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Modification of Bitumen by Varying Size of the Crumb Rubber in Coarse Graded Aggregates

FOAD ALI ZOLFAGHARI[1], FARZAD ZOLFAGHARI[2], MOHAMMAD JAVID[3]
[1]PG Scholar, Dept of Transportation Engineering, JNTUH, Hyderabad, India.
[2]B.Tech, Azad University, & [3]B.Tech, Azad University.

Abstract: The abundance and increase of waste tire disposal is a serious problem that leads to environmental pollution. Crumb rubber obtained from shredding of those scrap tires has been proven to enhance the properties of plain bitumen since the 1840s. It can be used as a cheap and environmentally friendly modification process to minimize the damage of pavement due to increase in service traffic density, axle loading and low maintenance services which has deteriorated and subjected road structures to failure more rapidly. Use of crumb rubber leads to excellent pavement life, driving comfort and low maintenance. The rheology of CRMB depends on internal factors such as crumb rubber quantity, type, particle size, source and pure bitumen composition, and external factors such as the mixing time, temperature, and also the mixing process (dry process or wet process). The present study aims in investigating the experimental performance of the bitumen modified with 15% by weight of crumb rubber varying its sizes. Four different categories of size of crumb rubber will be used, which are coarse (1mm - 600μm); medium size (600μm - 300μm); fine (300μm-150μm); and superfine (150μm - 75μm). Common laboratory tests will be performed on the modified bitumen using various sizes of crumb rubber and thus analyzed. Marshall Stability method is adopted for mix design. Finally a comparative study is made among the modified bitumen samples using the various sizes of Crumb Rubber particles and the best size is suggested for the modification to obtain best results.

Keywords: Bitumen, Crumb Rubber, CRMB, Polymer.

I. INTRODUCTION

A. General

Transportation is the movement of people, animals, and goods from one place to another. Modes of transport include air, water, road, rail, cable, pipeline, and space. Road transport is dominant of all other modes of transportation. It contributes to the economic, industrial, social and cultural development of any country. In other words it is the backbone of development. The beginning of road construction could be dated to the times of Romans. With the advancement of technology from carriages pulled by two horses to vehicles with power equivalent to 100 horses, road development had to follow suit. The construction of modern highways did not begin until the late 19th to early 20th century. The first earth tracks were created by humans carrying goods and often followed game trails. Tracks would be naturally created at points of high traffic density. As animals were domesticated, horses, oxen and donkeys became an element in track-creation. With the growth of trade, tracks were often flattened or widened to accommodate animal traffic. Later, the travois a frame used to drag loads was developed. Animal-drawn wheeled vehicles were probably developed in the Ancient Near East in the 4th or 5th millennium BC and spread to Europe and India in the 4th millennium BC and China in about 1200 BC.

The Romans had a significant need for goods roads to extend and maintain their empire and developed Roman Roads. In the Industrial revolution John Loudon McAdam (1756-1836) designed the first modern highways, using inexpensive paving material of soil and stone aggregate (macadam), and he embanked roads a few feet higher than surrounding terrain to cause water to drain away from the surface. That laid the foundation stone of modern roads. India has a road network of over 4,689,842 kilometres in 2013, the second largest road network in the world. It has primarily flexible pavement design which constitutes more than 98% of the total road network.

India being a very vast country has widely varying climates, terrains, construction materials and mixed traffic conditions both in terms of loads and volumes. Increased traffic factors such as heavier loads, higher traffic volume and higher tire 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 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). Crumb rubber is the term usually applied to recycled rubber from automotive and truck scrap tires. During the recycling process steel and fluff is removed leaving tire rubber with a granular consistency. Continued processing with a granulator and/or cracker mill, possibly with the aid of cryogenics or mechanical means, reduces the size of the particles. From physical and chemical interaction of crumb rubber with conventional bitumen Crumb Rubber Modified Bitumen (CRMB) is made. Its advantages are:

- Lower susceptibility to daily & seasonal temperature variations.
- Higher resistance to deformation at elevated pavement temperature.
- Better adhesion between aggregates & binder.
- Prevention of cracking & reflective cracking.
- Overall improved performance in extreme climatic conditions & under heavy traffic.

Economic growth might be teetering across the world, but the amount of garbage generated by global cities is only going up. Together, urban centres generate 1.3 billion tonnes of solid waste a year and it is set to grow to 2.2 billion tonnes by 2025, according to projections by the World Bank. Most of the waste is sent to landfills, or worse, to open dumps, raising concerns about air pollution, social unrest, and impact on poverty and so on. Managing solid waste has costs—$205.4 billion at present—and it's growing. It is set to touch $375.5 billion by 2025. Overall, the local communities generate 16,000 tons of domestic waste per day and the amounts per capita vary from 0.45 to 1.44 kg per day depending on the economic status of the areas concerned (Lau, 2004). With the rapid economic growth and urbanization that is taking place in currently, solid waste generation and management is becoming a major social and environmental issue. One of the approaches towards solving the issue would be recycling of waste materials. Besides that, waste tire is neither categorized as solid waste or hazardous waste. It is generally considered as industrial or trade waste and hence there is no specific law or regulation which governs waste tire management (Thiruvangodan, 2006).

B. Source of Crumb Rubber

The world generates about 1.5 billion waste tires annually, 40 percent of them in emerging markets such as China, India, South America, Southeast Asia, South Africa and Eastern Europe. Analysis indicates that 0.6 Million Tons of tires scrap is generated in India annually which seems to increase at an alarming rate. Crumb rubber can be obtained from truck tires or automobile tires or both (see fig 1). Truck tires contain 80 per cent more rubber hydrocarbons than automobile tires and also contain significantly higher amounts of natural rubber. Whole truck tire contains 18 percent natural rubber compared to 9 per cent in an automobile tire and 2 per cent in tire treads. The amount of natural rubber has shown to affect the properties of CRMB significantly. Each lot of crumb rubber may have different chemical composition depending on the source (truck tires or automobile tires or mixture of both) and, therefore, when combined with the same source of bitumen may give different time versus viscosity curve. In other words, the target (plateau) viscosity and the allowable time before degradation are unique to each specific combination of bitumen and crumb rubber. Any time the source of bitumen or crumb rubber is changed, the time versus viscosity must be obtained again.

