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EXPERIMENTAL STUDY ON FLEXIBLE PAVEMENT PERFORMANCE WITH CRUMB RUBBER MODIFIED BITUMEN

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ABSTRACT

India has embarked on a massive road construction and maintenance projects that will cost billions of rupees. India's road network is currently around 58 lakh kilometres long, carrying around 65 percent of freight and about 90 percent of passenger traffic. The number of automobiles has increased at a pace of 10.16 percent each year on average over the last five years. The roads are under a lot of strain and need to be widened and expanded to handle the increased traffic. The road's permanence is determined by a variety of elements, one of which is the binder's quality, which has a significant impact on the road's performance. The disposal of waste tyres in large quantities is a severe matter that pollutes the environment. Crumb rubber is made by mechanically pulverising scrap tyres, a process that has been shown to improve the characteristics of paving grade bitumen for decades. This is not only inexpensive, but it also offers a remedy to the environmental problems brought by rising rubber consumption. The midwifed bitumen has been developed by blending the crumb rubber to the conventional viscosity grade bitumen.

Keywords: *waste tyres, pulverising, environmental, viscosity*

1. INTRODUCTION

Bituminous mixes are used widely for paving applications in India and worldwide. Appropriate bituminous mix design is very vital to achieve high rut resistant as well as fatigue resistance mix. The serviceability of bituminous pavements during the design life is determined by the selection of appropriate paving binders while taking into account climatic and loading conditions, as well as the scientific design of the thicknesses of various pavement layers. Rutting, crack initiation and propagation in flexible pavements are caused not only by traffic loads, but also by the heat susceptibility of bituminous binders. The quality and quantity of binder used have a significant impact on the mechanical qualities of bituminous mixes.

1.1 USE OF CRUMB RUBBER IN FLEXIBLE PAVEMENT CONSTRUCTIONS

Use of Crumb rubber in the construction of flexible pavements has been adopted since few decades back by using both Dry and Wet Processes. In the dry process, the rubber aggregate is partly used by substituting the mineral aggregate. In the wet process, the crumb rubber modified bitumen is prepared by blending the shredded crumb rubber with the conventional bitumen at temperature between 160^0c to 170^0c by using mechanical means.

1.2 MAKING PROCESS OF CRUMB RUBBER

There are two techniques used generally to produce the Crumb Rubber i.e., Ambient grinding and Cyogenic process. Further, in the Ambient grinding two types of mechanical means are used to produce Crumb rubber i.e., Granulation and Cracker mills. In the ambient grinding technique, a series of machineries are used to distinct the steel, rubber and fibre components. In both Granulation and Cracker mills, the first processing phase is to lower the raw tyres to small pieces. The material is fed into the granulator or crack mill at room temperature. The second machine in this technology will grind the big size rubber aggregate to separate the rubber from fibre and steel. In the next process, a separate screening system will distinct the required sized particles and the screening system redirects the oversize granules to the second machine. The cracker mill produces crumb rubber particles that are typically long and narrow in shape, with a large surface area.

In the Cryogenic process liquid nitrogen is used to freeze the rubber prior to do the size reduction. Cryogenic temperatures can be used at any stage of the scrap tyre size reduction process. The size of the material while feeding in this process is generally below 2 inches. The raw rubber material is cooled by using liquid nitrogen in the tunnel chamber. Thereafter the cooled rubber is processed into small pieces by using the hammer mill.

1.3 SOURCE OF MATERIAL

The waste tyres has been obtained from tyre replacement shop at Asifabad and prepared the Crumb rubber of size passing from 0.300mm and retained on 0.150 mm by using mechanical means. The Bitumen grade of VG-40 is from BPCL, Mumbai and the aggregate is from Kowtala quarry, Asifabad district, Telangana.

