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Effect of Different Sizes of Crumb Rubber in Asphalt Mixes

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Abstract—*The rapid industrialization, urban development and construction of heavy duty pavements require modification of bitumen. The waste tyre of different sizes with different concentration has been used as modifier. The use of these materials will reduce the cost of bitumen, minimize the environmental pollution and also improve the durability and performance of flexible pavement for future highways construction. The study of the binder include the following testing procedures: penetration, softening point and ductility test while for the bituminous mixture: Marshall stability test to determine the properties of crumb rubber such as (size and percent of content) which provide the ultimate performance of hot asphalt mix. For this purpose the bitumen modified with 5%, 7%, 9% and 11% by weight of crumb rubber varying its size. Three different sizes of crumb rubber will be used, which are coarse (1.18mm-600µm); medium size (600µm-300µm) and fine (300µm-150µm). On the basis of experimental study the modified bitumen using different sizes and percent of crumb rubber content are analyzed and best size of crumb rubber is suggested.*

Keywords: *Bitumen, CRMB, crumb rubber, marshall stability test and flexible pavement*

1. INTRODUCTION

India has a road network of over 4.87 million kilometers (kms) in 2015 and the second largest road network as well as second fastest growing automobile in the world. As per Ministry of Road Transportation and Highway (MORTH) directives for National Highway Authority of India (NHAI) that an approx. 30 km road is to be constructed every day and approx 750 Metric Ton (MT) of bitumen is to be used for wearing course every day in India. An Engineer must consider the primary user's requirements of safety as well as the economy. To achieve this goal, designers should take into account three fundamental requirements which include environmental factors, traffic flow and asphalt mixtures materials [1]. Due to rapid growing of automobile there will be more traffic volume and more tire pressure on the road surface which required higher performance flexible pavements. So to minimize the cause of road surface and increase durability and performance of flexible pavement, the plain bitumen needs to be modified. There are 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) [2]. The waste crumb rubber has been used as the modified binding materials for asphalt mix .These are recycled rubber from the automotive and truck scrap tires. Overall a typical scrap tire containing 65–70% rubber, 15–25% technical-grade carbon and 10–15% high-quality metal by weight. The benefits of utilization of waste tire are to reduce the need of bitumen, increase strength, durability and performance of flexible pavement.

2. LITERATURE REVIEW

A detailed review of research works carried out related to present study is described as below.

Peiman Azarsa, Dr. P.Sravana, K.Sridhar Reddy (2015*)*, observed that performance of the modified asphalt binders was better than the plain asphalt. They concluded that the penetration values and softening points of plain bitumen can be improved signicantly by modifying it with addition of crumb rubber. They also observed that the sample prepared using crumb rubber size (0.3-0.15) mm gives the highest stability value of 1597.64 kg, minimum flow value, maximum unit weight, maximum air void and minimum VMA and VFB values and considered as crumb rubber size (0.3-0.15) mm is the best size CRMB.

Harpalsinh Raol, Abhijitsinh Parmar, Dhaval Patel, Jitendra Jayswal (2014), investigates that crumb rubber content of 15% by weight of bitumen is recommended for the improvement of the performance benefits of stabilizing asphalt mixture. By using 15% of crumb rubber content gives the highest Marshall Stability value of 1615.84 kg, which is 1.6 times greater than the Marshall Stability value of plainl bitumen mix.

Foad Ali Zolfaghari, Farzad Zolfaghari, Mohammad Javid (2014), has shown that the penetration value decrease with size of crumb rubber decrease whereas softening point increase with size of crumb rubber decrease. Their study observed that the sample prepared using crumb rubber size (0.3-0.15) mm gives the maximum stability value of 1597.64 kg among the other size, minimum flow value 3.74 mm, maximum unit weight of 2.34 gm/cc, maximum air void

4.84%, minimum VMA of 16.72% and minimum VFB of 71.1%. So crumb rubber size (0.3-0.15) recommended that the best size of crumb rubber.