Fig 1: Powdered Crumb rubber.

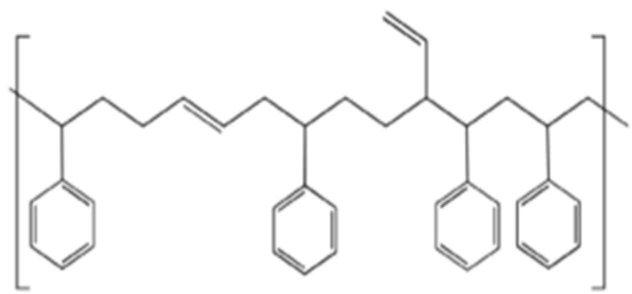

Fig.2: Structural unit of Styrene-Butadiene copolymer.

C. Objectives

- To study the effect of variation of sizes of crumb rubber in the properties of crumb rubber modified bitumen.
- To determine the Optimum Bitumen Content (OBC) for Bituminous Concrete as per MORT &H specifications.
- To study and compare the various marshall parameters among the different sizes of crumb rubber modified bitumen.
- To determine the best size of crumb rubber to be added for modification.

II. REVIEW OF LITERATURE

A. General

A detailed review of literatures made on researches related to crumb rubber modified bitumen are described in the following paragraphs. Majority of the roads all over the world are made up of flexible pavements. It consists of a bituminous layer on the surface course and sometimes in base course followed by granular layers in base and sub base courses over the subgrade. Due to increase in service traffic density, axle loading and low maintenance services the road structures have been deteriorated over the few years. So to minimize the damage of pavement surface and increase durability of flexible pavement, the conventional bitumen needs to be improved with regards to performance related properties, such as resistance to permanent deformation (rutting) and fatigue cracking. The modification of bituminous binder has been explored over the past years in order to improve road pavement performance properties. 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) (see fig 2). Crumb rubber is recycled rubber from automotive and truck scrap tires. During the recycling process steel and fluff is removed leaving tire rubber with a granular consistency. Continued processing with a granular and/or cracker mill, possibly with the aid of cryogenics or mechanical means, reduces the size of the particles further.

B. Physical and rheological properties of rubberized bitumen

1. Penetration properties

The penetration is a measure of hardness or softness of bitumen binder which shows an effect by adding crumb rubber to bitumen binder; it decreases as rubber content is increased. The penetration shows lower values as rubber content increases at different mix conditions of rubberized bitumen binder, indicating that the binder becomes stiff and more viscous (Mashaan et al, 2011a).

2. Viscosity and Softening point properties

The viscosity refers to the fluid property of the bitumen, and it is a gauge of flow – resistance. At the application temperature, viscosity greatly influences the potential of the resulting paving mixes. During compaction or mixing, the low or high viscosity has been observed to result in lower stability values. The softening point refers to the temperature at which the bitumen attains a particular degree of softening. The use of crumb rubber in bitumen modification leads to an increase in the softening point and viscosity as rubber crumb content increases (Mahrez, 1999; MAshaan et al, 20011a). Mahrez and Rehan (2003) claimed that there is a consistent relationship between viscosity and softening point at different aging phases of rubberized bitumen binder. Also, it is reported that the higher crumb rubber content leads to higher viscosity and softening point. The viscosity is a continuously increasing nonlinear function of rubber content and the relative increase is a factor related to the application of temperature (Bahia and Davies, 1995).

C. Rubber particle size

The study of Souza and Weissman (1994) using a binder with 15% rubber content (size of 0.2,0.4 and 0.6mm) in dense- graded bitumen. The mixture showed improved performance in dynamic stability, 48 h residual stability, flexural strength and strain value. Asphalt containing 0.2 and 0.4 mm size rubber indicated the best laboratory results (Souza and Weissman, 1994). The particles size disruption of crumb rubber influenced the physical properties of bitumen rubber blend. In general, small difference in the particles size has no significant effects on blend properties. However, the crumb rubber size can certainly make a big difference. According to a study of Shen et al. (2009), the particle size effects of CRM on high temperature properties of rubberized bitumen binders was an influential factor on visco- elastic properties. The coarser rubber produced a modified binder with high shear modulus and an increased content of the crumb rubber decreased the creep stiffness which in turn showed significant thermal cracking resistance.

III. EXPERIMENTAL INVESTIGATIONS

A. Introduction

This chapter describes the experimental works carried out in this present investigation. It has been divided into two parts. First part deals with the experiments carried out on the materials (aggregates, virgin bitumen, and crumb rubber modified bitumen), and second part deals with the tests carried out on bituminous mixes.

B. Tests on Materials

1. Tests on Aggregates

Common laboratory tests like Crushing test, Impact test, Specific gravity and Water Absorption test and Los Angeles test are performed as per MORT & H specifications to evaluate the aggregates and the results are tabulated in chapter 4.

2. Tests on plain bitumen and Crumb rubber modified bitumen

To evaluate the performance of plain VG-30 bitumen and crumb rubber modified bitumen common laboratory tests like Softening point test and Penetration tests are performed as per specifications which are tabulated in chapter 4.

