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Experimental Investigation on the Performance of Recycled Polyethylene and Crumb Rubber Modified Bitumen

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Abstract—In the present study, an attempt has been made to examine the properties of bitumen modified with polyethylene and crumb rubber. The low density polyethylene in the form of used carry bags and pulverized crumb rubber (CR) obtained from scrapped tires of automobile are used as a modifier. The grade of bitumen taken is 80/100. Various standard tests like penetration, softening point, ductility and specific gravity were conducted on bitumen with and without polyethylene and crumb rubber blend. The results of penetration, softening and ductility values show that the stiffness of the blinder increases with addition of increasing quantity of polymer. Elastic recovery test and storage stability test are also conducted on modified binder. The results confirm that the modified blinder have stability during prolonged storage at high temperature. Marshall Stability tests are performed on samples using 1, 2, 2.5, 3 &4% of polyethylene and 0, 5, 7.5,10, 12.5% of crumb rubber. Marshall Stabilities as high as 10.52KN are obtained as a result of modification (20% increase when compared with that of ordinary bitumen). Considering the properties of modified binder and mixes containing such as binder, the optimum quantity of additive (LDPE & CR) is 13% by weight of the binder. A significant quantity of bitumen can be saved by replacing with recycled wastes. This is achieved by blending 3% of PE and 10% of CR with the bitumen used in construction of flexible pavements.

Key Words—Recycled Plastic Roads, Modified Bitumen, Flexible Pavements, etc

I. INTRODUCTION

1.1. GENERAL

Bitumen is used as a binder in pavement construction. Bitumen may be derived from the residue left by the refinery from naturally occurring asphalt. As per definition given by the American Society of Testing Materials bitumen has been defined as "Mixtures of hydrocarbons of natural or pyrogenous origin, or combination of both, frequently accompanied by their non-metallic derivatives, which may be gaseous, liquid, semi-solid or solid, and which are completely soluble in carbon disulphide."

Bitumen found in natural state known as asphalt contains large quantities of solid mineral matter. When petroleum crude is refined in a refinery, they are separated by fractional distillation in the order of decreasing volatility. On distillation of the residual bituminous residue, straight-run bitumen is obtained. This bitumen is known as penetration grade bitumen or steam refined petroleum bitumen.

The grades of bitumen used for pavement construction is known as paving grades and that used for water proofing of structures is known as industrial grades. The grade of straight run bitumen is chosen depending upon the climatic conditions of the region in which surface dressing is to be constructed.

In most parts of India 60/70 and 80/100 grades bitumen is used. Heavier grade cut backs, rapid setting emulsions or heavier grade tars may also be used. The grade of basic bitumen is altered either by controlled refining or by mixing with diesel oil or other oils. For single dressings on WBM base course, quantity of bitumen needed ranges from 17 to 195 kg per 10

m^2 areas and 10 to 12 kg per 10 m^2 area in case of renewal of black top surfacing. For second coat of surface dressing, the quantity of bitumen needed ranges from 10 to 12 kg per 10 m^2 area. Bulk bitumen Lorries with tanks of capacity ranging from 5000 to 15000 liters are used to transport bulk bitumen.

1.2. TYPES AND PROPERTIES

The paving bitumen available in India is classified into two categories:

- Paving bitumen from Assam petroleum denoted as A-type and designated as grades A35, A90, etc.
- Paving bitumen from other sources denoted as S-type and designated as grades S35, S90, etc.
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Important properties of bitumen are

- Viscosity of bitumen should be adequate at the time of mixing and compaction.
- It is achieved by heating prior to mixing and by use of cutbacks and emulsion.
- In presence of water bitumen should not strip off from aggregate.
- Bitumen should be durable in all seasons. It should not become too soft during summers and develop cracks during winters.

1.2. OBJECTIVES OF THE STUDY

- To propose an effective method of disposal of waste plastic bottles (PET) by using them in flexible pavements.
- To conduct a series of laboratory tests conventional and modified bitumen binders and to study the suitability of the same for use in flexible pavement.
- To improve the quality of flexible pavement construction by combining the bituminous binder with identified recycled materials.

II. EXPERIMENTAL INVESTIGATIONS

2.1 MATERIALS USE FOR THE STUDY

2.1.1. Aggregate

There are two types of aggregate using our study, one is fine and other is coarse aggregate. Coarse aggregate fraction retained on IS sieving 4.75mm and fine aggregate fraction retained IS sieve 1.18 mm.

2.1.2. Bitumen

Bitumen of penetration grade 80/100 was used.

2.1.3. Polymers

Crum Rubber (CR)

Pulverized crumb rubber obtained from discarded truck and bus tyres passing through IS Sieve 1mm and retained by 150 micron was used.

Polyethylene (PE)

Recycled low density polyethylene (LDPE) in the form of waste plastic carry bags shredded to 3×3 mm size was used.

2.2. STANDARD TESTS CONDUCTED ON BINDER

The tests have been carried out on the modified bituminous mixes containing 1, 2, 2.5, 3 & 4% of Polyethylene and 0, 5, 7.5, 10 &12.5% of Crum rubber.

2.2.1. Penetration Test (IS 1203-1978)

The penetration test determines the hardness or softness of bitumen by measuring the depth in tenths of an mm to which a standard loaded needle will penetrate vertically in 5 seconds.