Adil Al Tamimi (2014), Observed that the three percentages of crumb rubber 5, 10, and 15% by weight of the binder content were considered to produce crumb rubber modified bitumen "CRMB". It was shown that the addition of 5% is adequate to satisfy.

Miss. Mane Priyanka Arun, Mr. Petkar Deepak Ganesh(2013*)*, study that the properties of bitumen by varying % of crumb rubber. The penetration value, ductility and vicscosity decrease with increase % of crumb rubber content whereas softening point and specific gravity increase with increase % of crumb rubber content. They also observed that using 10% addition of rubber crumbs has best suitability for blending it with bitumen.

3. MATERIALS

Locally available coarse aggregate, fine aggregate, 80/100 grade bitumen, crumb rubber, bitumen mixture machine, electric heater, penetration test apparatus, softening point apparatus and marshall stability test apparatus etc.

4. EXPERIMENTAL PROGRAMS

4.1. Mixing of crumb rubber with plain bitumen

Wet process method is used in preparing the sample. In preparing the modified binders, about 800 g of the bitumen was heated to fluid condition in a 2litre capacity metal container. For blending of crumb rubber with bitumen, it was heated to a temperature of 160 °C and then crumb rubber was added. For each mixture sample 5%, 7%, 9% and 11% of crumb rubber by weight of for three different sizes is used, which are coarse (1.18 mm - 600 µm); medium size (600 µm - 300 µm); and fine (300 µm-150 µm). The blend is mixed manually for about 3-4 minutes [1]. The mixture is then heated to 160 °C and the whole mass was stirred using a mechanical stirrer and rotated at 1440 rpm for 50 minutes. Care is taken to maintain the temperature between 160 °C to 170 °C ± 5°C. The modified bitumen is cooled to room temperature and suitably stored for testing.

Figure 1. Laboratory bitumen mixture.

4.2. Common test on aggregates

Common laboratory test like Impact test, Abrasion test, Specific gravity test, Water absorption test, Flakiness index test and Elongation index test are performed as per MORT &H specifications.

4.3. Common test on plain bitumen and crumb rubber modified bitumen

To evaluate the performance of plain bitumen and CRMB common laboratory test like penetration test, softening point test and ductility test are performed and the result are analyzed for further study

4.4. Preparation of bitumen mix

Approximately 1200gm of aggregates and filler is heated to a temperature of 150°C. Bitumen is heated to a temperature of 150°C with the percentage of bitumen 4.5 to 6% by weight of the mineral aggregates. The heated aggregates and bitumen are thoroughly mixed at a temperature of 160°C. The mix is placed in a mould of 7.5 cm height and 10.2 cm diameter and compacted with 75 numbers of blows on both the sides of specimen. The specimen is taken out from the mould after 24 hours using specimen extractor and further testing.

4.5. Marshall stability test

Before testing the specimens their dimensions is measured to note the volume and their weight in air, weight in water, and dry SSD weight are taken. Before the testing, the specimens were kept in hot water at 60^0C for 30-40 minutes. The specimens are tested within 3 to 4 minutes after taken out from water bath. The specimen is put out on Marshall Apparatus and Marshall Stability and flow dial gauge reading are recorded.

For Marshall Stability test optimum binder content was determined first for this purpose using following criterion.
(i) Bitumen content for maximum stability
(ii) Bitumen content for maximum unit wt. of compacted mix.
(iii) Bitumen content for 4% of air voids

4.6. Density and air void analysis

Density and Air Void Analysis are carrying out by following quantities: Bulk specific gravity of Compacted Mixture, Theoretical Maximum specific gravity, Percent air voids, Percent air voids in mineral aggregates (VMA), Percent aggregate voids filled with bitumen (VFB) and further graphs are plotted.

4.6.1 Bulk specific gravity (Gm)

Gm = [A/(B-C)]
Where;
A = Weight of specimen in air.
B = Dry SSD weight of specimen in air.
B = Weight of specimen in water.

