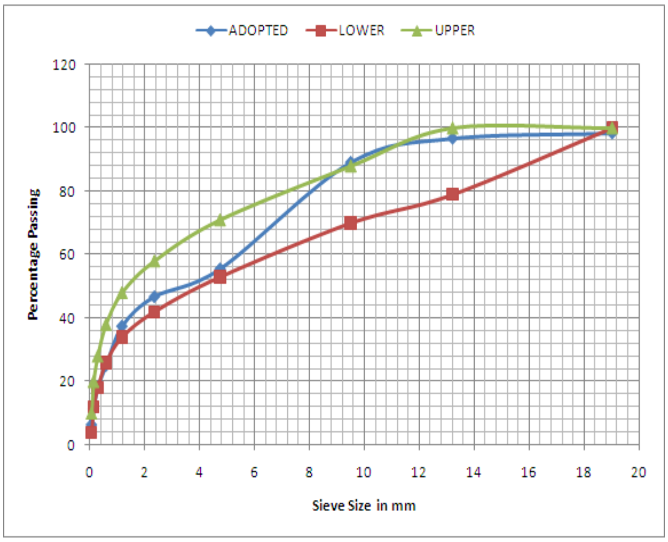

Fig -3: Gradation of Aggregate

5.4 Mix Design by Marshall Method

Cold Bituminous mixes were prepared by mixing the RAP, Virgin aggregates and Stone Dust with Slow Setting Emulsion (SS1) along with Cement. The RAP and Virgin Aggregates were Taken in the ratio of 40/20, 30/30 and 20/40 by weight of mix along with 35% of Stone dust and 5% of Cement by weight of mix. As per MoRT&H specification, the minimum binder content for the mix was 5.8% by weight of the mix, so the Cold Mix were prepared using the binder content 5%, 5.5% and 6.%) corresponding for each Ratio. The number of compactions was 75 blows for top and bottom side of the specimens as specified by IRC section 500 - MoRT&H. The sample were tested for bulk specific gravity G_{mb}, the maximum theoretical specific gravity G_{mm} as per AASHTO T9, the percent Air voids V_a, VMA, and VCA were calculated using following relationship:

Table 3: Bulk Specific Gravity of Compacted Mixture

Bitumen (%) (RAP:VA)		Wt. in Air	Wt. in Water	Volume	Density	Avg Density
5 (20:40)	1	1140	664	476	2.395	2.395
	2	1140	664	476	2.395	
	3	1140	664	476	2.395	
5.5 (20:40)	1	1134	662	472	2.403	2.403
	2	1134	662	472	2.403	
	3	1134	662	472	2.403	
6 (20:40)	1	1128	657	471	2.395	2.395
	2	1128	657	471	2.395	
	3	1128	657	471	2.395	
5 (30:30)	1	1147	669	478	2.400	2.400
	2	1147	669	478	2.400	
	3	1147	669	478	2.400	
5.5 (30:30)	1	1149	671	478	2.404	2.404
	2	1149	671	478	2.404	
	3	1149	671	478	2.404	
6 (30:30)	1	1148	670	478	2.402	2.402
	2	1148	670	478	2.402	
	3	1148	670	478	2.402	
5 (40:20)	1	1141	665	476	2.397	2.397
	2	1141	665	476	2.397	
	3	1141	665	476	2.397	
5.5 (40:20)	1	1146	669	477	2.403	2.403
	2	1146	669	477	2.403	
	3	1146	669	477	2.403	
6 (40:20)	1	1152	672	480	2.400	2.400
	2	1152	672	480	2.400	
	3	1152	672	480	2.400	

5.5 Volumetric Properties of BC Mix Using Rap

The volumetric properties of the samples were determined and the test results of the samples with various percentage of RAP and Virgin Aggregates were given in table below.