2.2.2. Ductility Test (IS 1208 -1978)

The ductility is expressed as the distance in centimeters to which a standard briquette of bitumen can be stretched before the thread breaks. The test is conducted at 27 ^{0}C and at a rate of pull of 50mm per minute.

2.2.3. Softening Point Test (IS 1205 – 1978)

The softening point is the temperature at which the substance attains a particular degree of softening under specified condition of test. The temperature at which the softened bitumen touches the metal plate at a specified distance below the ring is noted as softening point of bitumen.

2.2.4. Specific Gravity (IS 1202 – 1978)

The specific gravity of bituminous materials is determined by preparing a specimen in semisolid or solid state and by weighing in air and water.

Specific gravity $= \frac{W1}{(W1 - W2)}$

Where, W1 = Weight in air
W2 = Weight in water

2.2.5. Storage Stability Test

This test is used to determine the susceptibility of a pre-blended modified blinder to separation or instability during prolonged storage at high temperatures. A sample of modified binder contained in a closed vessel of 320 mm long and 60 mm internal diameter having a removable lid ad was maintained at 160±2^{0}C for 7 days ± 2 hours. The binder sample taken from the top and bottom thirds of the vessel was tested to determine the penetration and softening point, in accordance with IS 1203 and IS 1205.

2.2.6. Elastic Recovery Test

The elastic recovery of modified bitumen is evaluated by comparing recovery of thread after conditioning specimen for 1 hour at specified temperature and the specimen is elongated up to 10cm deformation in ductility machine.

III. RESULTS & DISCUSSION

TEST RESULTS AND DISCUSSION

3.1. Discussion on Binder Tests

Bitumen + % of Polyethylene		Penetration	Softening Point	Ductility	Specific gravity
1%	0% CR	85.5	40	60	1.049
	5% CR	71	41.2	38	1.050
	7.5% CR	69	41.8	35	1.052
	10% CR	66	42.3	33	1.054
	12.5%CR	60.5	42.6	31	1.062
2%	0% CR	78	41	56	1.044
	5% CR	66	41.9	36	1.048
	7.5% CR	63.5	42.4	31.5	1.055
	10% CR	59	42.7	28	1.057
	12.5 % CR	54	42.9	25.5	1.059
2.5%	0% CR	72	41.8	48	1.042
	5% CR	64.5	42.5	33	1.049
	7.5% CR	60	43	30	1.052
	10% CR	55	43.6	26	1.054
	12.5 % CR	51	44	23	1.056
3%	0% CR	65	42.6	43	1.041
	5% CR	59	43.4	32	1.045
	7.5% CR	53	43.9	28	1.048
	10% CR	48	44.2	25	1.050
	12.5 % CR	42	44.7	22	1.054
4%	0% CR	52	43.4	39	1.039
	5% CR	41	44	29	1.04
	7.5% CR	38	44.4	26	1.042
	10% CR	34.5	45.4	23.5	1.046
	12.5 % CR	30	46	21.5	1.05

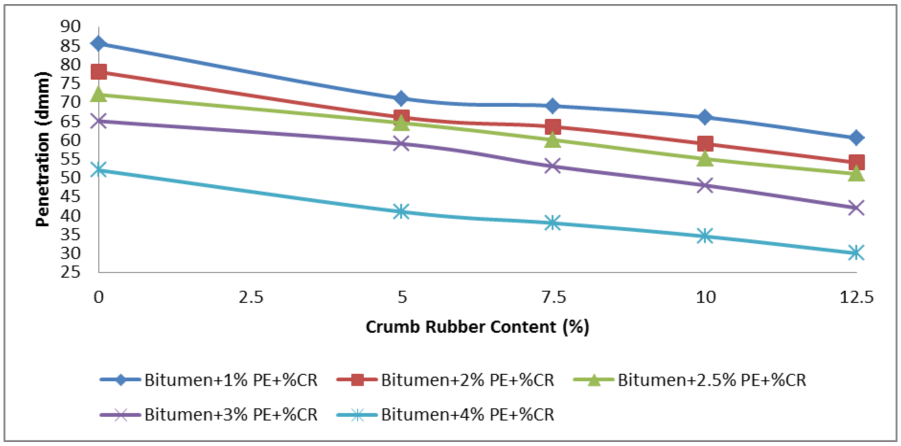

Figure 1: variation of Penetration with PE content for different proportion of CR Modifier

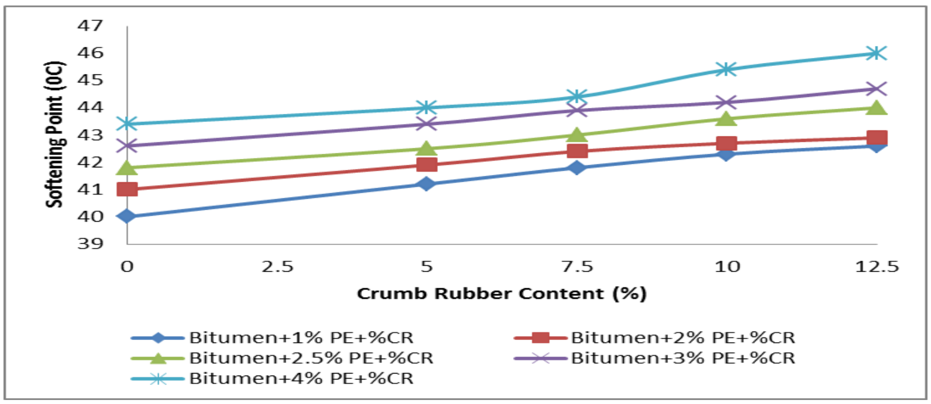

Figure 2: variation of Softening Point with PE content for different proportion of CR Modifier

