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USE OF WASTE PLASTIC AND CRUMB RUBBER IN CONSTRUCTION OF FLEXIBLE PAVEMENT

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Abstract:Generation of plastic waste and rubber waste is increasing dayby day and the necessity to dispose of this waste in a proper way is arising. Nowadays pavements are subjected to various kinds of loading which affects the pavement performance condition that causes various distresses. Use of plastic and rubber in pavement design as an innovative technology not only strengthened the road construction but also increase the road life.

In this study, different tests were conducted on aggregates, bitumen, and bituminous mixes. The effect of the addition of waste plastic in the form of locally available PET bottles had been checked on aggregates as well as on bitumen. As per visual inspection, 4%, 6%, 8% and 10% plastic coating were made on aggregates and sample were checked for crushing, impact, water absorption and coating and stripping value.

Effect of addition of waste plastic and crumb rubber on bitumen had been studied by varying concentrations of CRP from 0% to 12.5% i.e., 0%, 5%, 7.5%, 10% and 12.5% in bitumen. Various tests such as penetration, ductility, softening point, flash and fire point were performed on the samples. The optimum percentage was taken from these tests which had shown satisfactory results for all the tests performed. Later, that optimum percentage value was used for preparing bituminous mixes for testing pavement properties such as Marshall Stability, Marshall Flow values.

As per the test results, in DBM and BC about 7.5% and 10% plastic waste with crumb rubber replacement in bitumen shows better results than conventional bitumen as well as 10% plastic coating to aggregates also improve the load-bearing capacity.

By using plastic waste in flexible pavement design, the problem of plastic and waste rubber disposal gets solved as well as the performance of roads gets improved.

Keywords— Pavement, Bitumen, Waste plastic, Crumb rubber, Plastic coated aggregate, CRP (Crumb rubber with bitumen).

I. INTRODUCTION

India has a road network of over *5,472,144* kilometers *(*3,400,233 mi) as on 31 March 2015, the second largest road network in the world. Road network is the mode of transportation which serves as the feeder system as it is the nearest to the people. So, the roads are to be maintained in good condition. The quality of roads depends on materials used for construction. Pavements are generally of two types: flexible and rigid pavement. A flexible pavement is the one which has a bitumen coating on top and rigid pavements which are stiffer than flexible ones have PCC or RCC on top.

In the construction of flexible pavements, bitumen plays the role of binding the aggregate together by coating over the aggregate. Today, for most of the advance countries, flexible pavements are one of the important types of road construction. In recent times, it is been observed that due to raise in axel cargo and traffic intensity the efficiency of the bituminous binder is been reduced causing bleeding in hot circumstance, cracks in low temperature, rutting and pot holes.

To minimize the damage of pavement surface and increase durability of flexible pavement, the conventional bitumen needs to be improved. There are so many modification processes and additives that are currently used in bitumen modifications such as styrene butadiene styrene (SBS), styrene-butadiene rubber (SBR), ethylene vinyl acetate (EVA) and crumb rubber

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modifier (CRM).

Disposal of a diverseness of plastic & pencil eraser wastes in an eco-friendly way is the substance area of today 's research. The waste plastic and the crumb rubber for the twist of flexible pavement material which would give a better solidity, resistance and strong, suit to the road as compared to the conventional rubber. As they are remarkably non-biodegradable thus can be used as a modifier in bitumen and aggregates to increase their strength.

1.1 Objectives of the study:

The present study visualizes the use of waste material i.e., waste tyres powder and plastic mixed with bitumen, which has potential use in highway and construction industry. The large-scale use of such materials will not only help in conserving the ecological balances, but will open up opportunities for the industries to produce a low cost material based on these waste, for mass scale applications. The study also encourages the use of these potentially hazardous wastes for mass scale without affecting the environment, cultivation, human and animal lives.

1. To determine the basic properties of aggregates, bitumen, plastic wastes used and Crumb rubber.
2. To select the optimum percentage of plastic waste (PET) and rubber (fine size) to be blended with commonly used bitumen to produce maximum compressive strength.
3. To study the Marshall properties of the Dense Bituminous Macadam and bitumen concrete mixes with PET bottles and crumb rubber so as to determine how they affect the properties of mixes and to compare it with each other and with the conventional mix.

II.EXPERIMENTAL INVESTIGATIONS

The research methodology for the present study has adopted various tests to investigate the results on aggregate, bitumen and waste plastic with crumb rubber substituted bitumen and aggregate-bitumen-modified mix. The waste plastic and crumb rubber are mixed in equal proportion.

2.1 Aggregates:

2.1.1 Coarse Aggregates:

The Coarse aggregates consisted of stone chips, up to 4.75 mm IS sieve size. Its specific gravity was found as 2.67.

2.1.2 Fine Aggregates:

The Fine aggregates, consisting of stone crusher dusts with fractions passing 4.75 mm and retained on 0.075 mm IS sieve. Its specific gravity was found to be 2.61.

The following tests were conducted on aggregates and their results had shown in the given below.

Property	**Method of Test**	**Specification**
Aggregate Impact Value (%)	IS: 2386 (Part-IV)	Max 24%
Aggregate Crushing Value (%)		Max 35%
Coating And Stripping of Bitumen Aggregate Mix	(IS:6241)	Minimum Retained Coating 95%
Water Absorption (%)	(IS:2386 Part III)	Max 2%

2.2 Crumb Rubber:

The Crumb rubber used in Bitumen Tests and preparing Marshall samples was of Fine size (IS Sieves 300 μm - 150 μm). The Specific gravity was found to be 1.15.