4.6.2 Theoretical specific gravity (Gt)

Gt = A/(A+D-E)
Where;
A= mass of oven-dry sample on air
D = mass of flask filled with water up to neck at (25°C)
E = mass of container filled with sample and water up to neck at (25°C)

4.6.3. Air voids (Va)

Va = 100(Gt-Gm)/Gt

Where;
Gm = Bulk specific gravity
Gt = Theoretical specific gravity

4.6.4 Voids in mineral aggregate(VMA)

VMA = 100 [1–((Gm (1- Pb))/Gsb)]
Where;
Gm = Bulk Specific Gravity of compacted mix.
Gsb = Bulk Specific Gravity of total aggregate.
Pb = Percent of bitumen by weight.

4.6.5. Voids filled with bitumen (VFB)

VFB = 1-(Va/VMA)
Where;
Va = % Air voids
VMA = Voids in mineral aggregate

5. Analysis of test result and discussion

5.1. Test results of plain and modified bitumen

Table 1. Result of test for plain bitumen

Properties	Value
Penetration, (25 0C, 0.1mm, 100g, 5s)	91 mm
Softening Point (Ring & Ball), 0C, Min	45 0C
Ductility, (270C, 50mm/min, cm)	>100 cm

Table 2. Result of test for CRMB mix

Size (mm)	Properties			
	CR Content	Penetration	Softening	Ductility
1.18-0.6	5%	40 mm	55.13 0C	34 cm
	7%	37 mm	55.38 0C	28 cm
	9%	35 mm	56 0C	25 cm
	11%	32 mm	57.13 0C	23 cm
0.6-0.3	5%	38 mm	55.75 0C	31 cm
	7%	35 mm	56.13 0C	25 cm
	9%	33 mm	57.13 0C	21 cm
	11%	31 mm	58.25 0C	20 cm
0.3-0.15	5%	48 mm	55.25 0C	32 cm
	7%	42 mm	55.75 0C	22 cm
	9%	36 mm	57 0C	20 cm
	11%	34 mm	57.75 0C	19 cm

5.2. Test results of aggregates

Table 3. Result of test for aggregates used in testing

Properties	Results	Test method
Abrasion value	38 %	IS : 2386 (PART IV)
Aggregate impact value	18.5 %	IS : 2386 (PART IV)
Specific gravity	2.56	IS : 2386 (PART II)
Water absorption	1.6	IS : 2386 (PART III)
Flakiness index	10.62%	IS : 2386 (PART I)
Elongation index	13%	IS : 2386 (PART I)

Table 4. Composition of bituminous concrete mix

Sieve size(mm)	Percent Passing.		Wt. of aggregate (gm)	Aggregate %
	Recommended	Grading use		
12.5	100	-	0	0
10	80-100	90	120	10
4.75	55-75	65	300	25
2.36	35-56	45	240	20
0.6	18-29	24	252	21
0.3	13-23	18	72	6
0.15	8-16	12	72	6
0.075	4-10	7	60	5
Filler	-	-	84	7

5.3 Marshall stability tests for plain bitumen

Table 5. Observation table for marshall stability tests

Bitumen content (%)	Unit wt.	Air void(%)	VMA (%)	VFB (%)	Stability (kg)	Flow (mm)
4.5	2.21	6.37	10.47	39.21	1471.05	2.2
5	2.22	5.27	11.50	54.15	1789.73	2.8
5.5	2.25	3.34	12.51	73.27	1824.59	3.9
6	2.23	2.09	13.49	84.53	1801.35	5.5

5.4. Marshall stability tests for CRMB prepared by different sizes with different concentration of crumb rubber

Table 6. Observation table for marshall stability test on CRMB of crumb rubber (1.18mm-600µm) size