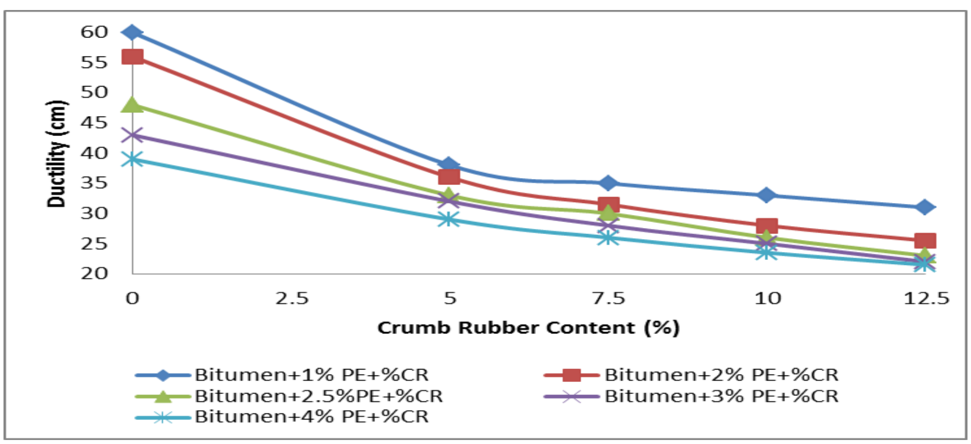

Figure 3: variation of Ductility with PE content for different proportion of CR Modifier

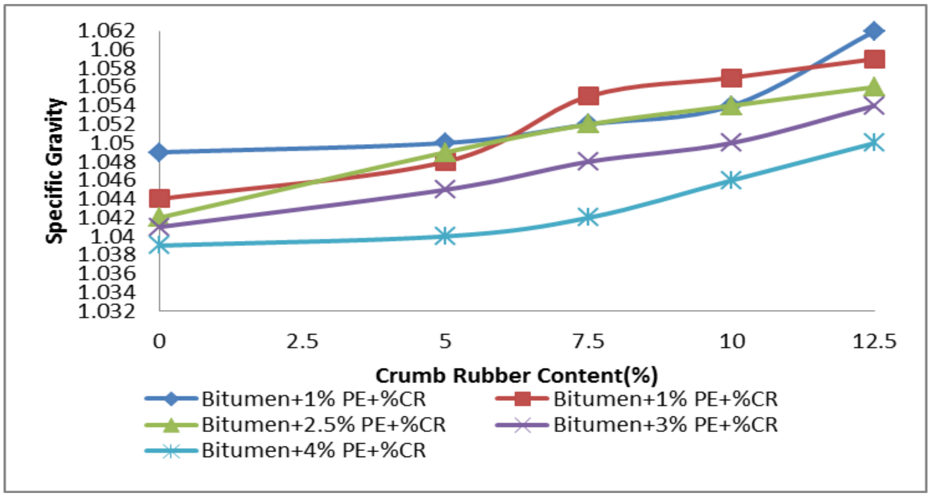

Figure 4: variation of Softening Point with PE content for different proportion of CR Modifier

3.2. Results of Tests on Bituminous Mix

The optimum binder content has been calculated on the average of maximum stability value, maximum unit weight and average% of air voids in the total mix.

Property Used	%of 80/100 Grade Bitumen				
Bitumen Content (%)	3.5	4.0	4.5	5.0	5.5
Theoretical Density	2.51	2.47	2.45	2.42	2.39
Unit Weight (gm/cc)	2.16	2.18	2.22	2.22	2.17
Air Voids (%)	16.2	13.3	10.36	9.01	8.64
Voids In Mineral Aggregate VMA (%)	25.2	22.4	19.6	18.31	17.8
Voids filled with Bitumen VFB (%)	35.8	40.7	47.3	50.8	51.5
Marshall Stability(KN)	7.1	7.54	8.76	8.32	8
Flow Value (mm)	2.15	2.45	2.7	3	3