2.3 Plastic:

The PET bottles shredded in shredding machine were used. The Specific gravity was found to be 1.38.

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Test	Result (%)					Stand Value
	Pure aggregates	4% coat	6% coat	8% coat	10% coat	
Crushing (%)	20.31	18.82	16.94	16.71	15	30% Max
Impact (%)	12	11.2	10	8.54	7.8	30% Max
Water absorption (%)	1	0.5	0	0	0	Max 2%
Coating and stripping value of aggregates (%)	98	99	99	100	100	Minimum Retained Coating 95%

2.4 Binder:

The Bitumen used in preparing Marshall samples was of 80/100 penetration grade. The Specific gravity was 1.01 and their important properties had shown below.

Property	Method of Test	Test Result
Specific gravity	IS : 1202-1978	1.01
Penetration at 25°C (mm)	IS : 1203-1978	85
Softening Point (°C)	IS : 1205-1978	48
Ductility (cm)	IS : 1208-1978	80
Flash Point (°C)	IS : 1209-1978	248
Fire Point (°C)	IS : 1209-1978	291

The following tests had carried out for normal aggregates and coated aggregates and their results had shown in the given below table 1.

Table 1: Test Results for Aggregates

The test results for the modified bitumen had shown in the table given below.

S. No	Crumb and plastic (%)	Penetration (mm)	Softening Point (°C)	Ductility (cm)	Flash Point (°C)	Fire Point (°C)
1	0	86	47	83	245	290
2	5	81	49	65	254	297
3	7.5	79	55	54	267	305
4	10	67	60	49	278	328
5	12.5	63	63	40	288	347
	Stand. Values	60Min	40Min	50Min	220Min	290Min

Table 2: Test Results for Modified Bitumen

The amount of raw materials for DBM had shown in the table 3.

DBM/BC	CRP%	VA	VMA	VFB
DBM-5.0	0	5.275	16.3666	67.769
	5	4.1525	16.7667	75.2336
	7.5	3.346	17.42578	80.7985
	10	2.727	18.05365	84.895021
	12.5	2.6788	19.46404	86.237184
BC 5.5	0	4.896817	16.24080719	69.86649
	5	3.793693	15.08037044	74.86333
	7.5	3.020358	14.21351566	78.88036
	10	2.837953	13.87345386	79.56232
	12.5	2.738914	13.61238478	79.9287

Table 3: Amount of raw materials for DBM

The amount of raw materials for BM had shown in the table 4.

BC	Bitumen (%)	CRP (%)	Weight of bitumen (gm)	Weight of CRP (gm)	Weight of Aggregate (gm)	Weight of Cement (gm)
BC	5.0	0	60	0	1083	57
		5	57	3		
		7.5	55.5	4.5		
		10	54	6		
		12.5	52.5	7.5		
	5.5	0	66	0	1077.3	56.7
		5	62.7	3.3		
		7.5	61.05	4.95		
		10	59.4	6.6		
		12.5	57.75	8.25		
		0	72	0	1071.6	56.4
		5	68.4	3.6		
		7.5	66.6	5.4		
		10	64.8	7.2		
		12.5	63	9		

DBM	Bitumen (%)	CRP (%)	Weight of bitumen (gm)	Weight of CRP (gm)	Weight of Aggregate (gm)	Weight of Cement (gm)
DBM	4.5	0	54	0	1088.7	57.3
		5	51.3	2.7		
		7.5	49.95	4.05		
		10	48.6	5.4		
		12.5	47.25	6.75		
	5.0	0	60	0	1083	57
		5	57	3		
		7.5	55.5	4.5		
		10	54	6		
		12.5	52.5	7.5		
	5.5	0	66	0	1077.3	56.7
		5	62.7	3.3		
		7.5	61.05	4.95		
		10	59.4	6.6		
		12.5	57.75	8.25		

Table 4: Amount of raw materials for BM

2.5 Volumetric Parameters:

The volumetric parameters are to be checked from the Marshall samples, prior to Marshall test and their mean calculations of VMA, VA and VFB had shown in the giventable 5.

Table 5. Mean Calculation of VMA, VA, VFB

2.6 MARSHALL TESTING:

The Marshall test was done as procedure outlined in ASTM D6927 – 06.

Marshall Stability Value:

It is defined as the maximum load at which the specimen fails under the application of the vertical load. It is the maximum load supported by the test specimen at a loading rate of 50.8 mm/minute (2 inches/minute).

Marshall Flow Value:

It is defined as the deformation undergone by the specimen at the maximum load where the failure occurs. During the loading, an attached dial gauge measures the specimen's plastic flow as a result of the loading. The flow value was recorded in 0.25 mm (0.01 inch) increments at the same time when the maximum load was recorded and the given below table i.e., Table 6 Provides the marshall stability and flow values for both DBM and BM.

Table 6. Marshall stability and flow values

From the Above marshall stability values, Adopted DBM (5.0%) and BC(5.5%). For the further investigation CRP used DBM – 5% and BC – 5.5%.