2. LITERATURE REVIEW

2.1 BRIEF OVERVIEW

Many experts have sought to identify various waste materials that can be employed in the construction of pavement sections. A number of studies have been carried out on the Crumb Rubber Modified Bitumen (CRMB) to improve the engineering properties of the bitumen. In India, the techniques implemented to design the flexible pavements are mostly based on experiential formulae established based on AASHTO guidelines. The rheology of CRMB depends on various internal factors like quantity of crumb rubber, mesh size, source, type, and pure bitumen composition, and external factors like temperature, curing time, mixing time, mixing rate and mixing process etc.,

2.2 RESEARCH CONTRIBUTIONS

International Journal of the Physical Sciences Vol. 7(2), pp. 166 - 170, 9 January, 2012[1]
Nuha S. Mashaan, Asim Hassan Ali Mohamed Rehan Karim and Mahrez Abdel Aziz presented presents their research in this paper titled ‘An overview of crumb rubber modified asphalt’. This review study presented the application of crumb rubber modifier in the asphalt modification of flexible pavement. From the results of previous studies, it aspires to consider crumb rubber modifier in hot mix asphalt to improve resistance to rutting and produce pavements with better durability by minimizing the distresses caused in hot mix asphalt pavement. Hence, road users would be ensured of safer and smoother roads. Waste was selected for further investigations.

International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-8, Issue-1, May 2019[2] Hanumantharao, Anil Pradhyumna, Durga Prasad, Naveen Kumar, Shantha Kumar Reddy, Hemanth Vardhan presents their research in the paper titled ‘Crumb Rubber Modified Bitumen and Quarry Dust in Flexible Pavements’. The comparison of pure bitumen and modified bitumen using waste crumb rubber is studied experimentally and discussed about the resistance against fatigue cracks, rutting cracks, strength of bitumen road and durability of modified bitumen at both high temperatures and low temperatures using “Marshall Stability Analysis”. The quarry dust, which is another waste generating from the quarries, is used as fine aggregate and filler. 15% of 20mm, 25% of 12.5mm, and 15% of 6 mm as coarse aggregate and 45% of quarry dust as fine aggregate and filler material is used. Waste crumb rubber materials are added to pure bitumen using wet process with percentage of 5%, 10%, 15% and 20% crumb rubber with size of 0.300mm to 0.150mm. Laboratory results indicated the crumb rubber can incur high elastic behaviour, low penetration and high softening point compared to pure bitumen. Also high stability and flow values of modified bitumen compared to pure bitumen concrete mix at both low and high temperatures.

Advances in Materials Science and Engineering, Volume 2013, May 2013[3] Mohd Rasdan Ibrahim presents their research in the paper titled "A Review on the Effect of Crumb Rubber Addition to the Rheology of Crumb Rubber Modified Bitumen" Crumb rubber modifications of bitumen have been proven to improve characteristics of bituminous binder such as the viscosity, softening point, loss modulus, and storage modulus. This subsequently improves the rutting resistance, resilience, and improving fatigue cracking resistance of asphaltic mixes. In order to achieve a superior and balanced CRMB in term of high and low temperature properties, factors such as the mixing time, temperature, characteristics, and source of the crumb rubber and bitumen type must be considered since these are the factors that govern the resulting performance of asphaltic mixes. Aging mechanism of CRMB is also important to be considered in order that the resulting CRMB has a workable viscosity to be applied in the construction process. Finally, chemical modification of CRMB is a new area that has promising possibilities in the future to further enhance the properties of CRMB and at the same time eliminate rubber particle settling problem that is one of the limiting factor in the current application of crumb rubber modified bitumen.

Mohammed Sadeque and K APatil, (2014) [4] The use of crumb rubber as a modifier performs to have positive effects on physical and strength properties of the binders, including improved penetration, softening point. However the ductility of the binder reduces with increase in Crumb Rubber content. It is therefore recommended to use the 5% to 10% of Crumb Rubber to keep the ductility with in permissible limit. The use of crumb rubber as an additive in bitumen modification would reduce pollution problems and protect our environment as well. There is a significant improvement in the stability value of bituminous concrete.

3. METHODOLOGY

3.1 PREPARATION OF CRUMB RUBBER MODIFIED BITUMEN

In preparing the Crumb Rubber Modified Bitumen, the paving bitumen of grade VG-40 about 500 g was heated to fluid condition in a metal container. For blending of crumb rubber with bitumen, the bitumen was heated to a temperature of 160 °C and after that crumb rubber was added at varying percentages of 8%, 10%, 12%, 14% and 16%. In the first trial, the crumb rubber of 8% by weight of bitumen is mixed manually for about 15 minutes manually. The mixed material has been thoroughly stirred with mechanical stirrer at a temperature of 170 to 180ºC for one hour. Thereafter the mix has been kept at room temperature and stored in a container for testing of various properties viz., Softening point, Penetration, Ductility, Elastic Recovery, Separation test etc., Similarly, the crumb rubber modified bitumen mixes have been prepared with rubber modifier of 10%, 12%, 14% and 16% by weight of bitumen.