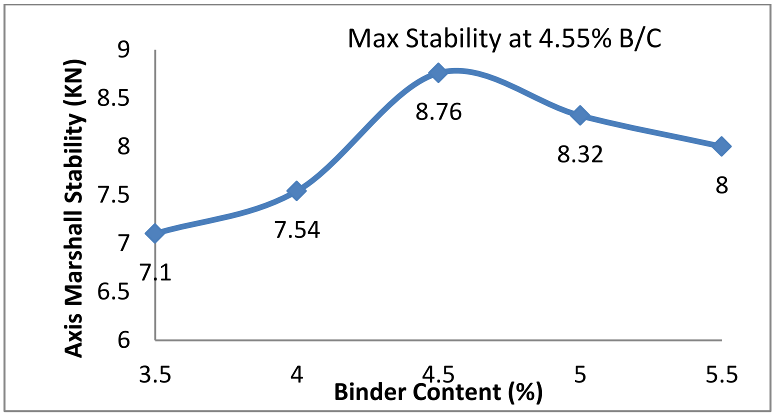

Figure 5: Variation of Marshall Stability with Plain Bitumen Blinder

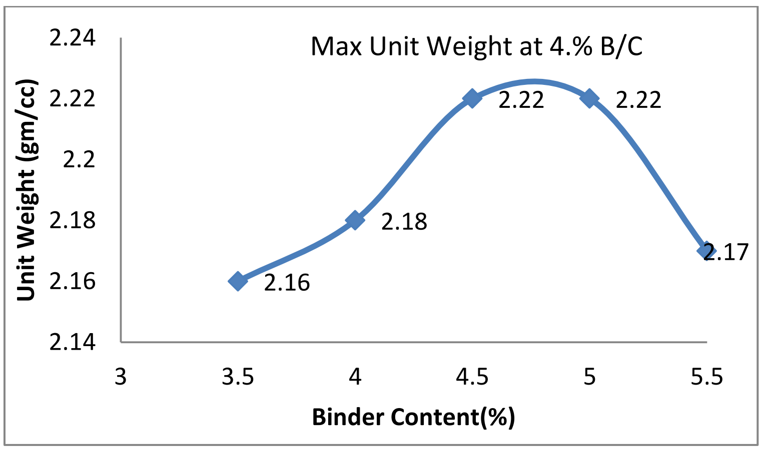

Figure 6: Variation of Unit Weight with Plain Bitumen Blinder

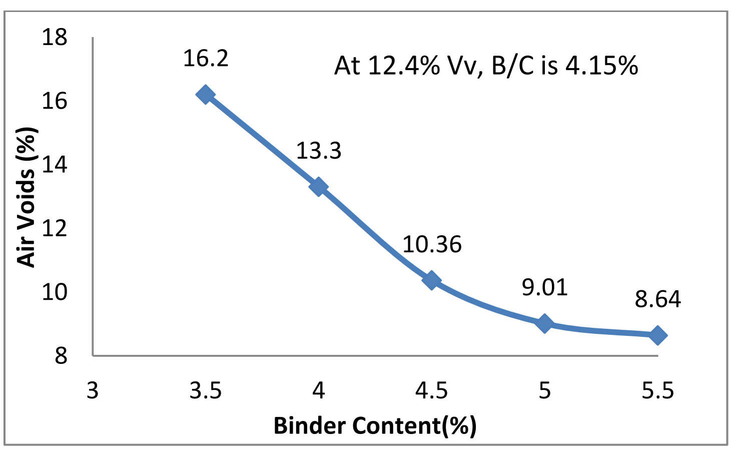

Figure 7: Variation of Air Voids with Plain Bitumen Blinder

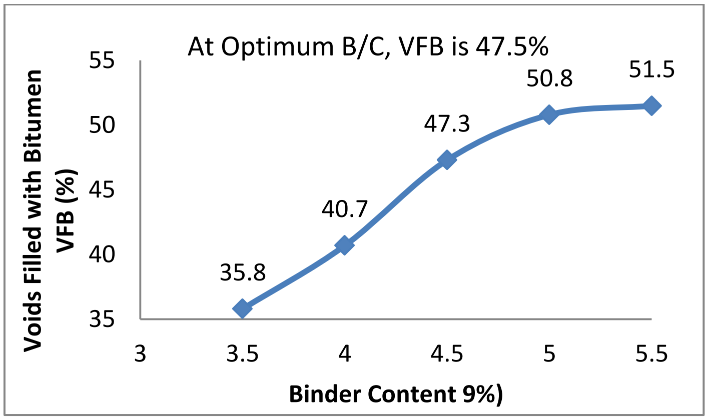

Figure 8: Variation of Voids Filled with Plain Bitumen Blinder

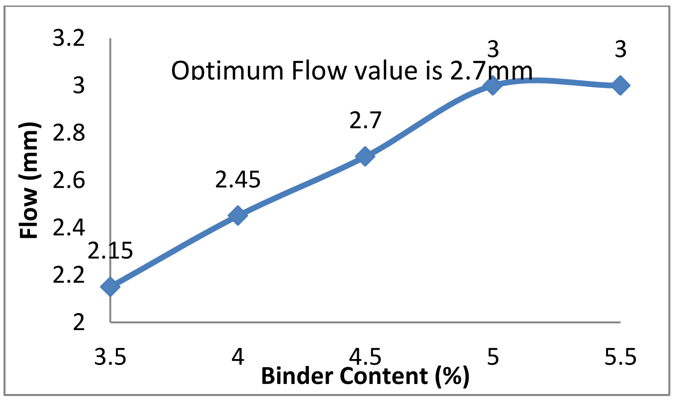

Figure 9: Variation of Flow Value with Plain Bitumen Blinder

3.3 Test properties of Bituminous Macadam Specimen Prepared with Plain Bitumen, different proportions PE and CR

% Poly Ethylene	Property Tested	Crumb Rubber (%by Weight)				
		0	5	7.5	10	12.5
1	Unit Weight (gm/cc)	2.2	2.21	2.21	2.23	2.19
	Air Voids (%)	10.9	10.85	10.6	10.76	11.87
	Voids In Mineral Aggregate VMA (%)	19.93	19.91	19.67	19.87	20.92
	Voids filled with Bitumen VFB (%)	45.3	45.5	46.11	45.84	42.5
	Marshall Stability(KN)	8.9	9.31	9.42	9.57	9.12
	Flow Value (mm)	2.2	2.7	2.6	2.5	2.8
2	Unit Weight (gm/cc)	2.21	2.23	2.24	2.25	2.22
	Air Voids (%)	10.4	9.4	8.92	8.93	10.81