BC (%)	CRP (%)	Sample	Stability (kg)	Flow (mm)
5.5	0	1	603	6.8
		2	610	6.6
		3	607	6.0
	5	1	759	5.7
		2	775	5.4
		3	772	5.2
	7.5	1	886	4.3
		2	895	4.2
		3	892	3.5
	10	1	989	3.6
		2	991	3.1
		3	990	3.0
	12.5	1	975	3.0
		2	982	2.8
		3	979	2.6

DBM/BC	Bitumen (%)	Mean Marshall Stability(kg)	Flow (mm)
DBM	4.5	651	6.1
	5.0	659	5.8
	5.5	654	5.4
BC	5.0	603	6.0
	5.5	610	5.5
	6.0	607	5.2

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The given below table shows the Marshall stability and flow values for DBM 5% for different percentages of CRP varying from 0%, 5%, 7.5%, 10% and 12.5%

Table 7 Marshall Stability and Flow Values For DBM

DBM(%)	CRP (%)	Sample	Stability(kg)	Flow (mm)
5.0	0	1	652	6.4
		2	659	6.2
		3	653	6.0
	5	1	789	5.8
		2	794	5.5
		3	792	5.3
	7.5	1	982	4.5
		2	989	4.4
		3	992	4.2
	10	1	952	3.8
		2	965	3.6
		3	959	3.3
	12.5	1	845	3.2
		2	862	3.0
		3	851	2.7

Table 8 Marshall Stability and Flow Values For BM

Table 8 shows the Marshall stability and flow values for DBM 5% for different percentages of CRP varying from 0%, 5%, 7.5%, 10% and 12.5%.

III.RESULTS AND DISCUSSIONS

3.1 Plotting Curves for Aggregate tests

Four curves were plotted, i.e:

- Aggregate Crushing Value (%) - [IS: 2386 (Part-IV)]
- Aggregate Impact Value (%) - IS: 2386 (Part-IV)
- Coating And Stripping of Bitumen Aggregate Mix - (IS:6241)
- Water Absorption (%) - (IS:2386 Part III)

