International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8, Issue-1, May 2019

Crumb Rubber Modified Bitumen and Quarry Dust in Flexible Pavements

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*Abstract--- **In urban region, the crumb rubber materials is causing alarming environmental issues and can be utilized as a partial replacement of bitumen with waste crumb rubber materials to reduce the construction cost of top layer of 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 behavior, 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.***

*Index Terms: **Crumb rubber modified bitumen, Marshall Stability test, flexible pavement, fatigue and rutting cracks, utilization of waste crumb rubber***

I. INTRODUCTION

India has a road network of over 5.9 Million kilometers in 2019, the second largest road network in the world. It carries about 65% of its goods transport and 85% of passenger traffic, where flexible pavements primarily constituents 98% of road network (IBEF-2019). In India due to extensively varying climatic conditions, construction materials, terrains and mixed traffic conditions increased the traffic factors. Because of increased traffic factors the pure bitumen and pure bituminous concrete layer cannot withstand rutting, fatigue cracking, deformations, pot holing, wear & tear problems (Niraj, 2013). So the bitumen and bituminous mixes needs to be improved to meet the requirements of flexible pavement by adding of blend of additives, which are called "Bitumen Modifiers" and the bitumen premixed with these modifiers is known as modified bitumen (IS 73:2013). There are several modification processes and additives that are presently used in bitumen modifications such as polyethylene (PE), ethylene vinyl acetate (EVA), ethylene butyl acrylate (EBA), ethylene-methyl-acrylate (EMA), styrene isoprene styrene (SIS), styrene butadiene styrene (SBS), styrene butadiene rubber (SBR), natural rubber (NR) and crumb rubber modifier (CRM) (IS:15462,2004 & IRC SP-53,2010).

Waste tyres in India are categorized as hazardous waste. India is the second largest producer of replenishment rubber after china. In the year 2011, India produced 90,000 metric tonnes of reclaimed rubber in the form of waste tyres. The amount of waste rubber dumped in open wet land area causes an ideal breeding ground for mosquitoes and spread various dangerous diseases such as malaria, dengue fever and other viral infections (Nitu et. al., 2017). During tyres were fired huge hazardous gases releases to environment causing the air pollution with large quantities of carbon, hydrocarbon and residue. The land filling of waste tyres increases cost and land space and indirectly causing the reduction in natural materials.

In this scenario, it became regular practice to use modifier as additives to strengthen the bitumen for making long lasting bituminous mixes and also reducing the waste tyres across the world. Crumb rubber is a recycled rubber produces from automotive scrap tires which are primarily natural rubbers, synthetic rubbers and carbon black rubbers. During the recycling process, steel and tire lacing are removed, leaving tire rubber with a granular consistency or crack mill process. The scrap tire is shredded into small pieces by the help of crack mill of mechanical blades up to sizes of 1mm to 0.075mm. Scrap tire rubber can be added into bitumen paving mixes using two different methods which are referred as the wet process and the dry process. Here the crumb rubber is added to pure bitumen at 180°C to 200°C temperature by using wet process (Nabin, 2014). Addition of crumb rubber to bitumen increases the modified bitumen viscosity, softening point and lower susceptibility to temperature variations, higher resistance to buckling at elevated pavement temperature.

Revised Manuscript Received on 30 May 2019.

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These modified bitumen shown higher durability, better adhesion between aggregate & binder, prevention of cracking, reflective cracking, and overall improved performance in extreme climatic conditions under heavy traffic condition (Shubham et. al., 2017).

II. MATERIALS USED

VG-30 grade bitumen is obtained from Sri Mukha Road Products & Civil Labs Pvt. Ltd, which is an approved lab at Perecherla, Guntur, Andhra Pradesh., India. Scrap tyre is used as Crumb Rubber Modifier (CRM), which is shredded into small pieces by the help of crack mill of mechanical blades up to sizes of 1mm to 0.075mm. Crumb rubber pieces are sieved through 0.600 mm sieve and passing material is collected between 0.300mm to 0.075mm. Coarse aggregates of 20 mm, 12.5 mm, and 6 mm sizes are derived from basalt rock from UBS stone crusher from Perecherla, Guntur, Andhra Pradesh, India. Quarry dust from UBS stone crusher from Perecherla, Guntur is used as fine aggregate and filler material.