	Voids In Mineral Aggregate VMA (%)	19.52	18.6	18.06	18.26	19.83
	Voids filled with Bitumen VFB (%)	46.72	49.46	50.6	50.74	45.49
	Marshall Stability(KN)	9.11	9.24	9.57	9.83	8.87
	Flow Value (mm)	2.2	2.5	2.4	3	3.1

2.5	Unit Weight (gm/cc)	2.22	2.24	2.25	2.26	2.23
	Air Voids (%)	10.36	9.38	8.8	8.41	9.86
	Voids In Mineral Aggregate VMA (%)	19.63	18.57	18.08	17.65	19.87
	Voids filled with Bitumen VFB (%)	47.22	49.48	50.85	52.35	47.86
	Marshall Stability(KN)	9.32	9.43	9.62	10.05	8.97
	Flow Value (mm)	2.7	2.2	2.5	2.3	2.6
3	Unit Weight (gm/cc)	2.24	2.25	2.26	2.27	2.24
	Air Voids (%)	9.38	8.88	8.4	7.93	9.36
	Voids In Mineral Aggregate VMA (%)	18.59	18.15	17.68	17.24	19.01
	Voids filled with Bitumen VFB (%)	49.54	51.07	52.49	54	48.5
	Marshall Stability(KN)	9.44	9.51	9.86	10.52	8.02
	Flow Value (mm)	2.7	3.6	3.2	3.1	3.2
4	Unit Weight (gm/cc)	2.24	2.24	2.25	2.26	2.22
	Air Voids (%)	9.37	9.37	8.89	8.41	10.36
	Voids In Mineral Aggregate VMA (%)	18.51	18.68	18.2	17.71	19.46
	Voids filled with Bitumen VFB (%)	49.37	49.83	51.15	52.51	46.76
	Marshall Stability(KN)	8.02	8.67	8.73	9.02	7.45
	Flow value (mm)	2.6	3	2.5	2.2	2.3