CR content	Bitumen content	Unit wt.	Va %	VMA %	VFB %	Stability kg	Flow mm
5%	4.5%	2.18	7.45	9.69	23.12	1754.86	2.4
	5%	2.22	5.27	10.73	50.82	1882.70	3.2
	5.5%	2.24	3.66	11.74	68.87	1847.84	4
	6%	2.23	3.67	12.73	71.20	1812.97	5
7%	4.5%	2.18	7.53	9.59	21.48	1824.59	2.6
	5%	2.19	6.47	10.62	39.05	1964.05	3.8
	5.5%	2.21	3.89	11.63	66.54	1952.43	4.2
	6%	2.23	3.56	12.61	71.74	1805.95	4.6
9%	4.5%	2.18	7.70	9.59	19.75	1882.70	2.3
	5%	2.19	6.77	10.62	36.21	1905.95	3
	5.5%	2.25	3.58	11.63	69.19	1859.46	3.8
	6%	2.24	3.34	12.61	73.53	1754.86	5
11%	4.5%	2.19	7.32	9.49	22.96	1652.11	3
	5%	2.20	6.16	10.52	41.43	1754.86	4.1
	5.%	2.25	3.47	11.52	69.85	1743.24	4.8
	6%	2.24	3.51	12.49	71.94	1731.62	5.3

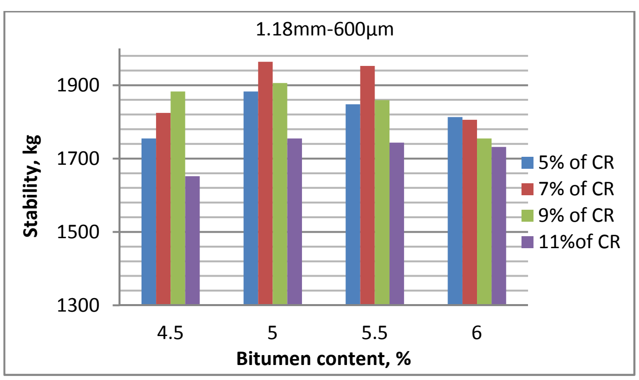

Figure 2: Effect of variation of crumb rubber content in stability values.

Table 7. Observation table for marshall stability test on CRMB of crumb rubber (600µm-300µm) size

CR content	Bitumen content	Unit wt.	Va %	VMA %	VFB %	Stability kg	Flow Mm
5%	4.5%	2.20	6.65	9.59	30.67	1584.21	2.90
	5%	2.21	5.84	10.62	45.02	1778.11	3.10
	5.5%	2.26	2.85	11.63	75.53	1905.95	3.50
	6%	2.25	2.84	12.61	77.49	1836.22	3.90
7%	4.5%	2.18	7.87	9.59	17.92	1853.65	3.10
	5%	2.21	5.71	10.62	46.23	1935.00	3.60
	5.5%	2.23	4.47	11.63	61.55	1772.30	4.00
	6%	2.23	3.69	12.61	70.71	1743.24	4.40
9%	4.5%	2.18	7.79	9.49	17.93	1929.19	3.30
	5%	2.19	6.73	10.52	36.00	1975.68	3.80
	5.5%	2.24	3.94	11.52	65.82	1900.7	4.10
	6%	2.23	3.96	12.49	68.27	1836.22	4.50
11%	4.5%	2.18	7.89	9.40	16.11	1859.46	3.60
	5%	2.22	5.50	10.42	47.19	1952.43	3.90
	5.%	2.24	4.25	11.41	62.78	1905.95	4.50
	6%	2.23	3.90	12.38	68.46	1836.22	5.00

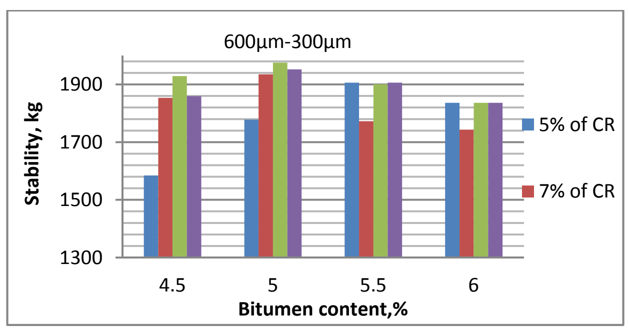

Figure 3: Effect of variation of crumb rubber content in stability values.

