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

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Abstract : Generation of plastic waste and rubber waste is increasing day by 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 Paper, 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 was 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), Marshall Stability, Marshall Flow values, DBM(Dense bituminous macadam), PET bottles.*

1.INTRODUCTION

In the construction of flexible pavements, bitumen plays the role of binding the aggregate together by coating over the aggregate. It also helps to improve the strength of the road. But its resistance towards water is poor. Anti-stripping agents are being used. Bitumen is a sticky, black and highly viscous liquid or semi-solid which can be found in some natural deposits or obtained as by-product of fractional distillation of crude petroleum. It is the heaviest fraction of crude oil, the one with highest boiling point (525°C) .Various Grades of Bitumen used for pavement purpose:30/40, 60/70 and 80/100.

The desirable properties of bitumen for pavement are:

- Excellent binding property with aggregates, both cohesive and adhesive in nature.
- Repellant to water.

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- Thermoplastic in nature (stiff when cold, liquid when hot).

It has primarily flexible pavement design which constitutes more than 98% of total road network. Being a vast country, India has widely varying climates, terrains, construction materials and mixed traffic conditions both in terms of loads and volumes. Increased traffic factors are such as heavier loads, higher traffic volume and higher tyre pressure demand higher performance pavements. So 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 modifier (CRM).

A. Crumb Rubber

Crumb rubber is recycled rubber produced from automobiles and truck scraped tires. During the recycling process of this rubber crumb, steel and tire cord (fluff) are removed, and tire rubber are produced with a granular consistency. Crumb rubber usually consists of particles ranging in size from 4.75 mm (No. 4 sieve) to less than 0.075 mm (No. 200 sieve). Most processes that incorporate crumb rubber as an asphalt or bitumen modifier use particles ranging in size from 0.6 mm to 0.15 mm (No. 30 to No. 100 sieve).

Crumb rubber is manufactured from two primary feedstocks: tire buffing (shredded rubber), a byproduct of tire retreading and scrap tire rubber. On average, 10 to 12 pounds of crumb rubber can be derived from one passenger tire. Crumb rubber used in hot mix asphalt normally has 100 percent of the particles finer than 4.75 mm (No. 4 sieve). Although the majority of the particles used in the wet process are sized within the 1.2 mm (No. 16 sieve) to 0.42 mm (No. 40 sieve) range, some crumb rubber particles may be as fine as 0.075 mm (No. 200 sieve). The specific gravity of crumb rubber is approximately 1.15, and the product must be free of fabric, wire, or other contaminants.

B. Plastic

A plastic is a type of synthetic or man-made polymer; similar in many ways to natural resins found in trees and other plants. India's consumption of Plastics will grow 15 million tonnes by 2015 and is set to be the third largest consumer of plastics in the world. Various activities like packing consume almost 50-60% of the total plastics manufactured .Plastic offer advantages lightness, resilience, resistance to corrosion, colour, fastness, transparency, ease of processing etc.The plastic constitutes two major category of plastics based on physical properties; (i) Thermoplastics and (ii) Thermo set plastics. The thermoplastics, constitutes 80% and thermo set constitutes approximately 20% of total postconsumer plastics waste generated .In a thermoplastic material the very long chain – like molecules are held together by relatively weak Van der Waals forces. In thermosetting types of plastics the molecular are held together by strong chemical bonds making it quite rigid materials and their mechanical properties are not heat sensitive.

Thermoplastic	**Thermosetting**
Polyethylene Terephthalate (PET)	Bakelite
Polypropylene (PP)	Epoxy
Polyvinyl Acetate (PVA)	Melamine
Polyvinyl Chloride (PVC)	Polyester
Polystyrene (PS)	Polyurethane

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Low Density Polyethylene (LDPE)	Urea – Formaldehyde
High Density Polyethylene (HDPE)	Alkyd

Table. 1 Types of plastic

PET	Drinking water bottles etc.,
PP	Bottle caps and closures, wrappers of detergent, biscuit, vapors packets, microwave trays for readymade meal etc.,
PVC	Mineral water bottles, credit cards, toys, pipes and gutters; electrical fittings, furniture, folders and pens, medical disposables; etc
PS	Yoghurt pots, clear egg packs, bottle caps. Foamed Polystyrene: food trays, egg boxes, disposable cups, protective packaging etc
LDPE	Carry bags, sacks, milk pouches, bin lining, cosmetic and detergent bottles
HDPE	Carry bags, bottle caps, house hold articles etc.