C. Preparation of CRMB mix

In preparing the modified binders, about 500 gm of the VG30 bitumen is heated to fluid condition in a 1.5 litre capacity metal container. The mixing is performed in the laboratory using an oven fitted with a mechanical stirrer and rotated at 1550 rpm for mixing the bitumen and crumb rubber. For blending of crumb rubber with bitumen, bitumen is heated to a temperature of 160 and then crumb rubber is added. The blend is mixed manually for about 3-4 minutes. The mixture is then heated to 170°C and the whole mass is stirred using a mechanical stirrer for about 50 minutes. Care is taken to maintain the temperature between 160°C to 170°C. Since there are four different sizes of crumb rubber used for the present study four different modified samples of mix is prepared. After mixing for the specified time the contents is cooled and suitably stored for further testing.

D. Job Mix Formula (JMF)

The end result of a successful mix design is a recommended mixture and asphalt binder. This recommended mixture, which also includes aggregate gradation and asphalt binder type is often referred to as the job mix formula (JMF). For HMA manufacturing target values of gradation and asphalt binder content are specified based on the JMF along with allowable specification bands to allow for inherent material and production variability. It bears repeating that these target values and specification bands are based on the JMF and not any general HMA gradation requirements. Thus, the mix designer is allowed substantial freedom in choosing a particular gradation for the JMF and then the manufacturer is expected to adhere closely to this JMF gradation during production.

E. Tests on Mixes

1. Marshall Mix Design

Marshall mix design is a standard laboratory method, which is adopted worldwide for determining and reporting the strength and flow characteristics of bituminous paving mixes. In India, it is a very popular method of characterization of bituminous mixes. This test has also been used by many researchers to test HMA mixes. This test method is widely accepted because of its simplicity and low cost. Considering various advantages of the Marshall method it was decided to use this method to determine the optimum binder content and also study various Marshall characteristics such as Marshall stability, flow value, unit weight, air voids etc. Following figures shows the Marshall apparatus with loaded Marshall specimen.

1.1 Steps of design

The following are the main steps involved in the mix design process:

1. Select aggregate to be used.
2. Determine the proportion of each aggregate size required to produce the design grading.
3. Prepare the trial specimens with varying asphalt contents.
4. Determine the specific gravity of each compacted specimen.
5. Perform stability and flow tests on the specimens.
6. Calculate the percentage of voids, and percent voids filled with bitumen in each specimen.
7. Select the optimum binder content as the bitumen content corresponding to 4% air voids from the bitumen content vs. air voids graph.
8. Evaluate the design with the design requirements.

In the present study three compacted samples for each binder content and one loose mix (without compaction) are prepared. The compacted ones are tested for stability and flow values determination and the loose mix is used to calculate the air voids present in the specimen. After determination of Optimum Binder Content (OBC) the same process is repeated for crumb rubber modified bitumen using binder content as the OBC found above.

1.2 Preparation of sample

The coarse aggregate, fine aggregate, and the filler material should be proportioned so as to fulfill the requirements of the relevant standards. The required quantity of the mix is taken so as to produce compacted bituminous mix specimens of thickness 63.5 mm. Approximately, 1200 gm of aggregates and filler are required to produce the desired thickness.

Fig.3: Weighing of Different sizes of Aggregates.

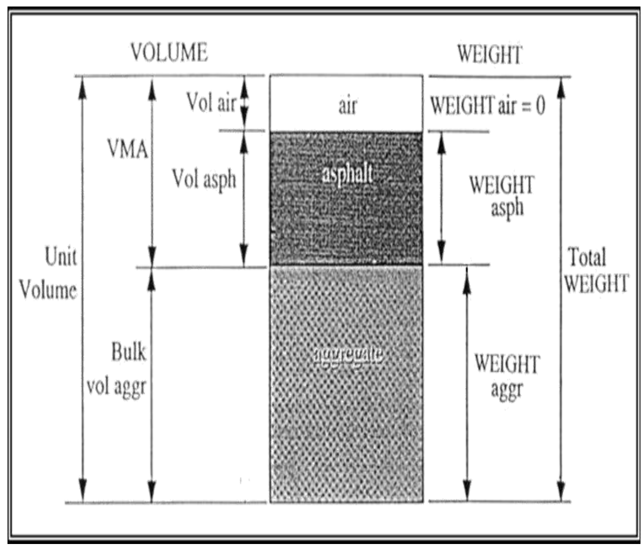

Fig. 4: Component Diagram of Compacted Sample.

Fig.5: Marshall moulds using Crumb Rubber Modified Bitumen.

The aggregates are heated to a temperature of 175°°C to 190°C the compaction mould assembly and rammer are cleaned and kept pre-heated to a temperature of 100°C to 145°C (see fig 3). The bitumen (plain and crumb rubber modified) is heated to a temperature of 121°C to 138°C and the required amount of first trial of bitumen is added to the heated aggregate and thoroughly mixed. The mix is placed in a mould and compacted with 75 number of blows on both the sides of the specimen. The sample is taken out of the mould after 24 hours using sample extractor and further tested. Fig 4 and 5 shows the component diagram of compacted sample and Marshall moulds using Crumb Rubber Modified Bitumen.

2. Air Voids (Va)

Air voids are small air spaces or pockets of air that occur between the coated aggregate particles in the final compacted asphalt mixture. A (4%) of air voids is necessary in all hot mix asphalt mixes to prevent the pavement from flushing, shoving, and rutting. The percent of air voids (Va) by volume in the specimen is given by:

$$Va = 100 [1- (Gmb / Gmm)] \quad (1)$$

Where;

Gmb = Bulk specific gravity

Gmm = Theoretical maximum specific gravity

3. Voids in Mineral Aggregate (VMA)

Voids in the mineral aggregate (VMA) are the void spaces that exist between the aggregate particles in the compacted paving asphalt mixture, including the space filled with the binder. VMA represents the space that is available to accommodate the effective volume of binder (i.e all of the binder except the portion lost by absorption into the aggregate) and the volume of air voids necessary in the asphalt mixture. The more VMA in the dry aggregates, the more the space available for the binder. The percent of voids in the mineral aggregate (VMA) in the specimen is given by:

$$VMA = 100 [1– ((Gmb (1- Pb)) / Gsb)] \quad (2)$$

Where;

Gmb = Bulk Specific Gravity of compacted mix.