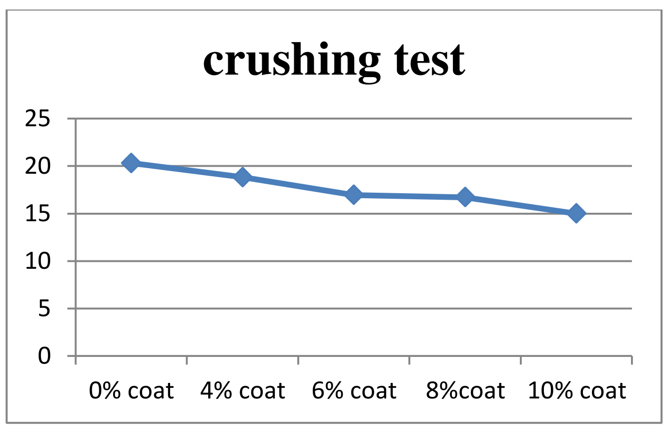

Figure 3.1 Crushing value of aggregates Vs % Plastic coated

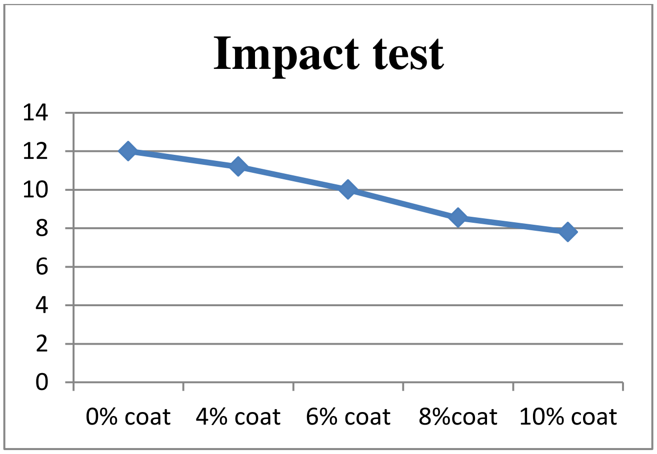

Figure 3.2Impact value of aggregates Vs % Plastic coated

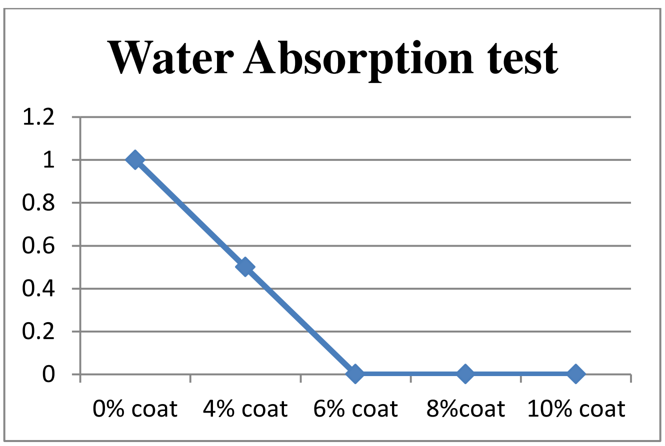

Figure 3.3Water absorption value of aggregates Vs % Plastic coated

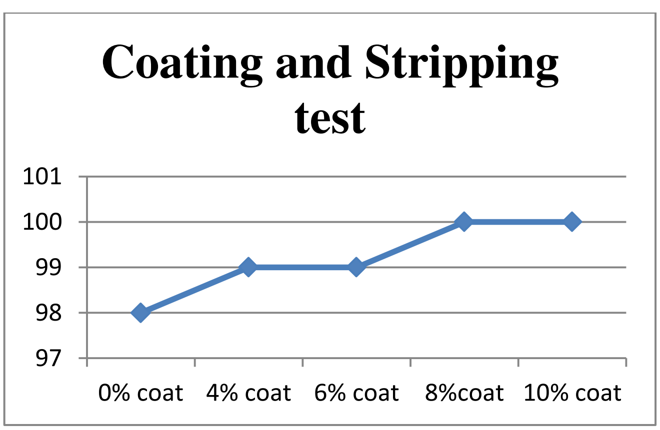

Figure 3.4Coating and stripping value of aggregates Vs % Plastic coated

3.2 Plotting Curves for bitumen tests

Five curveswere plotted, i.e.:

- Penetration Value vs. CRP Content
- Softening Point Value vs. CRP Content
- Ductility vs. bitumen CRP Content
- Flash Point vs. CRP Content
- Fire Point vs. CRP Content

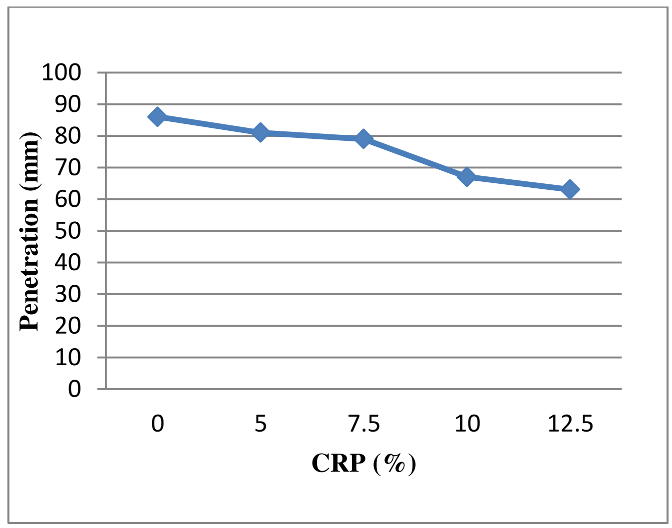

Figure 3.5Penetration Value vs. CRP Content

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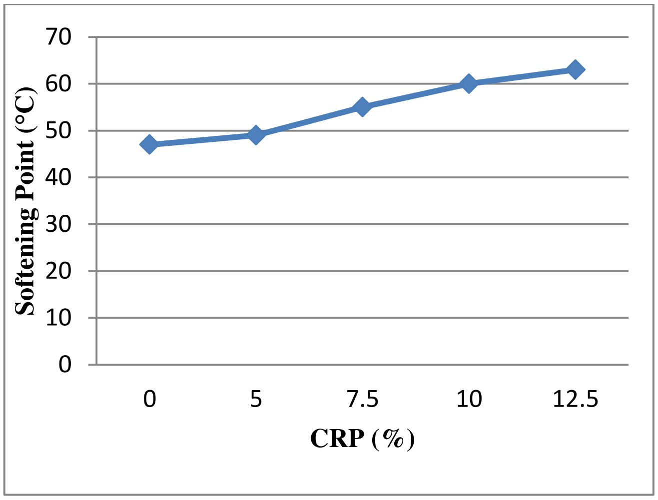