Table.2 Waste plastic and its sources

Plastics may be classified also according to their chemical sources. The twenty or more known basic types fall into four general groups: Cellulose Plastics, Synthetic Resin Plastics, Protein Plastics, Natural Resins, Elastomers and Fibers.

2. OBJECTIVE

a. To determine the basic properties of aggregates, bitumen, plastic wastes used and Crumb rubber.
b. 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.
c. 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.

3. MATERIALS USED

The grades of aggregates and their quantities to be used for preparing Marshall samples were graded as per Ministry of Road Transport and Highways (2001) given in Table.3 and Table.4 respectively.

The DBM mix, which use relatively larger size aggregate, are not only stiff or stable but also are economical because they use relatively lower bitumen contents and need less breaking and crushing energy or effort.

BC mix with smaller aggregate in the other way having relatively higher bitumen contents, which not only impart high flexibility but also increase their durability.

A. 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. Standard tests were conducted to determine their physical properties as summarized in Table.5

B. 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.

C. Filler

The Aggregate passing through 0.075 mm IS sieve is called as filler. Here Portland cement (Grade 43) was used as filler material. Its specific gravity was found to be 3.1.

IS Sieve	Percent Passing

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(mm)	Specification Grading	Grading adopted
37.5	100	-
26.5	90-100	-
19.0	71-95	85
13.2	56-80	66
4.75	38-54	40
2.36	28-42	33
0.300	7-21	12
0.075	2-8	2
Binder Content % by weight	Min. 4.5	4.5 to 5.5

Table.3 MORTH gradation for DBM (NMAS 25mm)

IS Sieve (mm)	Percent Passing	
	Specification Grading	Grading adopted
19	100	100
13.2	90-100	95
9.5	70-88	75
4.75	53-71	60
2.36	42-58	50
1.18	34-48	40
0.600	26-38	32
0.300	18-28	20
0.150	12-20	15
0.075	4-10	5
Binder Content % by weight	5-7	5.0 to 6.0

Table.4 MORTH gradation for BC (NMAS 13 mm)

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

Table.5 Tests on aggregates

D. Crumb rubber

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

E. Plastic

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

F. Binder

The Bitumen used in preparing Marshall samples was of 80/100 penetration grade. The Specific gravity was 1.01. It's important properties is given in table.6.

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

Table.6 Properties of Binder

Test	Result (%)					Stand. Value
	Pure aggregates	4 % co	6 % co	8 % co	10 %	

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		at	at	at	co at	
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%

Table.7 Tests results of aggregates

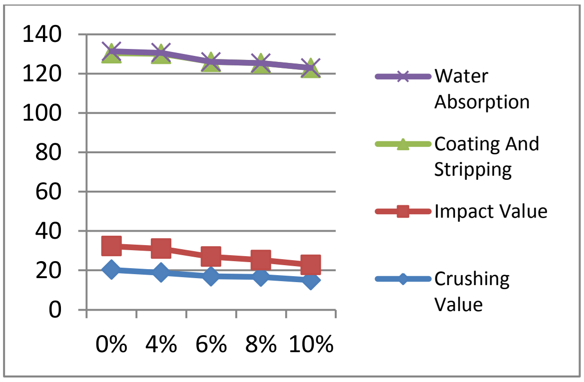

Figure.1 Aggregate tests Vs %coated plastic

4. TESTS ON MODIFIED BITUMEN

The addition of crumb rubber (50%) and plastic (50%) to the bitumen with varying percentages i.e: 0%, 5%, 7.5%, 10%, 12.5%. After addition of crumb rubber and plastic to bitumen, to prepare the samples for required test. CRP is crumb rubber and bitumen (50%plastic and 50% crumb rubber powder). The bitumen test results as follows in table.8.