3.2 CRITERIA FOR CRMB BASED ON ATMOSPHERIC TEMPERATURE AS PER IRC: SP-53-1999[17]

Different grades of CRMB bitumen is used based on the atmospheric temperature of the particular region. CRMB-55 grade bitumen is used for the moderate climate, whereas, CRMB-60 grade bitumen is used for the hot climate regions. The selection criterion is as per the table 1 shown below.

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Table 1: Selection criteria for CRMB based on Atmospheric Temperature as per IRC: SP-53-1999

Minimum Atmospheric Temperature, ^{0}C	Maximum Atmospheric Temperature, ^{0}C			
		< 30	30 to 40	>40
	< -15	CRMB-50	CRMB-55	CRMB-60
	15 to -15	CRMB-55	CRMB-55	CRMB-60
	>15	CRMB-55	CRMB-60	CRMB-60

3.3 PHYSICAL AND MECHANICAL PROPERTIES OF THE AGGREGATE OF VARIOUS SIZES

Various physical properties like Sieve analysis, Flakiness & Elongation index, coating and stripping of bitumen and Mechanical properties like Aggregate Impact value, Los Angles Abrasion Value, water absorption etc., has been conducted on different sizes of the aggregate 20mm, 10mm and quarry dust as per IS 2386 Part 1 to 5.Test results of the various mechanical properties are depicted in the Table 2.

Table 2: Test results of Aggregate

Property	Test	Test Result
Particle shape	Combined Flakiness and Elongation Index	27%
Cleanliness (passing 0.075 mm sieve)	Grain size Analysis	4%
Strength	Los Angeles Abrasion Value Aggregate Impact Value	22.74% 18.55%
Water Absorption	Water absorption	1.2%
Stripping (retained coating)	Coating and stripping of Bitumen Aggregate Mixtures	100%

3.4 PREPARATION OF BITUMINOUS CONCRETE MIX WITH CONVENTIONAL BITUMEN OF VG-40 GRADE AND CRUMB RUBBER MODIFIED BITUMEN (CRMB)

All individual sizes of aggregate and filler should be mixed at required proportionate so that the mix after mixing shall have the gradation within the required limits as per the design mix. The needed amount of mix is taken to make bituminous mix specimen after compaction with a height/thickness of about 63.5mm. Finally the Job Mix Formula (JMF) was adjusted based on the gradations of the individual size of the Aggregates. The selected mix proportions for the analysis are reported below.

19 mm size aggregate = 35%
10 mm size aggregate = 30%,
Stone dust = 33%
Cement Filler = 2%

1200 gm of mixed aggregate is taken to prepare the mould with a thickness of 63.5 mm as per the designed job m formulae. The conventional grade of Bitumen VG-40 and CRMB are heated separately at a temperature of 160°C to 170°C. The combined aggregate is heated to a temperature of 160°C to 175°C. Bitumen/CRMB at various percentages from 4.8% to 6.0% by weight of combined aggregate is mixed and heated the mix to a temperature of 160°C to 170°C. The difference in temperature between bitumen and aggregate should not exceed 14°C during mixing process. The mix is thoroughly mixed by using hand trowel till a uniform coating is obtained on all the aggregate. Three specimens are prepared in each batch at different percentages of bitumen content. The Marshall Moulds and hammer are simultaneously cleaned and preheated up to a temperature of 150°C by using hot plate and applied glycerine on inside faces of the moulds. A filter paper is placed at bottom surface of the mould and the prepared mix is transferred into the mould and laid in three equal layers and tampered by using spatula. The mix is compacted with 75 blows on each face of the mould by using Marshall Hammer. During the compaction the temperature of the mix is in between 160°C to 170°C. Similar procedure is adopted for preparation of moulds at various percentages of Bitumen/CRMB. The moulds are kept at room temperature for 24 hours and thereafter the specimens are extracted from the moulds by using the Marshall extractor.