Figure 3.6Softening Point Value vs. CRP Content

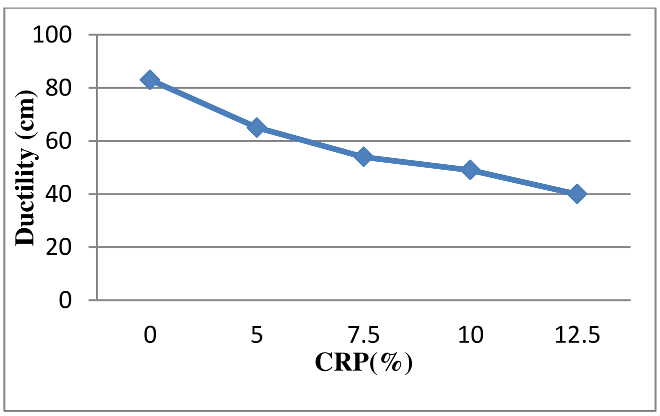

Figure 3.7Ductility vs. bitumen CRP Content

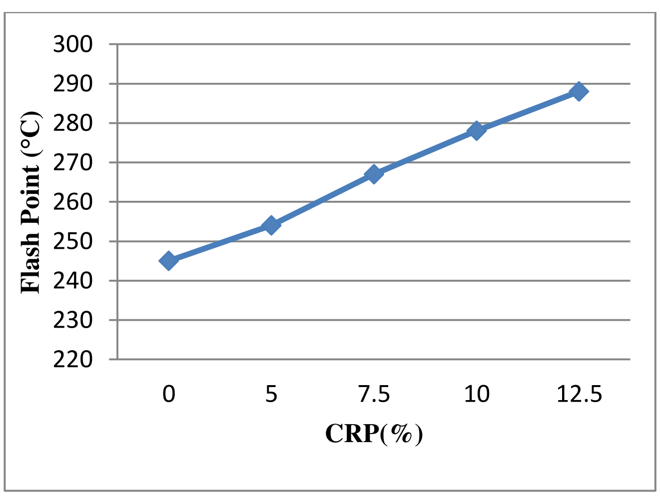

Figure 3.8 Flash Point vs. CRP Content

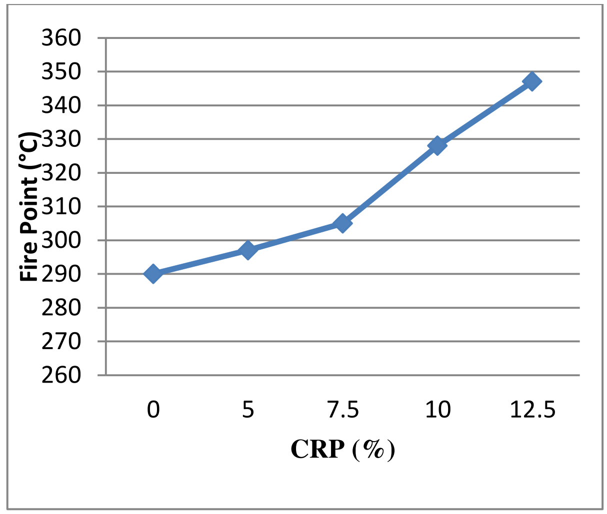

Figure 3.9Fire Point vs. CRP Content

3.3 Optimum Bitumen Content

Four curves were plotted, i.e.:

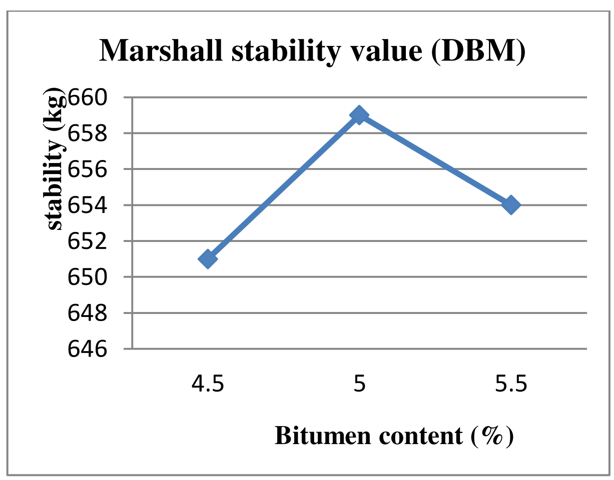

Figure 3.10 Marshall stability vs. Bitumen content

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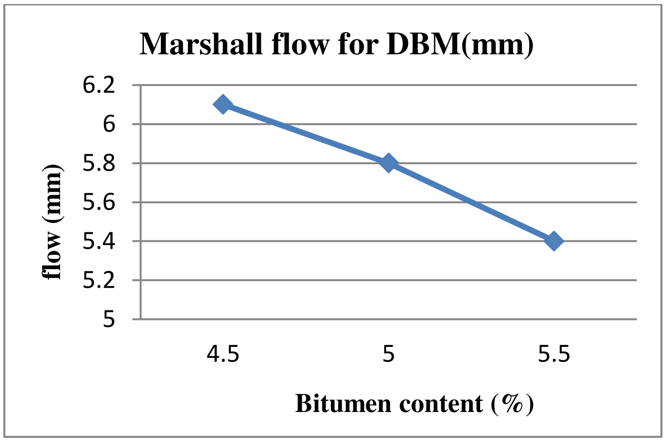

Figure 3.11 Marshall flow vs. Bitumen content

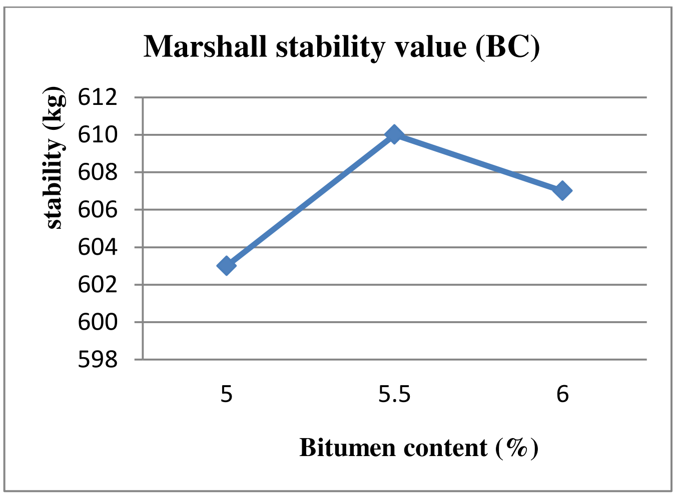

Figure 3.12 Marshall stability vs. Bitumen content

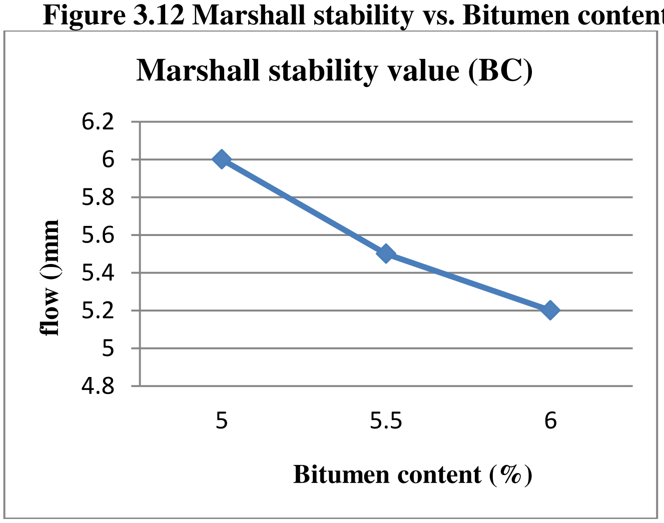

Figure 3.13 Marshall flow vs. Bitumen content

3.4 Plotting Curves for Marshall tests

Six curves were plotted. i.e:

- Marshall Stability Value vs. CRP Content
- Marshall Flow Value vs. CRP Content
- VMA vs. CRP Content
- VA vs. CRP Content
- VFB vs. CRP Content
- Bulk unit weight vs. CRP Content

For each % of CRP, 3 samplesof DBM and BC have been tested. So, the average value of the 3were taken.

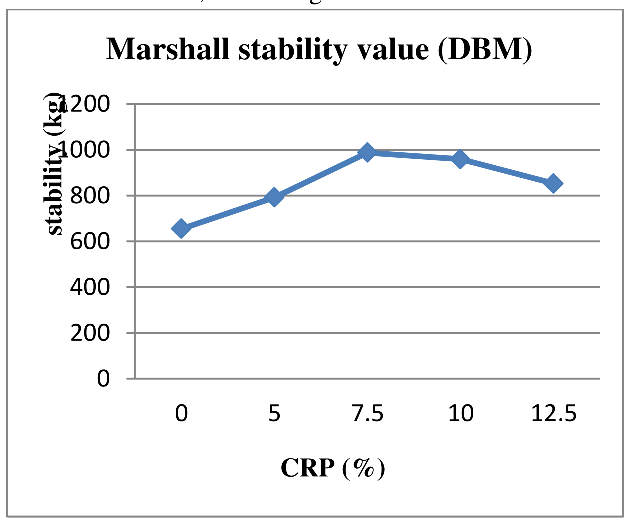

Figure 3.14Marshall Stability Value vs. CRP Content

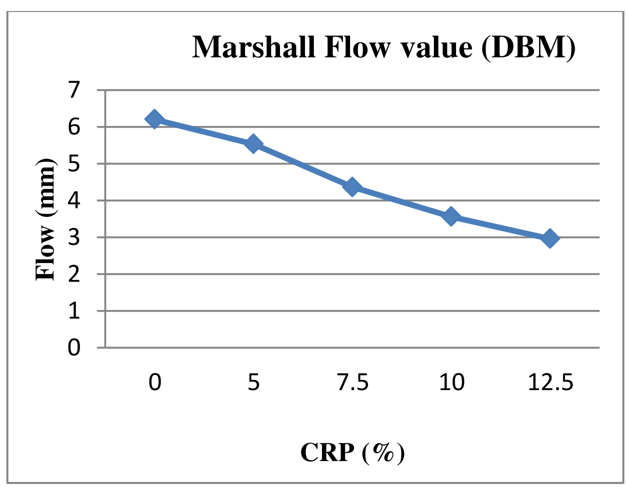

Figure 3.15 Marshall Flow Value vs. CRP Content

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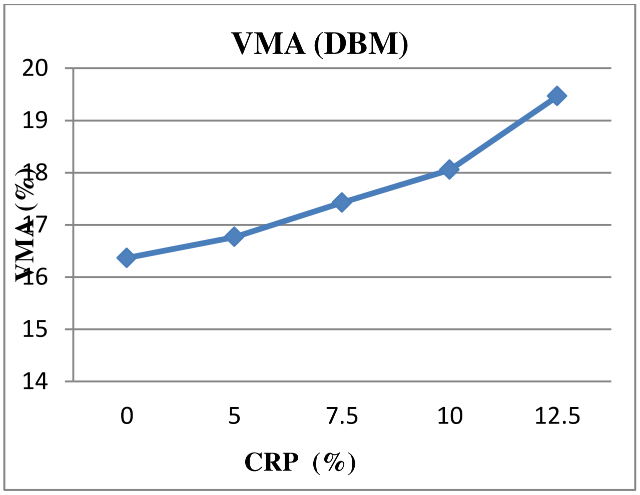