Gsb = Bulk Specific Gravity of total aggregate.

Pb = Percent of bitumen by weight.

The Bulk Specific Gravity of combined total aggregate (Gsb) can be determined using the formula given by:

$$Gsb = \frac{P1+P2+P3+....+Pn}{P1/G1+P2/G2+.....+Pn/Gn} \quad (3)$$

Where; P1, P2, P3……………=(%) proportions of different sizes of aggregates G1, G2, G3……......= Specific Gravities of different sizes of aggregates corresponding to P1, P2, P3……..Pn.

4. Voids filled with Bitumen (VFB)

Voids filled with bitumen (VFB) is the voids in the mineral aggregate frame work filled with the bitumen. It is inversely related to the percent air voids present in the specimen and is calculated as;

$$VFB = 1- (Va / VMA) \quad (4)$$

Where;

Va = % Air voids

VMA = Voids in mineral aggregate

5. Marshall Stability-Flow Tests

The Marshall stability of the mix is defined as the maximum load carried by the specimen at a standard test temperature of 60ºC. In conducting the stability test, the specimen is immersed in a bath of water at a temperature of 60° ± 1°C for a period of 30 minutes. It is then placed in the Marshall Stability testing machine and loaded at a constant rate of deformation of 5 mm per minute until failure. The total maximum in kg (that causes failure of the specimen) is taken as Marshall Stability. The stability value so obtained is corrected for volume of the specimen. The total amount of deformation is units of 0.25 mm that occurs at maximum load is recorded as Flow Value. The total time between removing the specimen from the bath and completion of the test should not exceed 30 seconds it shows in fig 6.

Fig.6: Marshall Tests Setup.

IV.ANALYSIS OF TEST RESULTS AND DISCUSSION

A. Introduction

It is mentioned earlier that 60/70 penetration grade bitumen have been used in the bituminous concrete mixes with hydrated lime as a filler and crumb rubber is added for modification. The details of the experiments carried out on these HMA mixes which were given in the previous chapter. In this chapter the results and observations of the tests conducted are presented, analyzed, and discussed.

B. Test Results of Plain and Modified Bitumen

1. Tests for plain bitumen

TABLE I: Results of Tests For Plain Bitumen

S.n	Test	Average Value
1	Penetration	49mm
2	Softening point	53°C

2. Tests for CRMB mix

TABLE II: Results of Tests for CRMB Mix

S.n	Sample	Crumb Size(mm)	Avg.Pentration (mm)	Avg.Softening point
1	Sample A	1-0.6	43.33	56.8°C
2	Sample B	0.6-0.3	41.17	58.05°C
3	Sample C	0.3-0.15	38.88	61.85°C
4	Sample D	0.15-0.075	36.17	63.7°C

TABLE III: Blending of Different Sizes of Aggregates For BC Gradation

Aggregate Blending for BC												
(Spec. Limits As per MORT & H,Table 500-18,Grading-1)												
Aggregate size (mm)	Description	% Passing I.S Sieves										
	I.S Sieve Size (mm)	26.5	19.0	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
20mm	Individual Gradations	100	85.67	31.87	2.9	0.00	0	0	0	0	0	0
10mm		100	100	99.5	75.26	9.8	2.4	1.7	2	1.51	1.34	1.04
Stone dust		100	100	100	100	96.6	76.9	54.6	40.4	25.4	14.0	6.2
Filler		100	100	100	100	100	100	100	100	100	100	90.3
	% Feed											
20mm	35	35.0	30.0	11.2	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10mm	24	24.0	24.0	23.9	18.1	2.4	0.6	0.4	0.4	0.4	0.3	0.2
Stone Dust	40	40.0	40.0	40.0	40.0	38.6	30.8	21.8	16.2	10.2	5.6	2.5
Filler	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.90
Combined Grading (JMF)		**100.0**	**94.98**	**76.02**	**60.07**	**41.98**	**32.33**	**23.25**	**17.55**	**11.53**	**6.92**	**3.62**
Spec.Upper Limits		100	100	79	72	55	44	34	27	20	13	8
Spec.Lower Limits		100	79	59	52	35	28	20	15	10	5	2
Mid Limits		100	90	69	62	45	36	27	21	15	9	5
Permissible variation		+/-7	+/-7	+/-6	+/-6	+/-5	+/-4	+/-4	+/-4	+/-3	+/-3	+/-1.5
JMF Upper Limit		100	100	79	72	47	39	27	22	15	10	5.5
JMF Lower Limit		100	92	72	60	37	30	20	14	10	5	2.5

TABLE IV: Composition of Bituminous Concrete Mix

Sieve size(mm)	JMF	aggregate %	Wt.of agg(gm)	Cummulative wt. (gm)
26.5	100	5.02	60.24	-
19	94.98	18.96	227.52	287.76
13.2	76.02	15.95	191.4	479.16
9.5	60.07	18.09	217.08	696.24
4.75	41.98	9.65	115.8	812.04
2.36	32.33	10.08	120.96	933
1.18	22.25	4.75	57	990
0.6	17.5	5.97	71.64	1061.64
0.3	11.53	4.61	55.32	1116.96
0.15	6.92	3.3	39.6	1156.56
0.075	3.62	2.62	31.44	1188
FILLER	1	1	12	Total =1200