S. No	CRP (%)	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	220 Min	290 Min

Table.8 Test results of Modified Bitumen

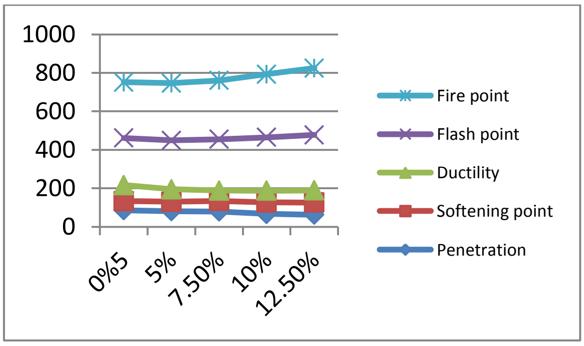

Figure.2 Tests on modified bitumen

5. MARSHALL STABILITY

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A. Mixing Procedure

The mixing of ingredients was done as per the following procedure (STP 204-8).

Required quantities of coarse aggregate, fine aggregate & mineral fillers were taken in an iron pan. This was kept in an oven at temperature 160^{0}c for 10min. This is because the aggregate and bitumen are to be mixed in heated state so preheating is required. The bitumen was also heated up to its melting point prior to the mixing.

1)The required amount of CRP was weighed and kept in a separate containers. 2)The aggregates in the pan were heated on a controlled gas stove for a few minutes maintaining the above temperature. 3)The CRP was added to the bitumen and it was mixed for 5 minutes. 4)For DBM: Now bitumen (54, 60, 66 gms), i.e. 4.5%, 5.0%, 5.5% was added to this mix and the whole mix was stirred uniformly and homogenously. This was continued for 15-20 minutes till they were properly mixed which was evident from the uniform colour throughoutthe mix. 5)For BC: Now bitumen (60, 66, 72 gms), i.e. 5.0%, 5.5%, 6.0% was added to this mix and the whole mix was stirred uniformly and homogenously. This was continued for 15-20 minutes till they were properly mixed which was evident from the uniform colour throughout the mix. 6)Then the mix was transferred to a casting mould. 7)This mix was then compacted by the Marshall Hammer. 8)75 no. Of blows were given per each side of the sample so subtotal of 150 no. of blows was given per sample. 9)Then these sample moulds were kept separately and marked.

Figure.3 Uniform colour throughout the mix

Figure.3 Closer view of Marshall sample

6. MARSHALL TESTING AND RESULTS

In this method, the resistance to plastic deformation of a compacted cylindrical specimen of bituminous mixture is measured when the specimen is loaded diametrically at a deformation rate of 50 mm/min. The Marshall stability of the mix is defined as the maximum load carried by the specimen at a standard test temperature of 60°C. The flow value is the deformation that the test specimen undergoes during loading up to the maximum load. In India, it is a very popular method of characterization of bituminous mixes due to its simplicity and low cost. In the present study the Marshall properties such as stability, flow value, unit weight and air voids were studied to obtain the optimum binder contents (OBC) and then compare

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mixes to check addition of which of the additive mentioned gives more stability.

Figure.4 Marshall stability test setup

In the Marshall method of mix design, each compacted test specimen is subjected to the following tests and analysis.
a. Bulk specific gravity (Gb) determination
b. Stability and Flow test
c. Density and Void analysis

A. Bulk specific gravity (Gmb) determination

Bulk specific gravities of saturated surface dry specimens are determined.

B.Stability and flow tests

After determining the bulk specific gravity of the test specimens, the stability and flow tests are performed. Immerse specimen in water bath kept at 60˚C ±1˚C for 30 to 40 minutes before testing. When the testing apparatus is ready, remove the specimen from water bath and carefully dry the surface. Place it centrally on the lower testing head and fit upper head carefully. Fix the flow meter with zero as initial reading. The load is applied at a constant rate of deformation of 51 mm (2 inches) per minute. The total load at failure is recorded as its Marshall Stability Value. The reading of flow meter in units of 0.25 mm gives the Marshall Flow value of the specimen. The entire testing process starting with the removal of specimen from bath up to measurement of flow and stability shall not take more 30 seconds. While the stability test is in progress, hold the flow meter firmly over the guide road and record.