Figure 3.16 VMA vs. CRP Content

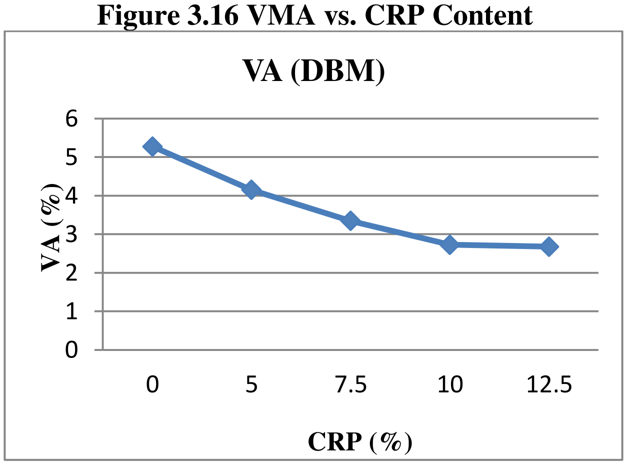

Figure 3.17 VA vs. CRP Content

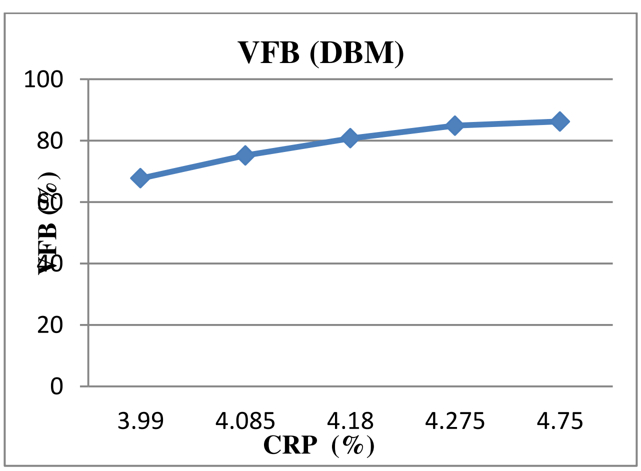

Figure 3.18 VFB Vs CRP Content

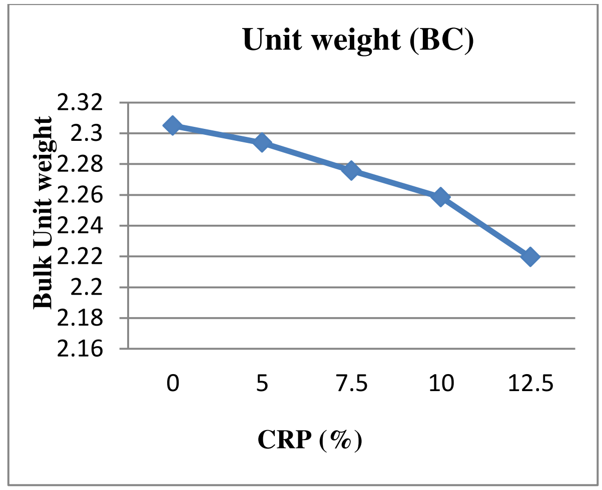

Figure 3.19 Bulk unit weight vs. CRP Content

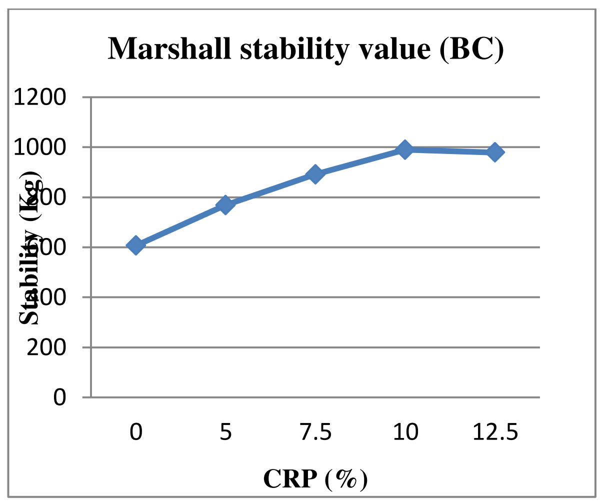

Figure 3.20Marshall Stability Value vs. CRP Content

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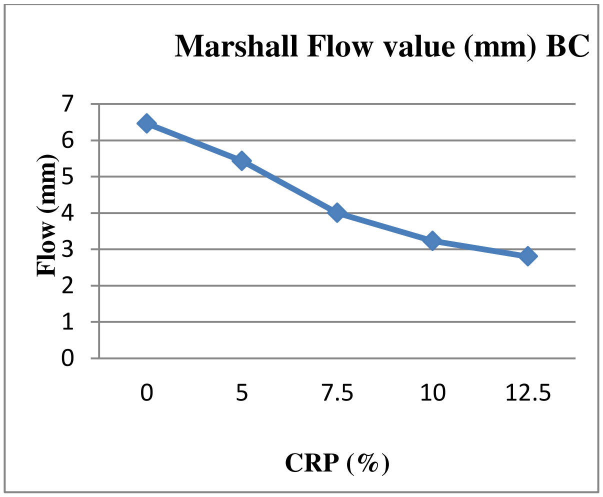