3.5 TESTING OF MARSHALL PROPERTIES

The specimens are kept submerged in a thermostatic water bath maintained at 60^0 C+/- 10^0 C for a period of 30 to 40 minutes. The specimens are taken out from water bath one by one and the outer surface shall be cleaned by using cloth. The specimens are positioned in the testing apparatus head to determine the Marshall Stability and flow. The ultimate load carried by the specimen before its failure designates the “Marshall Stability” value and the deformation by the specimen undergoes during maximum load indicates the “Flow” value. The flow value is measured in 0.25mm units. The appropriate correction factor is used to calculate the corrected “Marshall Stability” value of individual specimen. Before conducting the stability and flow testing, the other tests like unit weight, Maximum specific gravity of mix on test specimens are conducted to find out the other Marshall parameters Air voids, voids in mineral aggregate (VMA) and voids filled with bitumen(VFB).

4 DATA ANALYSIS AND DISCUSSION OF RESULTS

4.1 TEST RESULTS OF CRUMB RUBBER MODIFIED BITUMEN

Test results of the conventional viscosity grade bitumen of VG-40 and modified bitumen blended with crumb rubber with different percentages by weight of bitumen are shown in the given Table 3. From the test results, all the basic parameters of the binder are meeting the specified criteria with the rubber content from 12% to 14% IRC: SP: 53-2002. By blending Crumb Rubber at 14% by weight of the bitumen, it is perceived that the Penetration is reduced by 25.5% and Softening point is increased by 18.9%. The range of ideal percentages of crumb rubber waste for further investigations into Bituminous Concrete Mix was chosen based on the performance of the modified bitumen.

Table 3: Test results of Crumb Rubber Modified Bitumen (CRMB)

Sl.no	Property	Test results of VG-40	Test Result of CRMB				
			8% of CR	10% of CR	12% of CR	14% of CR	16% of CR
1	Penetration (1/10 mm)	47	42	40	38	35	32
2	Softening Point(^{0}C)	53	56	59	61	63	64
3	Ductility (Cm)	97	NA	NA	NA	NA	NA
4	Elastic Recovery (%)	NA	40	51	56	64	66

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The following figures 4.1 to 4.3 depicts the changes in different parameters like Penetration, Softening point and Elastic recovery at various percentages of crumb rubber by weight of bitumen.

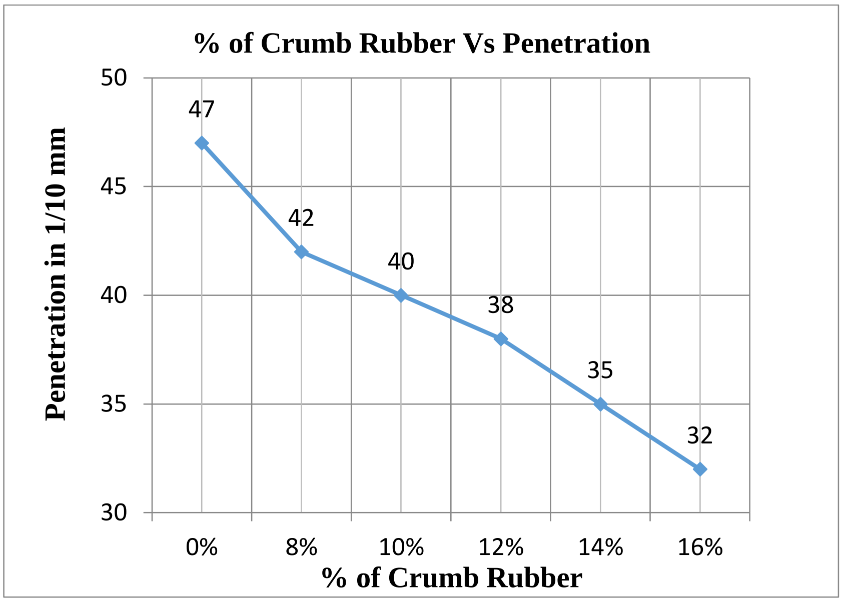

Figure 4.1 Graph showing % of Crumb Rubber vs Penetration

From the above figure 4.1, it is observed that the Penetration is reduced from 47 to 32 due to blending of crumb rubber.