C.Density and voids analysis

After completion of the stability and flow test, a density and voids analysis is done for each set of specimens. The Values are given in Table.10 & 11. Average the bulk density determinations, for each asphalt content. Values obviously in error need not be considered. This average value of Gb is used for further computations in void analysis.
(a) Determine the theoretical maximum specific gravity (Gmm) by equipment
(b)The BSG’s(Gsb) of the individual coarse aggregate fractions, the fine aggregate and mineral filler fractions are used.
(c) Vv, VMA and VFB are then computed using the standard equations

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

Table.9 Marshall stability and flow values for control mix

CRP (%)	Gmb	VA (%)	VMA (%)	VFB (%)
0	2.304925	5.275	16.3666	67.769
5	2.293893	4.1525	16.7667	75.2336

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7.5	2.275731	3.346	17.42578	80.7985
10	2.258427	2.727	18.05365	84.895021
12.5	2.219557	2.6788	19.46404	86.237184

Table.10 Density and void analysis for DBM control mix

CRP (%)	Gmb	VA (%)	VMA (%)	VFB (%)
0	2.668241	4.896817	16.24080719	69.86649
5	2.628602	3.793693	15.08037044	74.86333
7.5	2.584494	3.020358	14.21351566	78.88036
10	2.56012	2.837953	13.87345386	79.56232
12.5	2.52277	2.738914	13.61238478	79.9287

Table.11 Density and void analysis for BC control mix

CRP (%)	Mean Stability (Kg)	Mean Flow (mm)
0	654.6666	6.2
5	791.6666	5.53
7.5	987.6666	4.36
10	958.6666	3.56
12.5	852.6666	2.96

Table.12 Marshall stability and flow values for CRP DBM mix

CRP (%)	Mean Stability (Kg)	Mean Flow (mm)
0	606.6666	6.46
5	768.6666	5.43
7.5	891	4
10	990	3.23
12.5	978.6666	2.8

Table.13 Marshall stability and flow values for CRP BC mix

7. MARSHALL GRAPHS

A. DBM(Dense bituminous macadam)

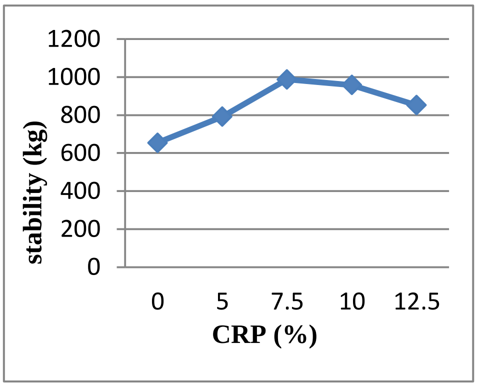

Figure.5 Marshall stability curve

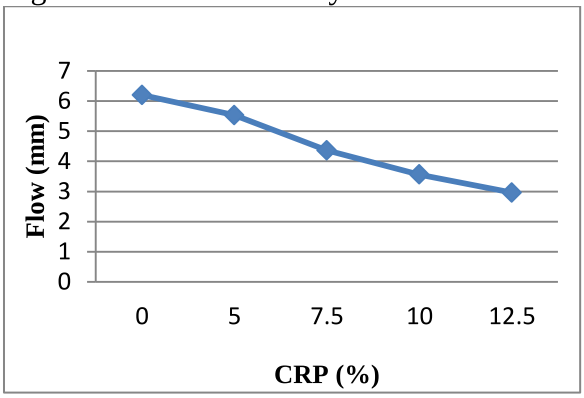

Figure.6 Marshall Flow curve

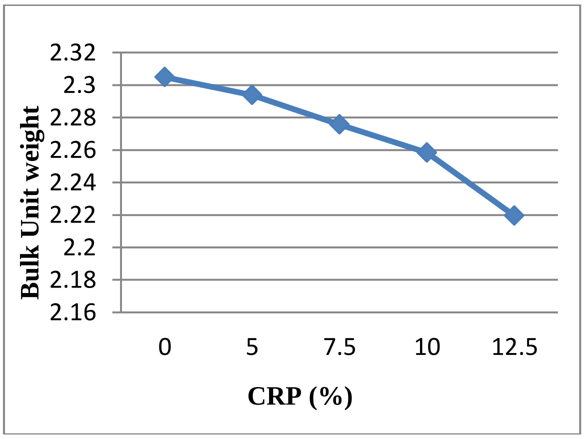

Figure.7 Bulk unit weight vs. CRP Content

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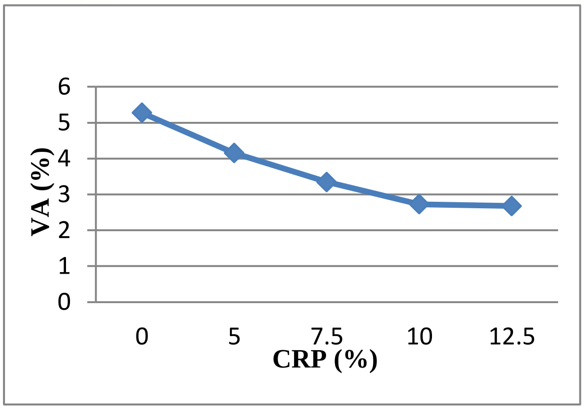