Table 4: Volumetric Properties of Cold mix at Various Binder Contents

RAP/VA	% Bitumen	Gmb	Gmm	Va,%	VMA	VFB
20/40	5	2.395	2.7	4.34	15.52	72.03
	5.5	2.403	2.7	3.34	15.68	78.7
	6	2.395	2.7	2.95	16.37	81.97
30/30	5	2.4	2.7	4.16	15.36	72.94
	5.5	2.404	2.7	3.29	15.64	78.95
	6	2.402	2.7	2.68	16.13	83.4
40/20	5	2.397	2.7	4.26	15.45	72.44
	5.5	2.403	2.7	3.34	15.68	78.69
	6	2.4	2.7	2.75	16.19	83.04

5.6 Relationship of Volumetric Properties of BC Mixtures

5.6.1 Bulk Density Vs Binder Content

The Bulk Specific Gravity (G_{sb}) is the ratio of the mass in air of a unit volume of a permeable at a stated temperature to the mass in air of equal density of an equal volume of gas-free distilled water at a stated temperature. The OBC is at the variation of the Bulk Density for the various ratio of RAP and virgin aggregates was shown in the Figure 4. For the ratio of 30/30 , the bulk density of the mix was higher than the other ratios of 20/40 and 40/20.

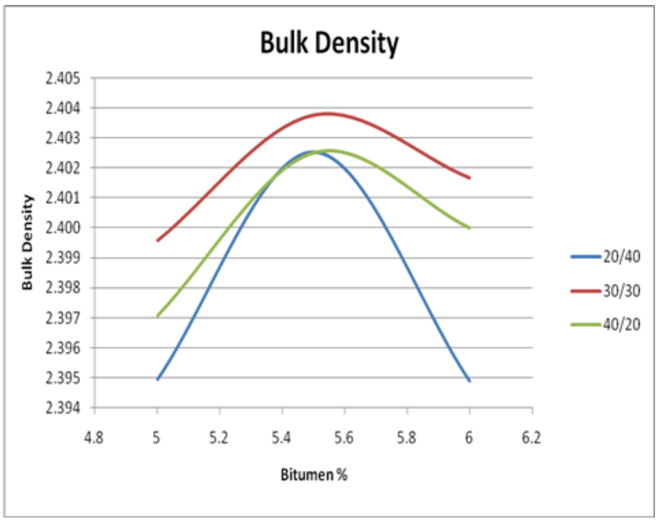

Fig -4: Relationship between Bulk Density and Binder Content for BC

5.6.2 Air Voids Vs Binder Content

The air voids, V_A, is the total volume of the small pockets of air between the coated aggregate particles throughout a compacted paving mixture. The variation of V_A for different ratios of RAP and virgin aggregates in standards compaction technique is shown in the Figure 5. The Air voids vary from 2.80 % to 4.40 % for the various ratios. As per specification requirement, 3.5 % Air Voids is given as the Mix Design parameters. The bitumen content corresponding to the 3.5% Air voids varies from 5.3% to 5.4% by the weight of the mix.

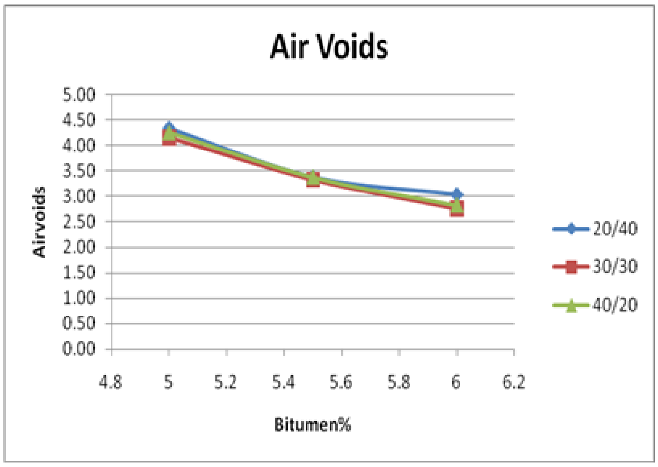

Fig -5: Relationship between Air Voids and Binder Content

5.6.3 Voids in Mineral Aggregates Vs Binder Content

Voids in Mineral Aggregaes can defined as the intergranular space occupied by the asphalt and air in a compacted asphalt mixture. An increase in the dust proportion will generally decrease the VMA. The variation of VMA with different ratios of RAP and virgin aggregates in the BC mixes were shown the Figure 6. The Air voids vary from 15.3 % to 16.3 % for the various ratios. As per specification requirement, a minimum of 15 % of Voids in Mineral Aggregates has to be present in the mix as the Mix Design parameters. The curve shows an increasing pattern for the increase in the percentage of the binder content but the curve pattern increases for 40 % virgin aggregates but 30/30 ratio shows neat curve.