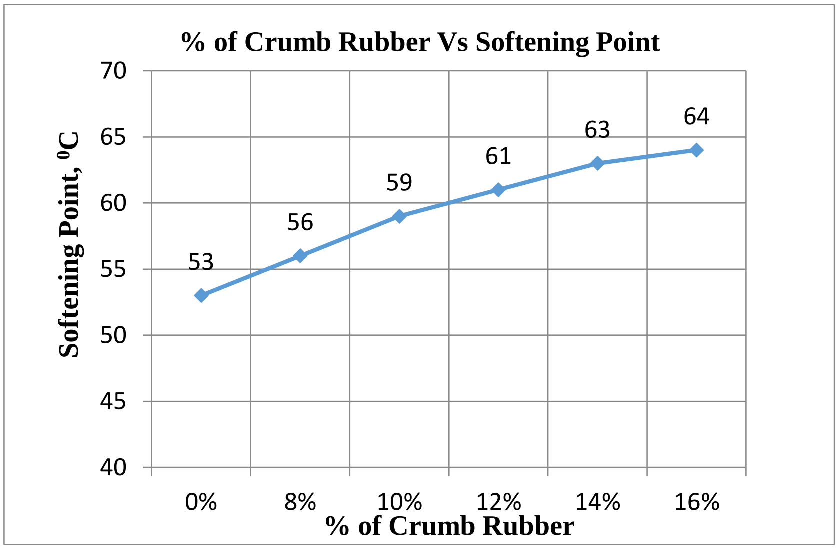

Figure 4.2 Graph showing % of Crumb Rubber vs Softening point

From the above figure 4.2, it is observed that there is profound change in the softening points by blending crumb rubber to the plain paving grade bitumen. The softening point is increased to 64^0c from 53^0c due to blending of crumb rubber at 16% by weight of bitumen.

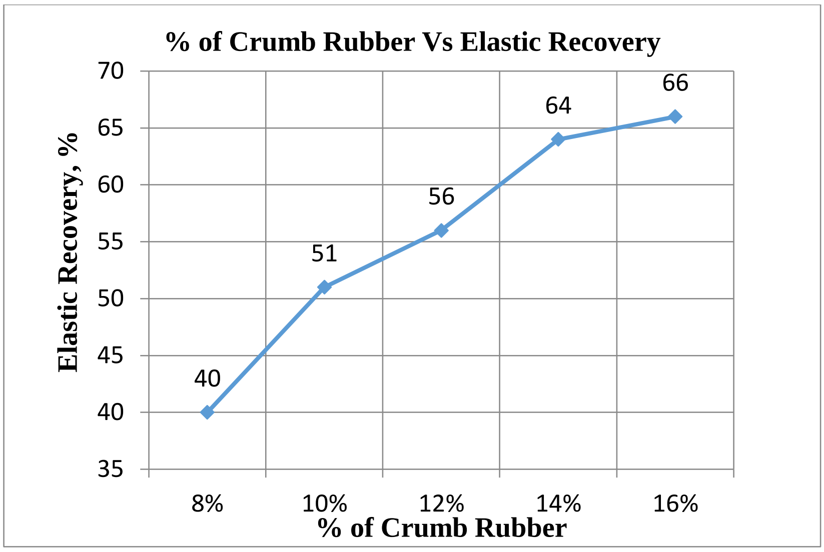

Figure 4.3 Graph showing % of Crumb Rubber vs Elastic Recovery

From the above figure 4.3, it is observed that there is significant improvement in the Elastic recovery property by using the crumb rubber from 8% to 16% in the bitumen.

4.2 TEST RESULTS OF MARSHALL PROPERTIES

Marshall parameters like Stability, Flow, VA, VMA and VFB are determined from "Marshall Stability" test to assess the "optimum binder content" and quality of Bituminous Concrete. The range of ideal percentages of crumb rubber waste for further investigations into Bituminous Concrete Mix was chosen based on the performance of the modified bitumen. By using the "Crumb rubber modified bitumen", it is observed from the results that the Marshall stability of Bituminous Concrete mix increases by 27%, Bulk density reduces by 1% and Air voids increases by 8%. And also from the results of Refusal density, it is observed that, with VG-40 grade bitumen, the Air voids reduced by 52% when using the compaction effort of 75 blows to 400 blows on each face of the Marshall sample. However, with CRMB bitumen the Air voids reduced by 33% only. By using the 14% CRMB with the VG-40 bitumen, it is observed from the results that the Marshall stability of Bituminous Concrete mix increases by 27%, Bulk density reduces by 1% and Air voids increases by 8%. Test results of Marshall Properties with and without CRMB (blended with 14% CR) at varying percentages of the bitumen contents are shown in the Table 4and 5 respectively.