Figure.8 VA vs. CRP Content

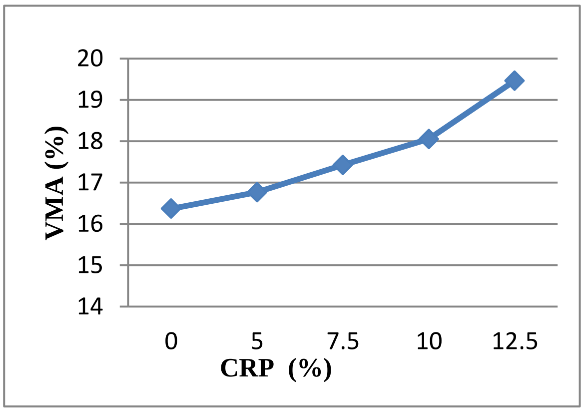

Figure.9 VMA vs. CRP Content

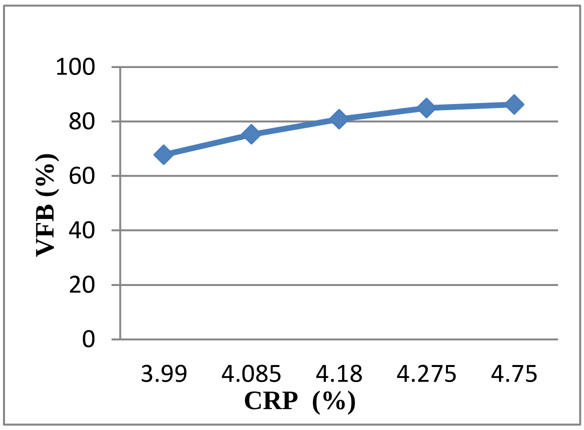

Figure.10 VFB Vs CRP Content

B. BC(Bituminous concrete)

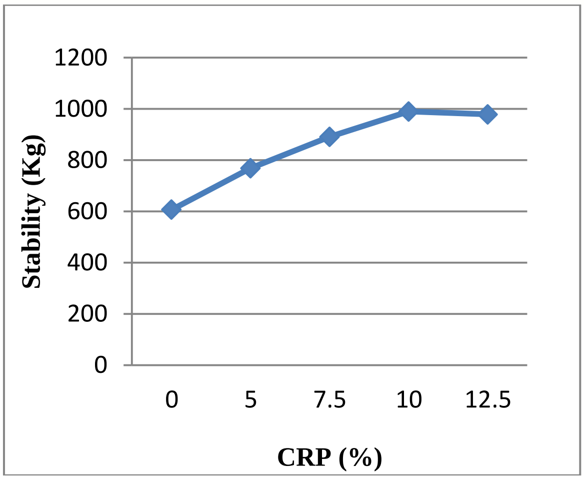

Figure.11 Marshall stability curve

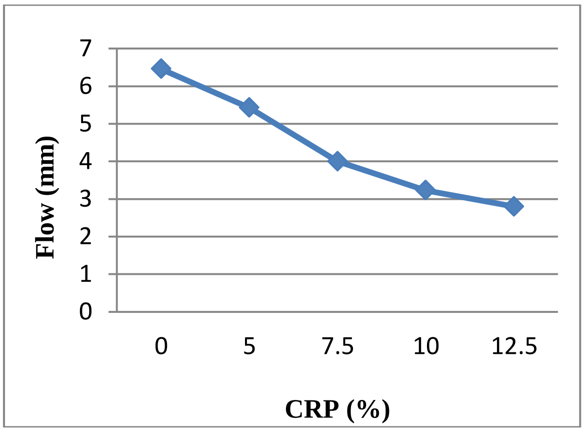

Figure.12 Marshall Flow curve

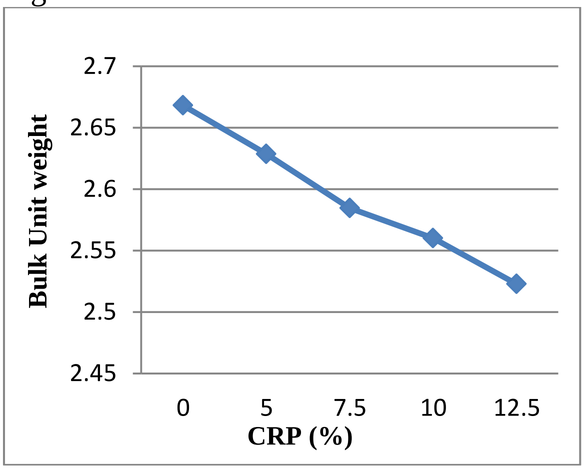

Figure.13 Bulk unit weight vs. CRP Content

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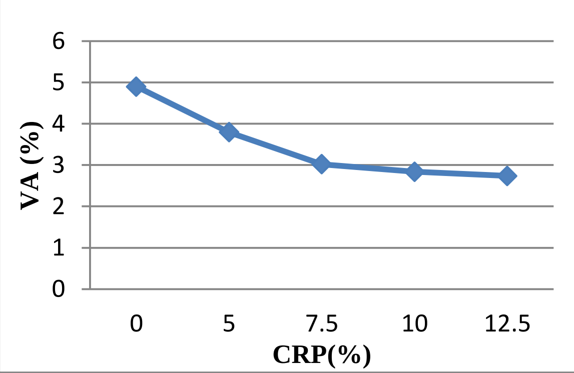

Figure.14 VA vs. CRP Content

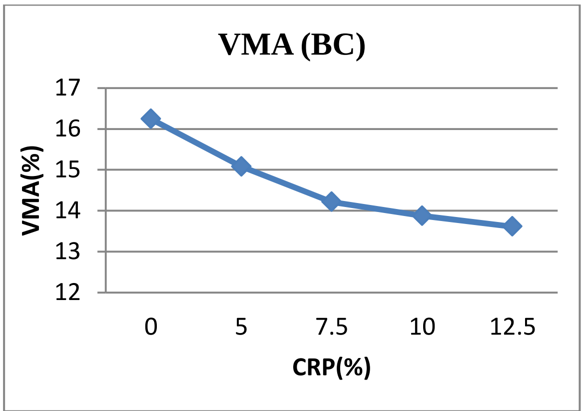

Figure.15 VMA vs. CRP Content

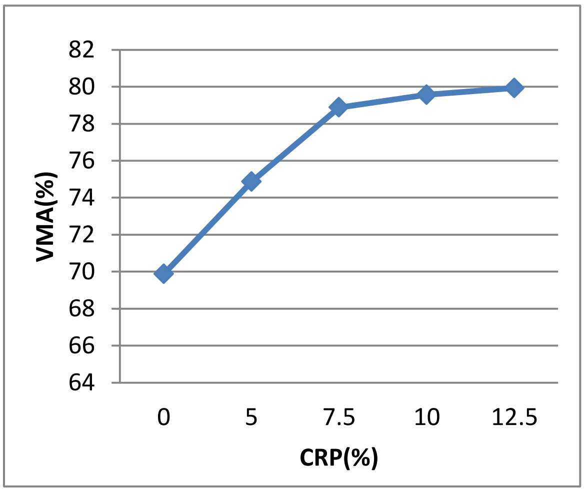

Figure.16 VFB Vs CRP Content

8. ANALYSIS

A. Finding Optimum Bitumen Content

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. 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. 5.5% gives optimum bitumen content value.

B. Finding Optimum CRP Content

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.

9. CONCLUSION

a) 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.

b) 10% of plastic coating samples showed more strength than conventional bitumen.

c) Overall, the rheological and mechanical test results were made it

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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.

d) From the table 4.1 it can be observed that the DBM sample prepared using 7.5% CRP
e) give the highest stability value of 987.6666 kg, minimum flow value, maximum unit weight, maximum air voids and minimum VMA and VFB % values.
f) 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.
g) Plastic with crumb rubber can be utilized as a partial blending material in design of flexible pavement.
h) It can be used as a partial replacement in bitumen as well as coating over aggregate.

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