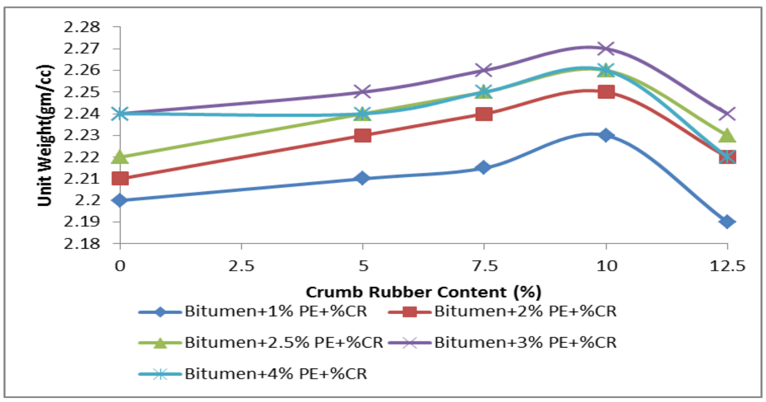

Figure 10: Variation of Unit Weight for Different PE and CR Proportions

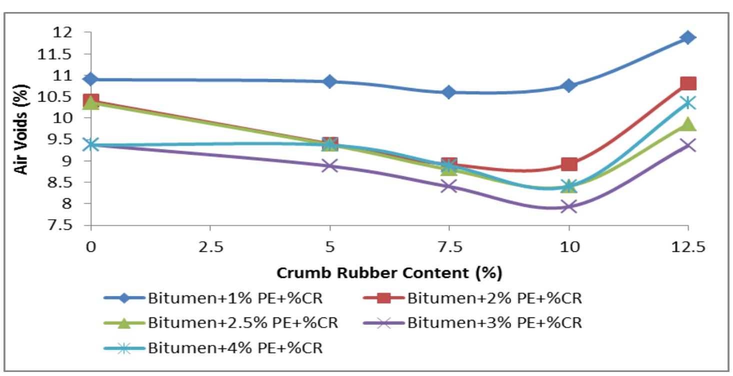

Figure 11: Variation of Air Voids for Different PE and CR Proportions

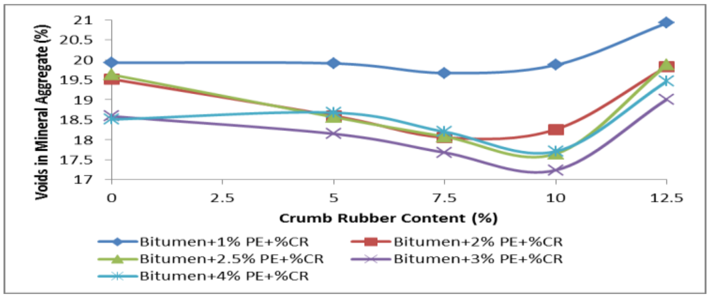

Figure 12: Variation of VMA for Different PE and CR Proportions

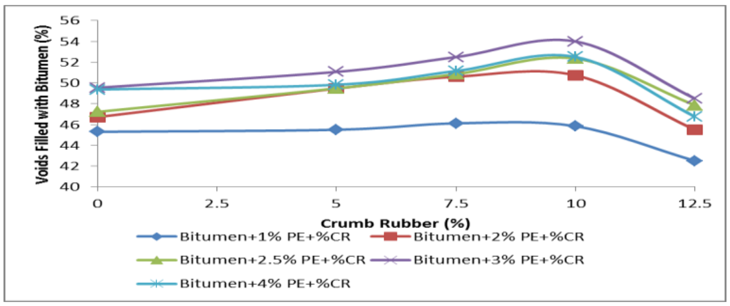

Figure 13: Variation of VFB for Different PE and CR Proportions

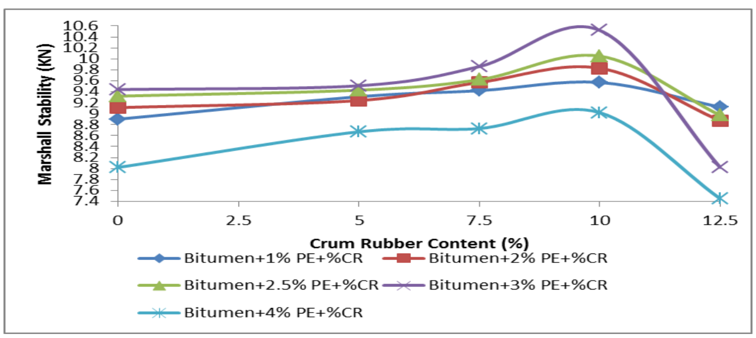

Figure 14: Variation of Marshall Stability for Different PE and CR Proportions

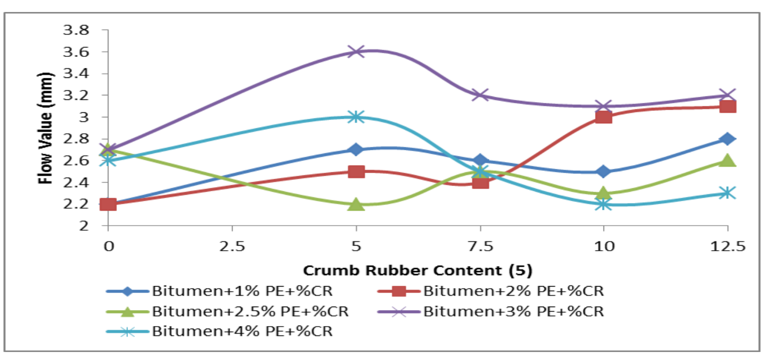

Figure 15: Variation of Flow Value for Different PE and CR Proportions

3.4 Test properties of Bituminous Macadam Specimen Prepared with Plain Bitumen, different proportions CR and PE

% Crumb Rubber	Property Tested	Crumb Rubber (%by Weight)				
		1	2	2.5	3	4
0	Unit Weight (gm/cc)	2.2	2.21	2.22	2.24	2.23
	Air Voids (%)	10.9	10.4	10.36	9.38	9.86
	Voids In Mineral Aggregate VMA (%)	19.93	19.52	19.63	18.59	18.96
	Voids filled with Bitumen VFB (%)	45.3	46.72	47.22	49.54	48.08
	Marshall Stability(KN)	8.9	9.11	9.32	9.44	8.02
	Flow Value (mm)	2.2	2.2	2.7	2.7	2.6
5	Unit Weight (gm/cc)	2.21	2.23	2.24	2.25	2.24
	Air Voids (%)	10.85	10	9.38	8.88	9.37
	Voids In Mineral Aggregate VMA (%)	19.91	18.6	18.57	18.15	18.68
	Voids filled with Bitumen VFB (%)	45.5	49.46	49.48	51.07	49.83
	Marshall Stability(KN)	9.31	9.24	9.43	9.51	8.67
	Flow Value (mm)	2.7	2.5	2.2	3.6	3
7.5	Unit Weight (gm/cc)	2.215	2.24	2.25	2.26	2.25
	Air Voids (%)	10.6	10.1	8.88	8.4	8.89
	Voids In Mineral Aggregate VMA (%)	19.67	18.06	18.08	17.68	18.2
	Voids filled with Bitumen VFB (%)	46.11	50.6	50.85	52.49	51.15
	Marshall Stability(KN)	9.42	9.57	9.62	9.86	8.73
	Flow Value (mm)	2.6	2.4	2.5	3.2	2.5
10	Unit Weight (gm/cc)	2.23	2.25	2.26	2.27	2.26
	Air Voids (%)	9.4	8.93	8.61	7.43	8.41
	Voids In Mineral Aggregate VMA (%)	19.41	18.26	17.65	17.24	17.71
	Voids filled with Bitumen VFB (%)	47.4	50.74	52.35	54	52.51
	Marshall Stability(KN)	9.57	9.83	10.05	10.52	9.02
	Flow Value (mm)	2.5	3	2.3	3.1	2.2
12.5	Unit Weight (gm/cc)	2.19	2.22	2.23	2.24	2.22
	Air Voids (%)	11.87	10.81	9.86	9.3	10.36
	Voids In Mineral Aggregate VMA (%)	20.92	19.83	19.87	19.01	19.46
	Voids filled with Bitumen VFB (%)	42.5	45.49	47.86	48.3	46.76
	Marshall Stability(KN)	9.12	8.87	8.97	9.02	7.45
	Flow value (mm)	2.8	3.1	2.6	3.2	2.3