Table 8. Observation table for marshall stability test on CRMB of crumb rubber (300µm-150µm) size

CR content	Bitumen content	Unit wt.	Va %	VMA %	VFB %	Stability kg	Flow mm
5%	4.5%	2.19	7.06	9.69	27.11	1357.89	2.50
	5%	2.21	5.60	10.73	47.79	1766.49	3.15
	5.5%	2.23	4.38	11.74	62.67	1538.95	3.57
	6%	2.22	3.82	12.73	69.99	1335.26	4.16
7%	4.5%	2.18	7.76	9.59	19.03	1403.16	3.20
	5%	2.19	6.77	10.62	36.21	1516.32	3.60
	5.5%	2.23	4.28	11.63	63.19	1743.24	3.90
	6%	2.23	3.92	12.61	68.93	1629.47	4.40
9%	4.5%	2.18	7.70	9.59	19.75	1754.86	3.20
	5%	2.19	6.69	10.62	37.02	1772.30	3.50
	5.5%	2.24	3.85	11.63	66.86	1783.92	3.80
	6%	2.23	3.85	12.61	69.48	1754.86	4.20
11%	4.5%	2.20	7.02	9.49	26.11	1681.4	3.40
	5%	2.21	5.80	10.52	44.88	1854.86	3.90
	5.5%	2.22	4.16	11.52	63.84	1899.97	4.40
	6%	2.21	3.78	12.54	69.77	1789.73	4.60

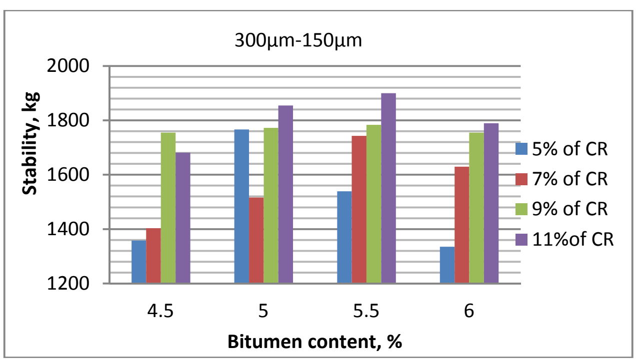

Figure 4: Effect of variation of crumb rubber content in stability values.

Table 9. Observation table for maximum marshall stability value of three different sizes of crumb rubber

Size	CR content	Bitumen content	Unit wt.	Va %	VMA %	VFB %	Stability kg	Flow mm
1.18mm-600µm	7%	4.5 %	2.18	7.53	9.59	21.48	1824.59	2.6
		5%	2.19	6.47	10.62	39.05	1964.05	3.8
		5.5 %	2.21	3.89	11.63	66.54	1952.43	4.2
		6%	2.23	3.56	12.61	71.74	1805.95	4.6
600µm-300µm	9%	4.5 %	2.18	7.79	9.49	17.93	1929.19	3.30
		5%	2.19	6.73	10.52	36.00	1975.68	3.80
		5.5 %	2.24	3.94	11.52	65.82	1900.7	4.10
		6%	2.23	3.96	12.49	68.27	1836.22	4.50
300µm-150µm	11 %	4.5 %	2.20	7.02	9.49	26.11	1681.4	3.40
		5%	2.21	5.80	10.52	44.88	1854.86	3.90
		5.5 %	2.22	4.16	11.52	63.84	1899.97	4.40
		6%	2.21	3.78	12.54	69.77	1789.73	4.60