Figure 3.21 Marshall Flow Value vs. CRP Content

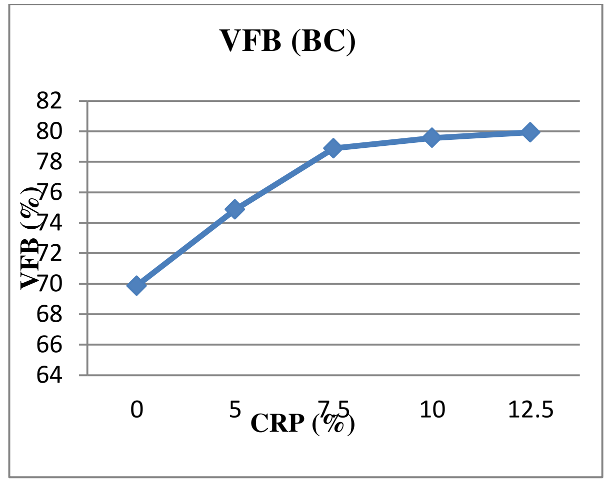

Figure 3.24 VFB vs. Bitumen Content

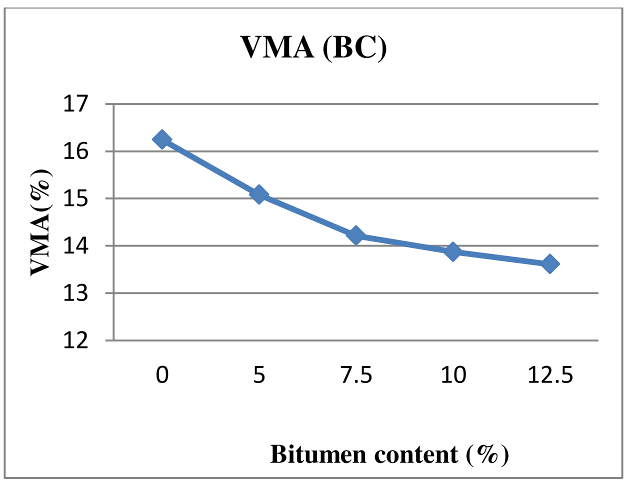

Figure 3.22 VMA vs. Bitumen Content

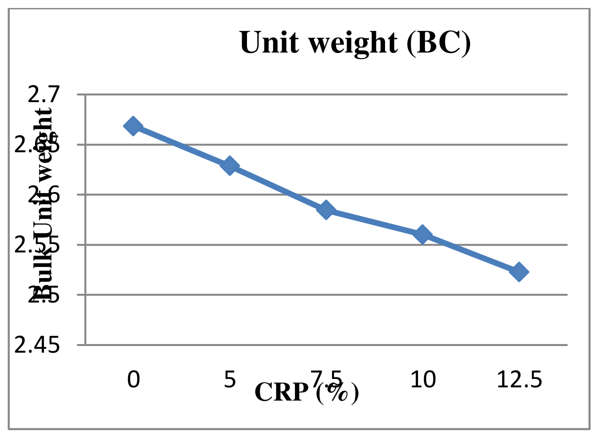

Figure 3.25 Bulk unit weight vs. CRP Content

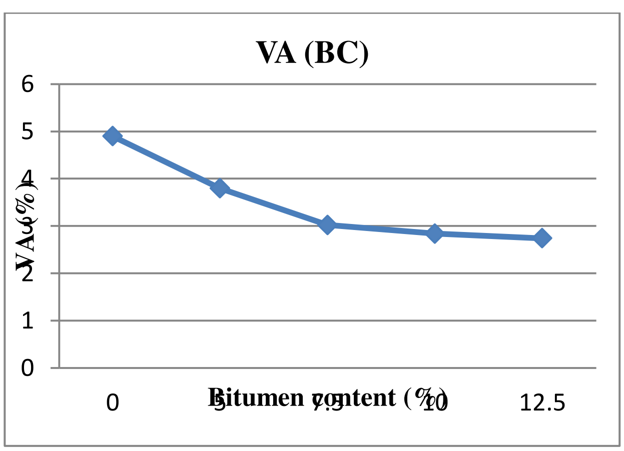

Figure 3.23 VA vs. Bitumen Content

3.5 ANALYSIS

3.5.1 Finding Optimum BitumenContent

The value of Bitumen content at which the sample has maximum Marshall Stability Value and minimum Marshall Flow Value is called as Optimum Bitumen Content.

For DBM: 4.5%, 5.0% and 5.5% of bitumen contents performed the marshall stability and flow tests. (From table 3.14 & Figures 4.10, 4.11) 5.0% gives optimum bitumen content value.

For BC:5.0%, 5.5% and 6.0% of bitumen contents performed the marshall stability and flow tests. (From table 3.14 & Figures 4.12, 4.13) 5.5% gives optimum bitumen content value.

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4.5.2 Finding Optimum CRPContent

For DBM: From the Figure 4.14&4.15 we get the Optimum CRP Content as 7.5% and also from Figures 4.16, 4.17&4.18 we conclude that upon addition of CRP the voids present in the mix decreases.

For BC: From the Figure 4.20&4.21 we get the Optimum CRP Content as 10% and also from Figures 4.22, 4.23&4.24 we conclude that upon addition of CRP the voids present in the mix decreases.

IV CONCLUSIONS

- By studying the test results of common laboratory tests on plain bitumen and CRP modified bitumen it is concluded that the penetration values, softening points flash point and the fire point of plain bitumen can be improved significantly by modifying it with in addition of crumb rubber and plastic which is a major environment pollutant. Use of crumb rubber and plastic leads to be excellent pavement life, driving comfort and low maintenance.
- 10% of plastic coating samples showed more strength than conventional bitumen.
- Overall, the rheological and mechanical test results were made it apparent that CRP modification exhibits superior performance with respect to bitumen and mixture properties. In addition, 10% of CRP content for BC and 7.5% of CRP content for DBM was determined to be the most suitable content, yielding much better test results than unmodified bitumen and the other mixtures. The use of crumb rubber and plastic will also prevent the accumulation of this waste material in the environment.
- From the table 4.1 it can be observed that the DBM sample prepared using 7.5% CRP give the highest stability value of 987.6666 kg, minimum flow value, maximum unit weight, maximum air voids and minimum VMA and VFB % values.
- From the table 4.2 it can be observed that the BC sample prepared using 10% CRP give the highest stability value of 990 kg, minimum flow value, maximum unit weight, maximum air voids and minimum VMA and VFB % values.
- Plastic with crumb rubber can be utilized as a partial blending material in design of flexible pavement.
- It can be used as a partial replacement in bitumen as well as coating over aggregate.

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