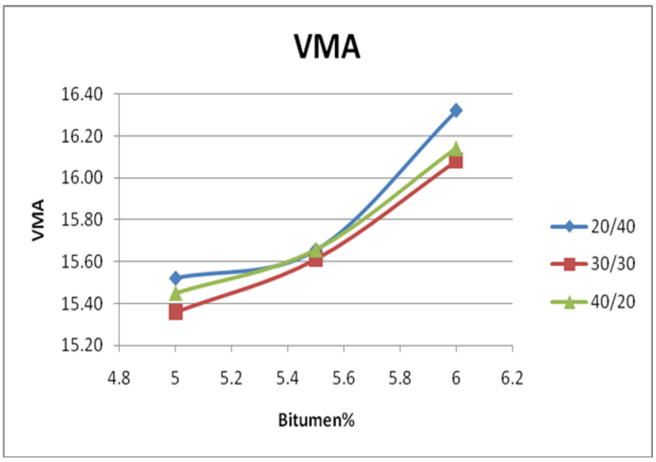

Fig -6: Relationship between VMA and Binder Content

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5.6.4 Voids Filled with Bitumen Vs Binder Content

The variation of Voids filled with bitumen for Mix with different ratios of RAP and virgin aggregates in the BC mixes were shown the Figure 5.5. The VFB vary from 72 % to 83 % for the various dosages of the fibres. As per specification requirement, Voids filled with bitumen should be 75%.The bitumen content for 75% was found to be 5.2%.

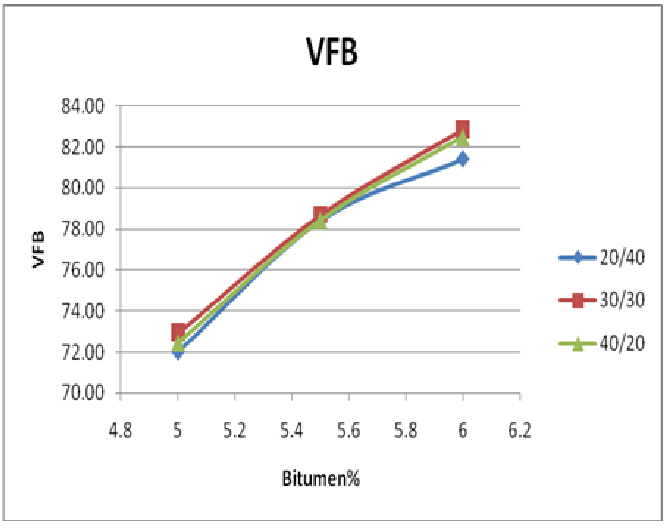

Fig -7: Relationship between VFB and Binder Content

5.6.5 Tensile Strength Ratio Vs Binder Content

The variation of Indirect Tensile Strength Ratio for Mix with different ratios of RAP and virgin aggregates in the BC mixes were shown the Figure . The TSR vary from 52% to 87% for the various ratios. As per specification requirement, Indirect Tensile Ratio for the Mix should be more than 75% of the Design parameters. The 30/30 ratio for 5.5% binder content show better result. This shows the presence of the resistance to cracking and moisture damage.