III. METHODOLOGY

Preparation of Crumb Rubber Modified Bitumen (CRMB)

In preparing the modified bitumen, 1500g bitumen was heated to a fluid condition in a 3-litre capacity metal container. CRMB is produced by the wet process in which bitumen heated at a temperature around 160°C to 180°C and then crumb rubber was added. Crumb rubber particles added to the plain bitumen with percentages of 5%, 10%, 15% and 20% with size of 0.300mm to 0.150mm. In preparing the 5% CRMB sample, mixture is stirred manually for 15 minutes at 160°C temperature with help of Gas stove until there is a reaction between the bitumen and crumb rubber. After that 5% CRMB sample mixture stirred with the help of Mechanical stirrer with a speed of 2000 rpm stirred for one hour at 180°C to 200°C temperature with help of hot oven, which is also combined with stirrer as shown in Figure 1. The rubber particles swell as they absorb oils, which cause the viscosity of the 5% CRMB sample to increase during the first hour. The 5% CRMB sample is cooled at room temperature and suitably stored for testing. Similar procedure is followed to prepare 10%, 15% and 20% CRMB samples but 10%, 15% and 20% CRMB samples is stirred one hour 30 minutes, two hours and 3 hours respectively at 180°C to 200°C temperature.

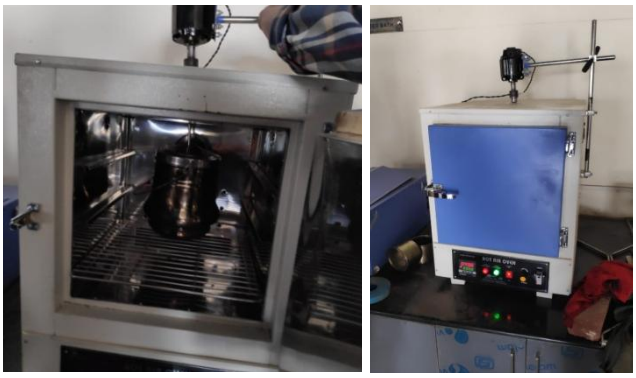


Figure 1: Mixing crumb rubber and bitumen with mechanical stirrer with oven

Physical properties of pure Bitumen and CRMB

The physical properties such as Softening point test, penetration test, viscosity test, ductility test and specific gravity test on the pure bitumen and 5%, 10%, 15%, 20% CRMB are conducted as per IS: 1201-1220 (1978) and the results are provided in Figure 2A to Figure 2 E respectively.

Physical Properties of coarse aggregates (20mm, 12.5mm, 6mm) and quarry dust

The aggregate crushing value test, aggregate impact value test, Los Angeles abrasion test, specific gravity test, water absorption test, shape tests (flakiness index elongation index tests) and aggregate stripping value tests are conducted as per IS: 2386 part 1 to part 5, 1963 as reported in Table 1.