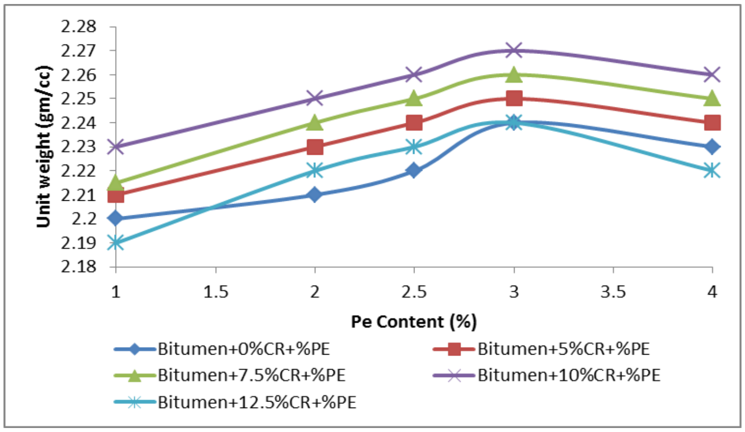

Figure 16: Variation of Unit Weight for different CR&PE Proportions

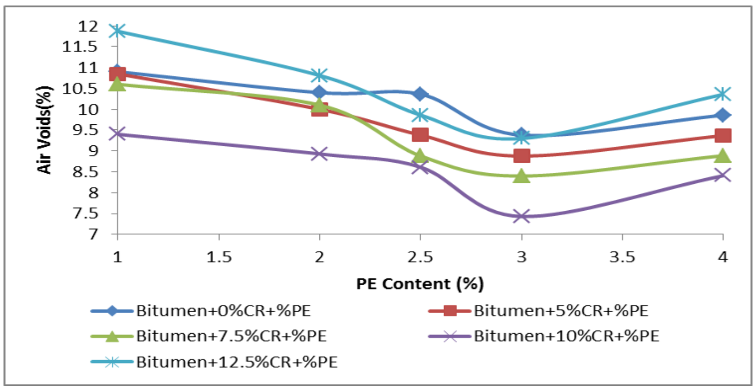

Figure 17: Variation of Air Voids for different CR&PE Proportions

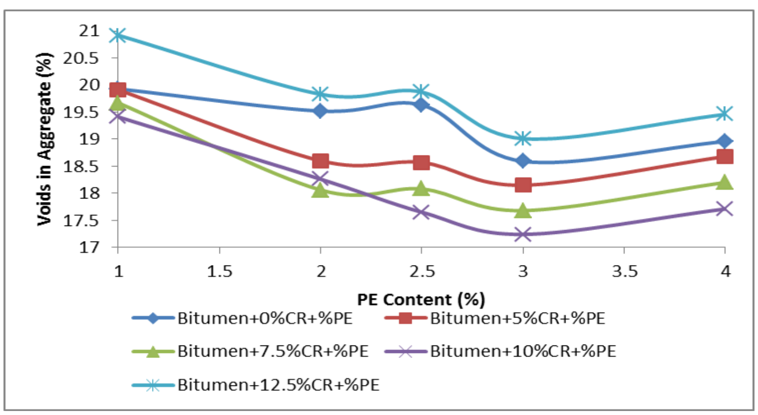

Figure 18: Variation of VMA for different CR&PE Proportions

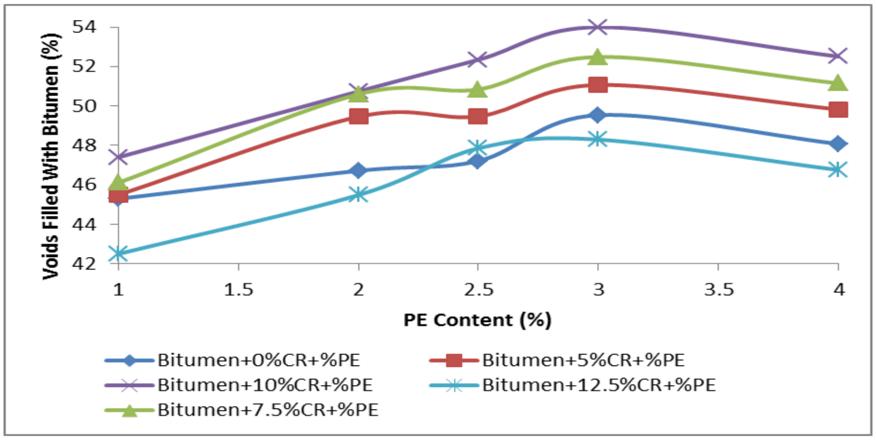

Figure 19: Variation of VFB for different CR&PE Proportions

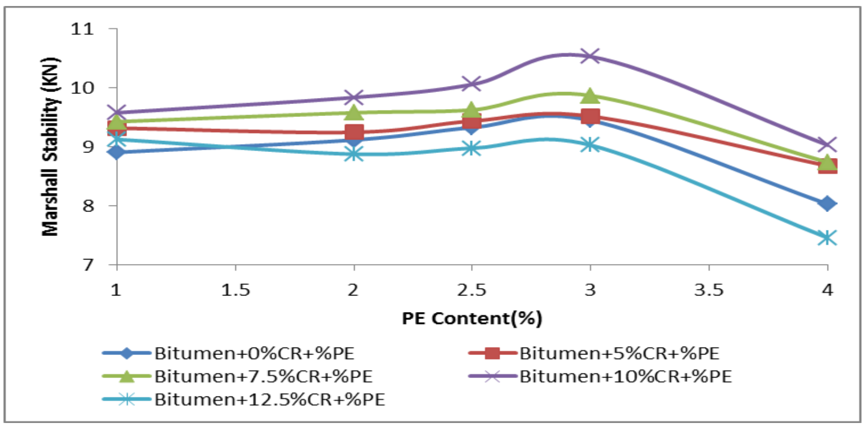

Figure 20: Variation of Marshall Stability for different CR&PE Proportions

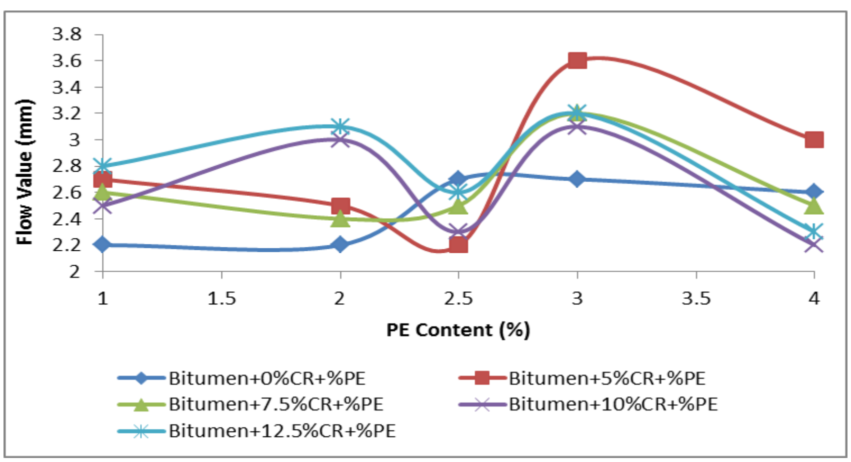

Figure 21: Variation of Flow Value for different CR&PE Proportions

3.5. Elastic Recovery and storage Test

The elastic recovery and storage stability tests conducted on optimum modified binder. The storage stability test was conducted at 160⁰C in an oven for a period of 24 hours. The results are given below table,

Property Used	%of Bitumen:% of PE:%of CR				
	89:1:1 0	88:2:1 0	87.5:2.5:1 0	87:3:1 0	86:4:1 0
Elastic Recovery	32	30	28	25	23

Storage Stability		**%of Bitumen:% of PE:%of CR**				
		89:1:10	**89:1:10**	**89:1:10**	**89:1:10**	**89:1:10**
Softening Point (⁰C)	Top	41.4	42	42.5	43.8	44.2
	Bottom	44.4	44.5	45	44.3	46.4
	Variation	3	2.5	2.5	0.5	2.2
Penetration (dmm)	Top	62	55	56	50	35
	Bottom	66	59	59	53	39
	Variation	4	4	3	3	4

Results indicate that the percentage of elastic Recovery is decreased with increasing percentage of PE content. CR content is almost same in each type of modified blend. All binders having more than 20% elastic recovery values at 27⁰C confirms that, modified binders have potential to withstand are less susceptible to creep deformation development of reflection cracking.