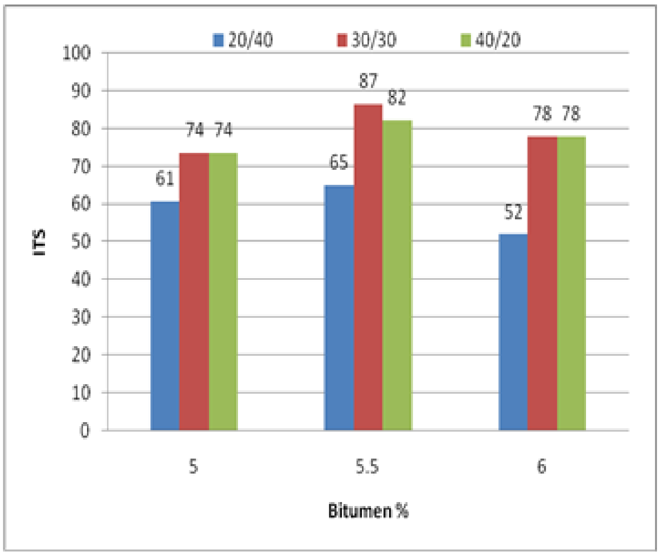

Fig -8: Relationship between TSR and Binder Content

5.6.6 Compression Strength Vs Binder Content

The variation of Compressive Strength for Mix with different ratios of RAP and virgin aggregates in the BC mixes were shown the Figure 8.

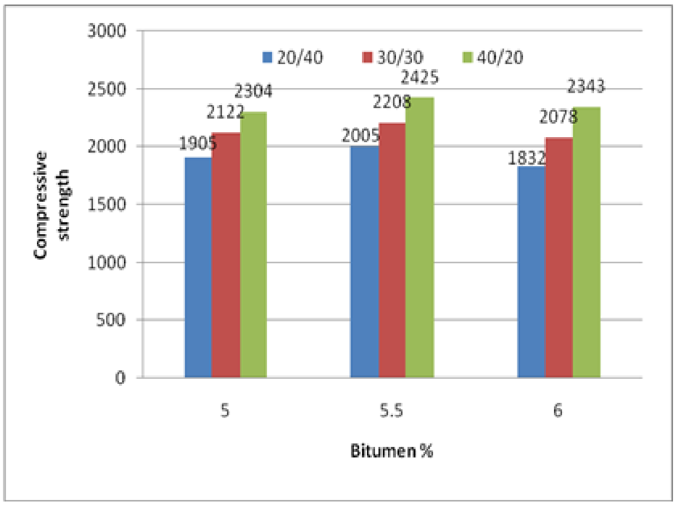

Fig -9: Relationship between Compressive Strength and Binder Content

5.8 Properties of BC Mixture at Optimum Binder Content

OBC for BC mix has been estimated at which the air voids (V_a), and minimum voids in mineral aggregates (VMA) are 3.5 and 15 percent respectively. Volumetric analyses of BC mixtures at various binder contents are presented in Table 5.

Table 5: Volumetric Properties of BC Mixtures at OBC

Properties	Value Obtained
RAP by Wt. of mix, percent	50%
Optimum Binder Content by Wt. of Agg, percent	5.8
Optimum Binder Content by Wt. of Mix, percent	5.6
Bulk Specific Gravity of Compacted Mixture, Gmb	2.4
Air Voids, percent	3
VMA, percent	15.7
TSR, percent	87

6. CONCLUSIONS

- Design of BC Mix done with the available Virgin aggregates in Chennai region and RAP collected from Chennai Corporation fulfilled the minimum design criteria of BC mix. 70 percent of 12.5 mm nominal size aggregate along with RAP Materials were taken in the ratio of 20/40, 30/30 and 40/20, 25 percent of stone dust, 5 percent of cement by weight of mix were mixed together to get the desired grading of BC. It can be seen from table 5 that the OBC was about 5.6 percent binder. To design a sustainable recycled pavement 50% of RAP Materials were combined with 50% of Virgin aggregates and mixed with Cationic Slow Setting Emulsion and their properties at OBC is given in table 5.

• The 17% Voids in Mineral aggregate and 3-5% air voids in the mix were fulfilled as BC mix design criteria.

• Based on the above performance, 30 -30 i.e., the RAP and Virgin Aggregates taken in the ratio of 30/30 by weight of mix shows better performance comparing the other mix proportions.

• The above results were taken for the samples which were cured for three days. However, the above results may vary if the curing period for the samples were increased.

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