Table 4: Test results of Marshall Properties with VG-40 grade bitumen

Bitumen Content in %	Stability in kN	Unit Wt in gm/cc	Flow in mm	VA in %	VMA in %	VFB in %
4.80	13.92	2.351	2.5	5.29	15.52	65.90
5.10	15.20	2.354	3.1	4.75	15.68	69.73
5.40	15.89	2.355	3.5	4.27	15.90	72.25
5.70	15.66	2.353	3.7	3.93	16.25	75.79
6.00	15.19	2.351	3.9	3.57	16.57	78.48

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From the above test results it is observed that all the Marshall properties are meeting the specified criteria in the bitumen content range of 5.1% to 6.0%.

Table 5: Test results of Marshall Properties with CRMB

CRMB Content in %	Stability in kN	Unit Wt in gm/cc	Flow in mm	VA in %	VMA in %	VFB in %
4.80	15.45	2.320	2.7	6.39	16.64	61.59
5.10	16.59	2.324	3.0	5.77	15.68	69.73
5.40	17.51	2.342	3.6	4.62	15.90	72.25
5.70	17.28	2.345	4.0	4.04	16.25	75.79
6.00	16.37	2.339	4.4	3.88	16.57	78.46

From the above test results it is observed that all the Marshall properties are meeting the specified criteria within the bitumen content range of 5.1 % to 6.0%.

4.3 REFUSAL DENSITY

Some of the Asphalt concrete mix designs designed by using MS-2 have failed prematurely after few months of construction due to plying of heavily loaded vehicles which leads to plastic deformation/bleeding of bitumen/Rutting in the flexible pavements due to reduction of air voids in the mix. The importance of the refusal density is to achieve the required air voids in avoiding the plastic deformation. Refusal density has been conducted on the bituminous mix specimens prepared with VG-40 grade bitumen and CRMB at 5.4% of bitumen content with compaction effort of 75 to 400 blows on each side. Test results of the refusal density are shown in table 6 given below. From the results of Refusal density, it is observed that, with VG-40 grade bitumen, the Air voids reduced by 52% when using the compaction effort of 75 blows to 400 blows. Whereas, with CRMB bitumen, the Air voids reduced by 33% only.

Table 6: Test results of Refusal Density

No. of blows	Air voids(%) in Mix with VG-40	Air voids(%) in Mix with CRMB
75	4.27	4.64
100	3.74	4.48
200	3.09	3.91
300	2.34	3.42
400	1.63	3.09

The graphs have been plotted between Number of blows and Air voids for the mix prepared with normal paving bitumen (VG-40) and CRMB, which are shown in figure 4.4 and 4.5 respectively.