TABLE V: Table for Marshel Stability

Bitumen Content %	Sample No.	Wt. in Air	Wt. in Water	SSD Wt. in Air	Avg Ht.	Vol. of specimen	Unit Wt.	G_{mb}	G_{mm}	(Va) %	VMA %	VFB %	MARSHALL STABILITY				Flow (mm)
													Reading	Load(Kg)	C.F	Corrected	
4	1	1.240	0.709	1.256	7.03	551.964	2.276	2.267	2.456	6.36	17.06	62.74	216	1166.4	0.89	1038.10	2.15
	2	1.230	0.711	1.235	6.58	516.607	2.391	2.347					271	1463.4	1	1463.40	3.64
	3	1.241	0.712	1.255	6.73	528.393	2.375	2.285					223	1204.2	0.96	1156.03	1.98
	AVERAGE						**2.347**	**2.300**	AVERAGE							**1219.18**	**2.59**
4.5	1	1.233	0.709	1.236	6.45	506.786	2.439	2.340	2.453	5.52	16.84	67.21	238	1285.2	1.04	1336.61	2.76
	2	1.241	0.707	1.244	6.50	510.714	2.436	2.311					264	1425.6	1	1425.60	4.03
	3	1.250	0.710	1.253	6.75	530.357	2.363	2.302					214	1155.6	0.96	1109.38	2.67
	AVERAGE						**2.412**	**2.318**	AVERAGE							**1290.53**	**3.15**
5	1	1.249	0.715	1.251	6.53	512.679	2.440	2.330	2.441	4.47	16.74	73.31	282	1522.8	1	1522.80	4.61
	2	1.251	0.713	1.252	6.63	520.536	2.405	2.321					258	1393.2	1	1393.20	3.23
	3	1.252	0.719	1.253	6.95	546.071	2.295	2.345					238	1285.2	0.93	1195.24	2.87
	AVERAGE						**2.380**	**2.332**	AVERAGE							**1370.41**	**3.57**
5.5	1	1.251	0.712	1.253	6.83	536.250	2.337	2.312	2.406	3.87	17.89	78.38	248	1339.2	0.96	1285.63	4.39
	2	1.249	0.713	1.250	6.75	530.357	2.357	2.326					216	1166.4	0.96	1119.74	3.64
	3	1.253	0.710	1.255	6.78	532.321	2.358	2.299					237	1279.8	0.96	1228.61	4.44
	AVERAGE						**2.350**	**2.312**	AVERAGE							**1211.33**	**4.16**
6	1	1.261	0.717	1.265	6.70	526.429	2.403	2.301	2.392	3.95	18.86	79.03	166	896.4	0.96	860.54	4.04
	2	1.259	0.716	1.270	7.05	553.929	2.293	2.273					236	1274.4	0.89	1134.22	6.03
	3	1.259	0.719	1.262	6.85	538.214	2.345	2.319					184	993.6	1	993.60	5.55
	AVERAGE						**2.347**	**2.297**	AVERAGE							**996.12**	**5.21**

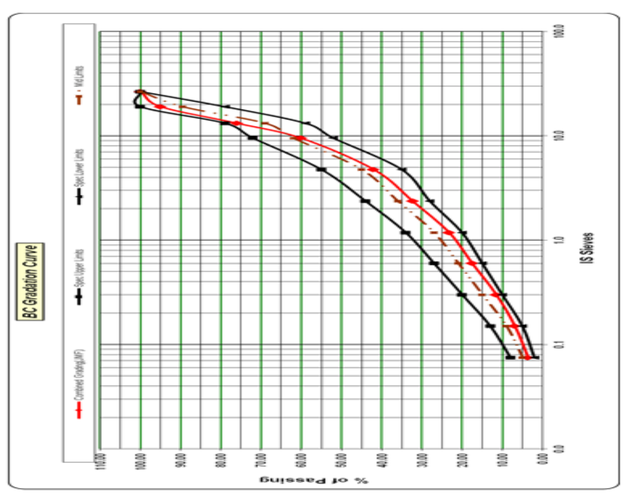

Fig7: BC Gradation Curve.

C. Summarized Test Results of Aggregates

TABLE VI: Summarized Results of Various Tests on Aggregates

Property	Description	Results	Test method
Particle shape	Flakiness and Elongation Index (combined)	21.75%	IS 2386 Part I
Strength	Los Angeles Abrasion Value	24.62%	IS 2386 Part IV
	Aggregate Impact Value	20.39%	
Toughness	Aggregate Crushing Value	22.06%	IS 2386 Part IV
Specific Gravity	20 mm	2.654	
	10 mm	2.656	
	Stone Dust	2.676	
Water absorption	20 mm	0.104	IS 2386 Part III
	10mm	0.095	
	Stone Dust	0.798	

D. Graphs of binder content with various Marshall Parameters

The figures from 8 to 13 shows the Graphs of binder content with various Marshall Parameters

1. UnitWeig

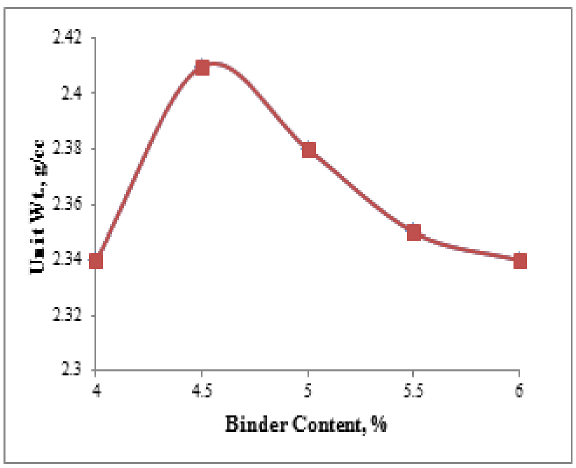

Fig.8: Variation of Unit Wt. with binder Content.