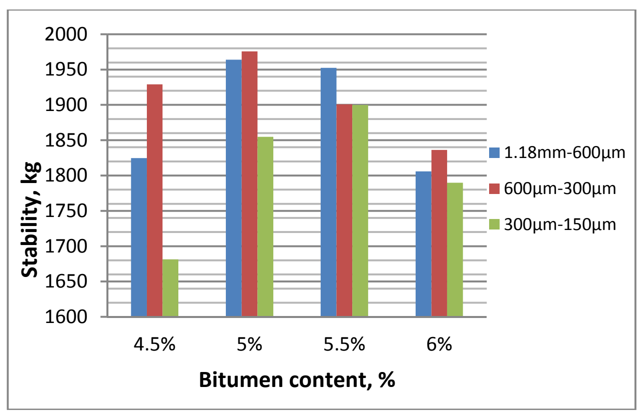

Figure 5. Effect of different sizes of crumb in stability values.

Table 10. Observation table for maximum marshall stability value among three different sizes of crumb rubber

Size	CR content	Bitumen content	Unit wt.	Va %	VMA %	VFB %	Stability kg	Flow mm
600µm-	9 %	4.5 %	2.18	7.79	9.49	17.93	1929.19	3.30
		5%	2.19	6.73	10.5	36.0	1975.6	3.80

					2	0	8	
		5.5 %	2.24	3.94	11.52	65.82	1900.7	4.10
		6%	2.23	3.96	12.49	68.27	1836.22	4.50

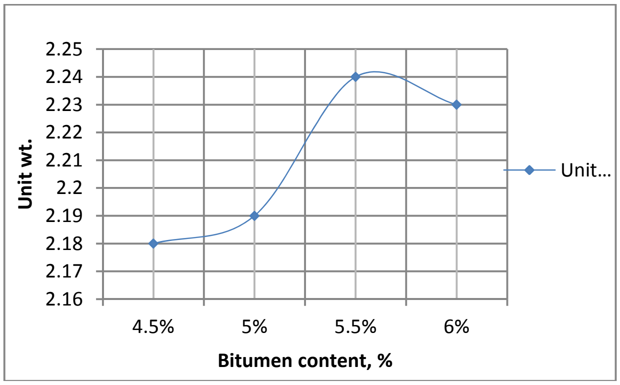

Figure 6. Variation of unit wt. with binder content.

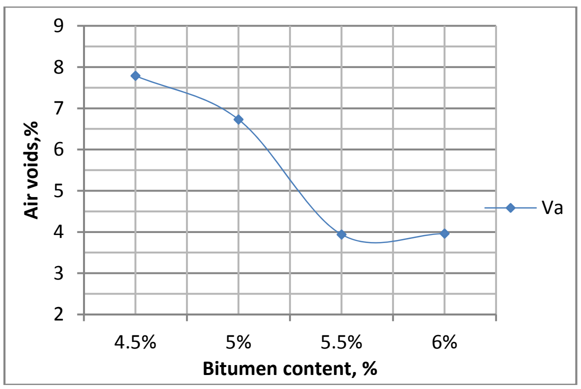

Figure 7. Variation of air voids with binder content.

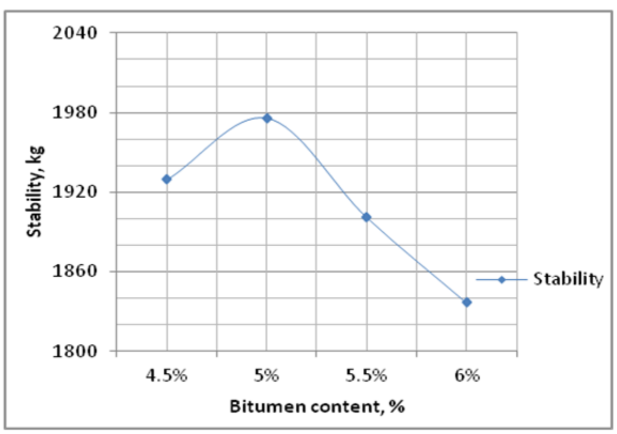

Figure 8. Variation of marshall stability with binder content.