From the storage stability test results, softening point variation between top and bottom sample for each proportion of optimum binder content is less than 5⁰C, which is within the allowable limit. Penetration value variation also is not high. From the above results, it is seen that the pre blended modified binder have stability during prolonged storage at high temperature.

IV. CONCLUSION

Based on the laboratory tests conducted, it is proved that the addition of Polyethylene and Crumb Rubber produces favorable changes in the properties of bitumen and mixes prepared using such binders. On the basis of observation and analysis of the results following conclusion are drawn:

- The low Density Polyethylene (LPDE) and Crum Rubber (CR) are compatible with 80/100grade bitumen to get a homogeneous mix.
- The penetration and ductility values decreases with increasing percentages of polyethylene and Crumb rubber content.
- The softening point value increases with increasing percentages of PE and CR content.
- Marshall Stability value as high as 10.52KN was obtained as a result of modification with 3% PE and 10% CR proportion by weight of bitumen in 4.55 binder content.
- The Marshall Stability value of modified binder when compared with plain bitumen increases. Maximum value is attained at 3% PE with 10% CR after that the stability value is decreases.
- Increase in maximum value Marshall Stability due to the addition of 3% PE and 10% CR modifier is found to be 205 more than maximum stability of plain bitumen.
- According to storage stability test, the PE and CR modified binder has compatibility and stability of plain bitumen.

- Above saving in bitumen is not at the cost of another material, but at a beneficial use of non-bio-degradable wastes like PE and CR which are most common ingredients of Municipal wastes.
- The environment crisis due to stock piling of the non-bio-degradable wastes can be partly solved.

V.REFERENCES

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