2. Marshall Stability

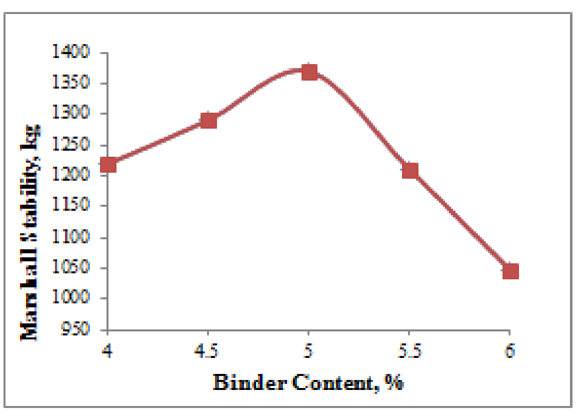

Fig.9: Variation of Marshall stability values.

3. Flow Value

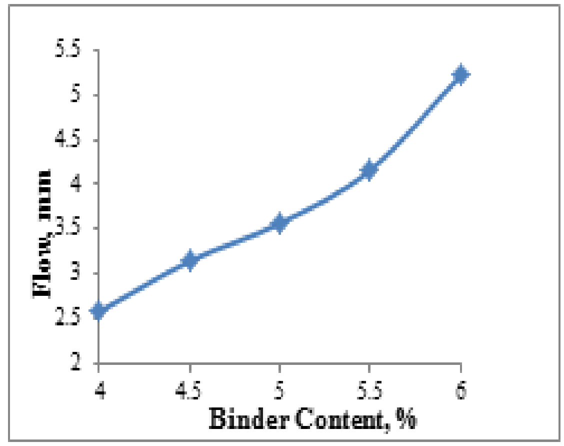

Fig.10: Variation of flow values with binder content.

4. Air Voids

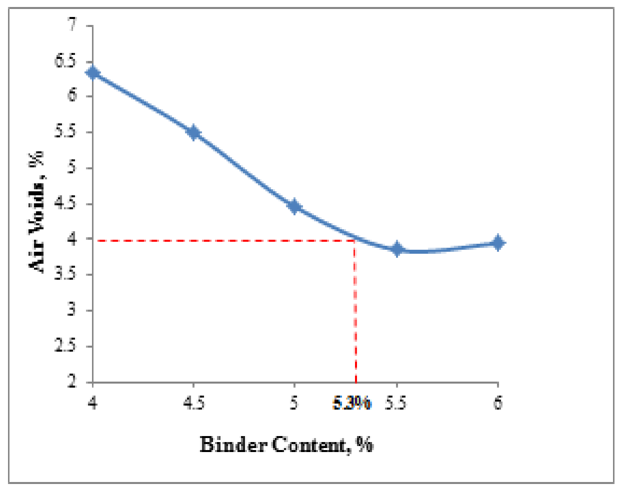

Fig.11: Variation of Air Voids with Binder Content.

5. Voids in Mineral Aggregate (VMA)

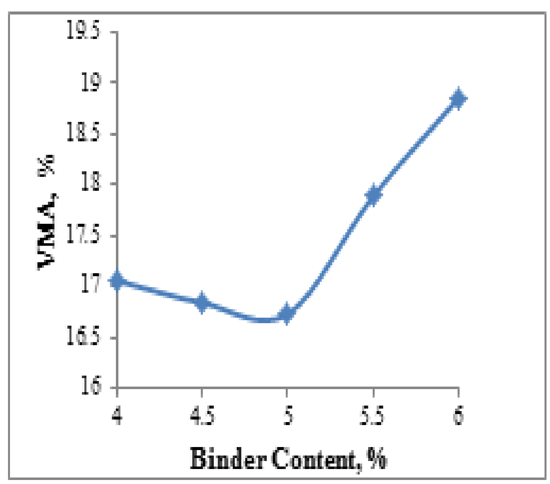

Fig. 12: Variation of VMA with Binder Content.

6. Voids Filled with Bitumen (VFB)

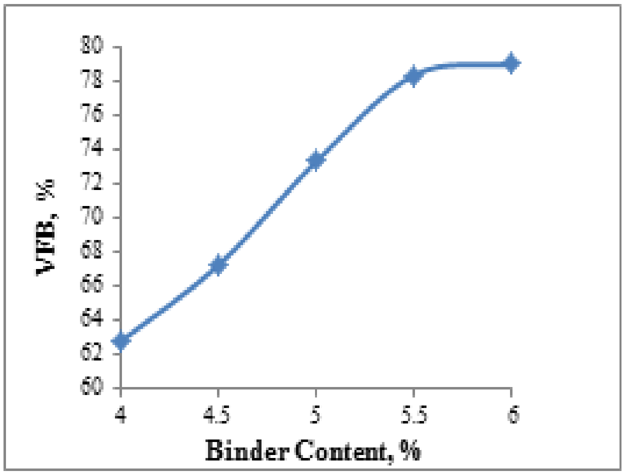

Fig. 13: Variation of VFB with Binder Content.