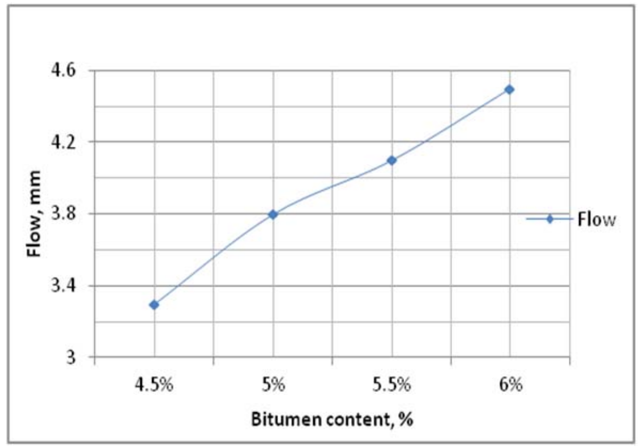

Figure 9. Variation of flow value with binder content.

5. CONCLUSION

By studying the test results of common laboratory tests on plain bitumen and crumb rubber modified bitumen it is concluded that the penetration values, softening points and ductility value of plain bitumen can be improved significantly by modifying it with addition of crumb rubber which is a major environment pollutant. As the percent of crumb rubber increase the penetration value and ductility value decreases where as softening point increases. From the table 9 it can be observed that the sample prepared using crumb rubber size (0.6- 0.3mm) give the highest stability value of 1975.68 kg, maximum unit weight, maximum air voids and minimum VMA and VFB% values among the other sizes by using 9% of crumb rubber powder with bitumen mix . The stability is increased by 10.39% on modification. So the best size to be used for crumb rubber modification can be suggested as (0.6-0.3mm) of size for commercial production of CRMB with optimum binder content 5.3%.

REFERENCE

[1] Peiman Azarsa, Dr. P.Sravana, K.Sridhar Reddy (2015). " Analysis of Crumb Rubber Performance by Modified Bitumen of Varying Sizes," International Journal of Research in Engineering and Technology ISSN 2319-8885 Vol.04,Issue.02 January-2015, Pages:0384-0390.

[2] Nabin Rana Magar "A Study on the Performance of Crumb Rubber Modified Bitumen by Varying the Sizes of Crumb Rubber", International Journal of Engineering Trends and Technology (IJETT) – Volume 14 Number 2 – Aug 2014 ISSN: 2231-5381 http://www.ijettjournal.org Page 51

[3]Ministry of Road Transport & Highways (MORT & H), "Specifications for road and bridge works".

[4] Foad Ali Zolfaghari, Farzad Zolfaghari, Mohammad Javid (2014)"Modification of Bitumen by Varying Size of the Crumb Rubber in Coarse Graded Aggregates", International Journal of Research in Engineering and Technology ISSN 2319-8885 Vol.03,Issue.22 September-2014, Pages:4435-4444.

[5] Adil Al Tamimi, Isam A. H. Al Zubaidy, Abhijit Upadhye, Liyakat Ali(2014) "Evaluation of Sustainable Asphalt Mixture",

Study of Civil Engineering and Architecture (SCEA) Received 8 April 2014; Accepted 9 June 2014; Published 8 July 2014 © 2014 Science and Engineering Publishing Company.

[6] Miss. Mane Priyanka Arun, Mr. Petkar Deepak Ganesh[2013] **"**Laboratory Evaluation of Usage of Waste Tyre Rubber in Bituminous Concrete", International Journal of Scientific and Research Publications, Volume 3, Issue 9, September 2013 1 ISSN 2250-3153.

[7] Harpalsinh Raol, Abhijitsinh Parmar, Dhaval Patel, Jitendra Jayswal (2014) "Effect Of The Use Of Crumb Rubber In Conventional Bitumen On The Marshall Stability Value", International Journal of Research in Engineering and Technology eISSN: 2319-1163 | pISSN: 2321-7308.

[8] Siddharth(2012)", use of waste plastic and waste rubber tyres in flexible highway pavement", international conference on future environment and energy,2012,vol-28,pp 105-108.