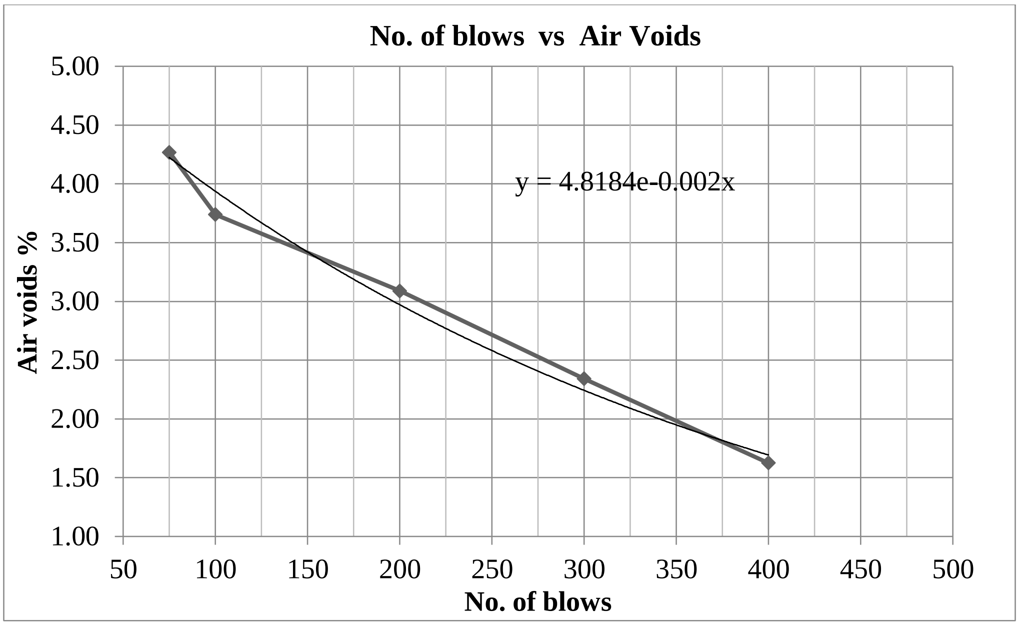

Figure 4.4 Refusal Marshall Curve showing No. of blows vs Air voids with VG-40

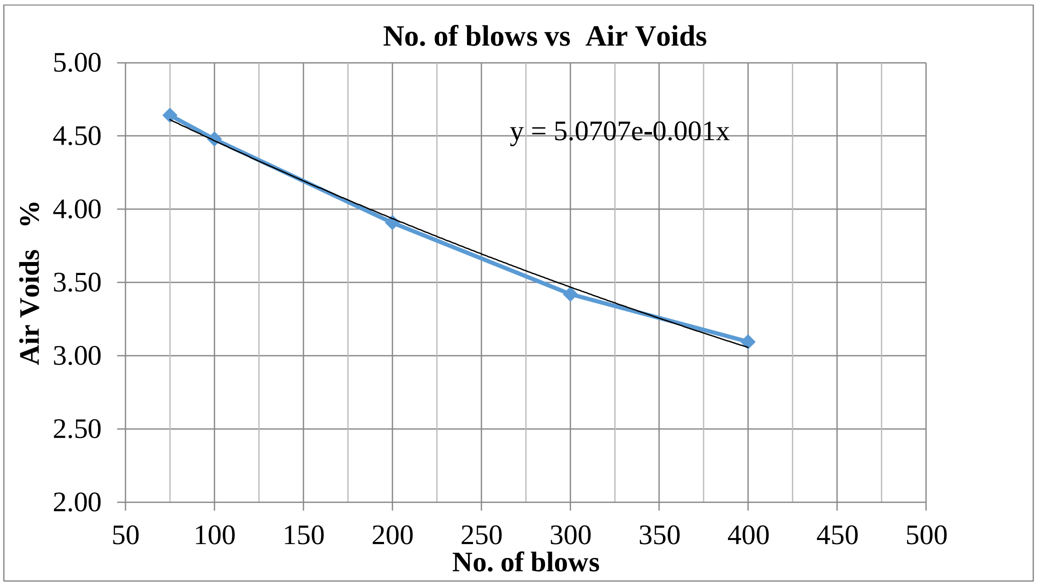

Figure 4.5 Refusal Marshall Curve showing No. of blows vs Air voids with CRMB

From the above figure 4.4, it is observed that the air voids reduced from 4.27% to 1.63% after applying the compaction effort of 400 blows. However, by using the CRMB, the air voids reduced from 4.64% to 3.09% only.

5. CONCLUSIONS

The goal of this study is to find a way to use waste materials, such as “crumb rubber” waste, on a large scale, such as in road and highway building, while being environmentally friendly. By blending the Crumb Rubber at 14% by weight of the bitumen, it is observed that the Penetration is reduced by 25.5% and Softening point is increased by 18.9%. And the Marshall properties of the of Bituminous Concrete mix like Stability increased by 27%, Bulk density reduced by 1% and Air voids increased by 8%. Rubber can help to improve the road's condition and performance. We can save certain quantity of natural stone aggregate and bitumen by using the Crumb Rubber in the bituminous mix. The use of waste Crumb rubber in the construction of roads also help in consume large quantity of waste Crumb rubber so that we can reduce the usage of valuable natural resources. The stabilization process is also very effective in controlling the environmental contamination; because the waste materials are completely reprocessed without any adverse impact on the environment. CRMB provides superior bonding between aggregate and increases the performance and pavement life.

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