TABLE VII: Observation Table for Marshall Stability Tests on CRMB

Sample	Sample no	Wt. of specimen: in air (A)	Wt. of specimen: in water (B)	Wt. of specimen: SSD (C)	Avg.Ht	Vol. of the specimen	Unit Wt.	G_{mb}	G_{mm}	V_a %	VMA %	VFB %	Stability(kg): Reading	Stability(kg): Load Kg	Stability(kg): CF	Stability(kg): Corrected value	Flow mm
A	1	1.263	0.728	1.279	69.5	546.071	2.313	2.292	2.394	4.55	18.68	80.83	210	1134	0.93	1054.62	3.1
	2	1.258	0.722	1.276	70.25	551.964	2.279	2.271					305	1647	0.89	1465.83	4.7
	3	1.247	0.719	1.263	69	542.143	2.300	2.292					282	1522.8	0.93	1416.20	2.2
	AVERAGE						2.297	2.285								1312.22	3.33
B	1	1.25	0.719	1.272	69.25	544.107	2.297	2.260	2.364	3.93	19.75	76.45	355	1917	0.93	1782.81	5.2
	2	1.254	0.71	1.266	70	550	2.280	2.255					297	1603.8	0.89	1427.38	3.96
	3	1.256	0.718	1.276	71.5	561.786	2.236	2.251					286	1544.4	0.86	1328.18	3.6
	AVERAGE						2.271	2.256								1512.79	4.25
C	1	1.255	0.728	1.261	68.5	538.214	2.332	2.355	2.459	4.84	16.72	71.06	334	1803.6	0.93	1677.35	4.3
	2	1.248	0.719	1.26	67.75	532.321	2.344	2.307					297	1603.8	0.96	1539.65	2.9
	3	1.253	0.731	1.262	68.25	536.25	2.337	2.360					304	1641.6	0.96	1575.94	4.03
	AVERAGE						2.338	2.340								1597.64	3.74
D	1	1.26	0.729	1.276	69.75	548.036	2.299	2.303	2.362	2.33	17.89	86.97	254	1371.6	0.89	1220.72	5.8
	2	1.259	0.73	1.273	67.5	530.357	2.374	2.319					301	1625.4	0.96	1560.38	4.6
	3	1.262	0.725	1.274	71.25	559.821	2.254	2.299					272	1468.8	0.89	1307.23	4.3
	AVERAGE						2.309	2.307								1362.78	4.9

TABLE VIII: Results Of Tests For CRMB MIX

Sample	Crumb Size(mm)
Sample A	1-0.6
Sample B	0.6-0.3
Sample C	0.3-0.15
Sample D	0.15-0.075

E. Bar Charts of Effects of variation of Crumb Rubber sizes on Marshall parameters.

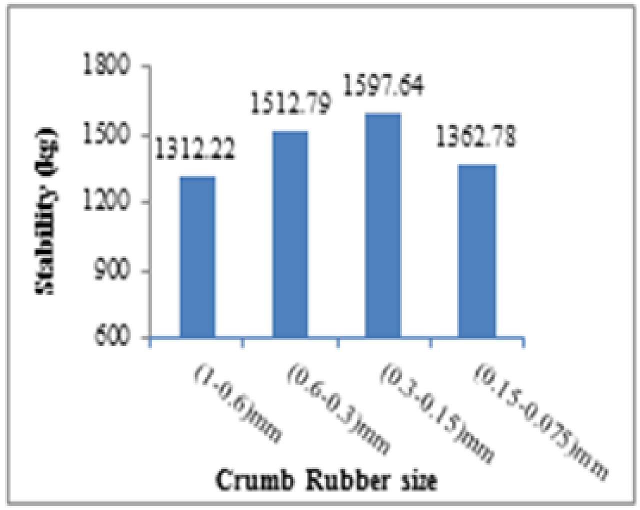

Fig.14: Effect of variation of sizes of Crumb Rubber in Stability values.

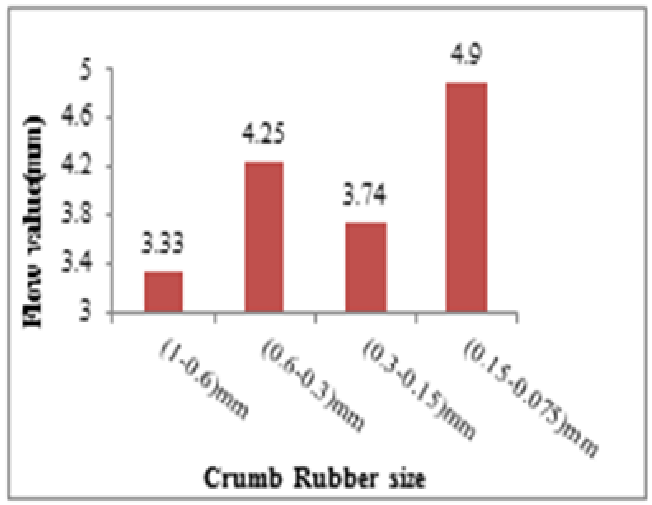

Fig.15: Effect of variation of sizes of Crumb Rubber in Flow values.

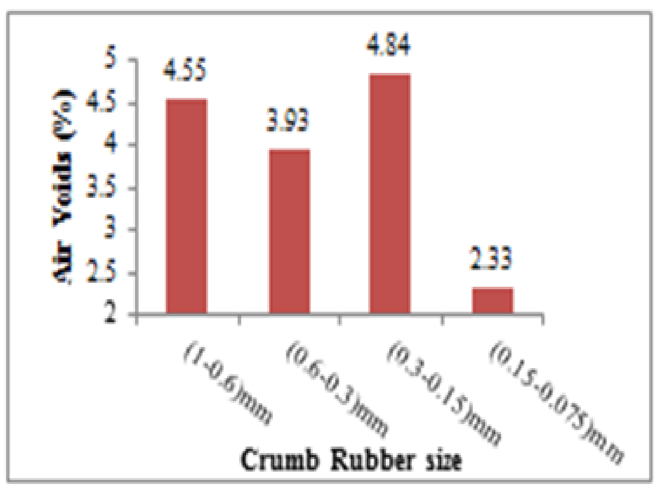

Fig. 16: Effect of variation of sizes of Crumb Rubber in Air Voids.

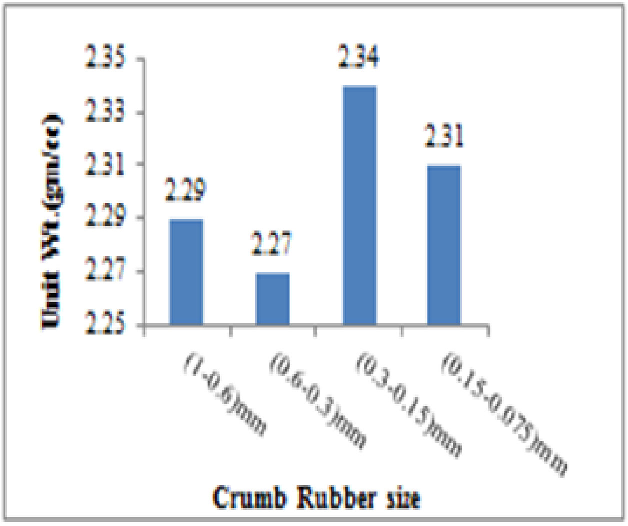

Fig. 17: Effect of Variation of sizes of Crumb Rubber in Unit Wt.

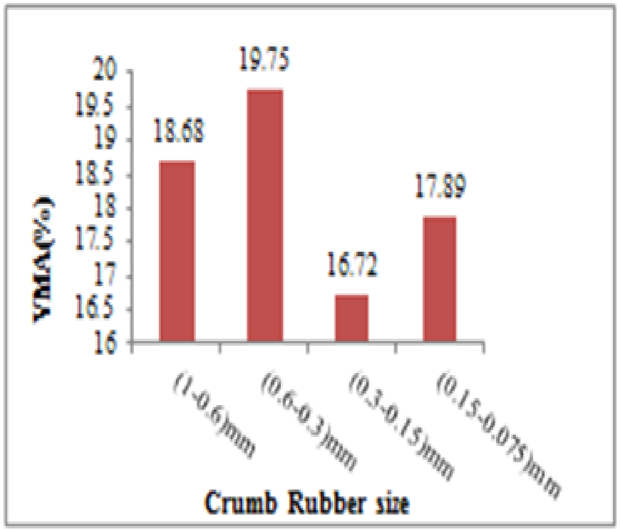

Fig.18: Effect of Variation of sizes of Crumb Rubber in VMA.

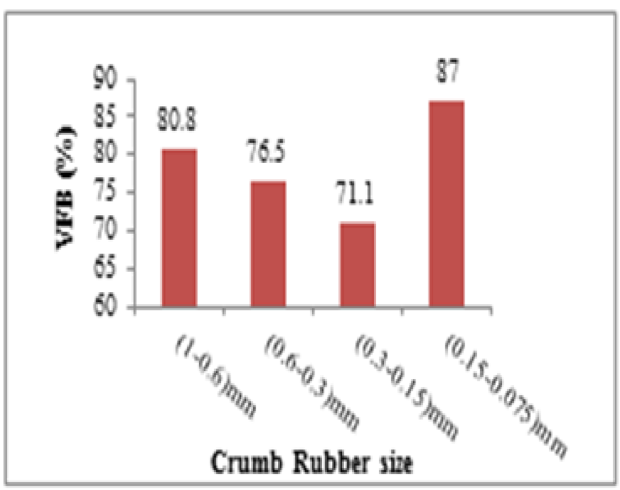

Fig.19: Effect of Variation of sizes of Crumb Rubber in VFB.

The figures from 14 to 19 depict the effects of variation of sizes of crumb rubber in stability values, flow values, air voids, unit Wt, VMA and VFB.

V. CONCLUSIONS

Today, a serious problem that leads to environment pollution is the abundance and increase of waste tire disposal. Large amounts of rubber are used as tyres for cars and trucks, and so forth. Although rubber as a polymer is a thermosetting material cross-linked to processing and molding, it cannot be softened or remolded by reheating unlike other types of thermoplastics polymer which can be softened and reshaped when heated. Due to an increase in service traffic density, axle loading and low maintenance services road structures have deteriorated and are therefore subjected to failure more rapidly. To minimize the damage of pavement such as resistance to rutting and fatigue cracking, asphalt mixture modification is required.

Virgin polymer offers the possibility of producing mixtures that can resist both rutting and cracking. Thus, using recycled polymer such as crumb rubber is a good alternative and inexpensive. Also, it is considered as sustainable technology, that is, “greening asphalt” which would transform unwanted residue into a new bituminous mixture highly resistant to failure. Thus, utilizing crumb rubber obtained from scrap automobile tyre is not only beneficial in terms of cost reduction but also has less ecological impact in keeping the environment clean and to achieve better balance of natural resources. The primary purpose of this research work was to study the various changes in the properties of crumb rubber modified bitumen to the plain bitumen. On the basis of laboratory tests performed in the study and graphs plotted, the following conclusions can be drawn.

- The crumb rubber obtained from waste disposed tires can be used to modify the asphalt mixture performance if added to aggregate with a specific size, thickness and content. Hence, the use of waste tire modified bitumen for pavement is one of the best methods for easy and safe disposal of discarded tires.
- As the size of crumb rubber decreases the penetration value decreases whereas the softening point increases this explains the swelling of the rubber particles during interaction with plain bitumen. So common laboratory properties can be improved significantly by crumb rubber modification.
- The modified bitumen sample prepared using crumb rubber size (0.3-0.15) mm give the highest stability value of 1597.64 kg among the other sizes which is more than the maximum stability value 1370.41 kg obtained using just the plain VG 30 bitumen. The stability is increased by 16.6 % on modification.
- Further with (0.3-0.15) mm size of crumb rubber 3.74 mm flow value, 4.84 % air voids, maximum unit weight of 2.34 gm/cc, minimum VMA of 16.72% and minimum VFB of 71.1% values are obtained in comparison to other sizes of crumb rubber. So it can be

recommended that the best size of crumb rubber to be used for commercial production of CRMB would be (0.3-0.15) mm.

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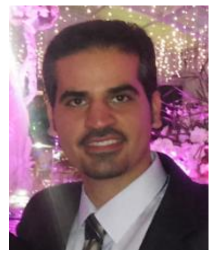
Author’s Profile:

Foad Ali Zolfaghari, Post graduate student of Transportation Engineering from JNTUH, Hyderabad, India.



Farzad zolfaghari, Graduate Student of Azad University.

Mohammad Javid, Post Graduate Student of Azad University.