Preparation of Bituminous Mix and Crumb rubber Bituminous Mix

Bituminous concrete mix gradation and blending is made as per specifications stated in MORTH 5th revision table 500-17 for bituminous concrete pavement layers. Aggregates are oven dried and sieved according to BC gradation and separated. 15% of 20mm, 25% of 12.5mm, 15% of 6mm and 45% of quarry dust is mixed which produced a mixed aggregate of 1250gm as per gradation. Bitumen / CRMB and aggregate are heated separately at 160°C to 180°C and 150°C to 170°C respectively. The first trial percentage of 4.5% bitumen / CRMB is poured in mixture of aggregates, according to MORTH specifications. 4.5% of bitumen added to blended aggregates for surface layer of flexible pavements and repeated the process for 5% and 5.5% bitumen. The mixture of aggregates and bitumen is mixed till a uniform coating is obtained on aggregate. The temperature is maintained around 170 °C during mixing. Three specimens of 100 mm diameter and 63.5 (±3) mm height are made in Marshall Moulds. Three specimens are prepared for each trial and average of these three specimens is considered for stability, flow, density and voids analysis. The specimen mould and compaction hammer are cleaned thoroughly and mould assembly is heated in hot air oven at a temperature of 160 °C. A little grease is applied to the mould before the mix is poured. The mould is assembled and the mix is transferred and tampered by using spatula. A filter paper is placed on bottom of the mould before placing the mix in mould. Then 75 blows are applied on both sides of the moulds using Marshall Compactor. The specimen is extracted after 24 hours from the Marshall mould.

Density, air voids calculations and Marshall Stability Tests

Before testing the Specimen their dimensions are measured to note the volume and their weight of specimen in air, weight of specimen in water, and weight of specimen saturated and dry conditions are taken. The following quantities are worked out for analysis i.e., Bulk specific gravity of Compacted Mixture, Theoretical maximum specific Gravity, Percent of air voids, Percent of air voids in mineral aggregates (VMA), Percent of voids filled with bitumen (VFB) and further the results are plotted as shown in Figure 3.

After that the specimens are kept in water bath maintained at 60°C for 60 minutes. The specimens are tested 3 to 4 minutes after taken out from water bath. The specimen is put in Marshall Apparatus and Marshall Stability and flow dial gauge readings are observed according to ASTM D6927-15 standards. Repeat the same process for remaining specimens. The Marshall observations of Pure Bituminous Mixes and CRMB bituminous mixes are mentioned in the Table 3 and also shown in the Figure 2.

IV. RESULTS AND DISCUSSIONS

Softening point, penetration, viscosity, Ductility and specific gravity tests were conducted for pure bitumen and Crumb rubber modified bitumen with 5%, 10%, 15% and 20% of Crumb rubber waste added.

Figure 2(A) shows that the increase of percentage of waste crumb rubber content added is directly increases the softening point value of Crumb rubber modified bitumen. 5% and 10% CRMB shows the properties of CRMB 55 grade. 15% CRMB shows the properties of CRMB 60 grade and 20% CRMB is obtained high softening point value compare to 15% CRMB. Due to high softening point value of 20% CRMB it cannot used for bituminous pavement mixes which changes the elastic properties of bituminous pavements as per IS: 15462, MORTH. CRMB 60 has high softening point and it is preferred in hot climates zones whereas CRMB 55 is preferred in cold climates zones.

Figure 2(B) shows that the increase of percentage of waste crumb rubber content added is directly decreases the Penetration value of Crumb rubber modified bitumen. 5% and 10% CRMB shows the properties of CRMB 55 grade. 15% CRMB shows the properties of CRMB 60 grade as per IS: 15462, MORTH 5th revision. Lower Penetration value of 15% CRMB increases the durability of pavement, increases the strength of pavement and it is preferred in hot climate zones. 5% CRMB has high penetration value when compared to 10% CRMB. So 5% CRMB is preferred in cold climates zones.

Figure 2(C) shows that the increases of percentage of waste crumb rubber content added is directly increases the Viscosity of Crumb rubber modified bitumen. 15% CRMB has high viscosity which decreases the flow with ambient temperature in hot climate zones. Viscosity of 15% CRMB shows the properties of CRMB 60 grade and 5% and 10% CRMB shows the properties of CRMB 55 grade.

Figure 2(D) shows that the increase of percentage of waste crumb rubber content added is directly decreases the Ductility value of crumb rubber Modified bitumen. Ductility of 15% CRMB is also shows the CRMB 60 grade and 5% and 10% CRMB shows the properties of CRMB 55 grade properties. 15% CRMB lower the ductility value of bitumen which increases the stiffness of pavement and it becomes hard pavement.

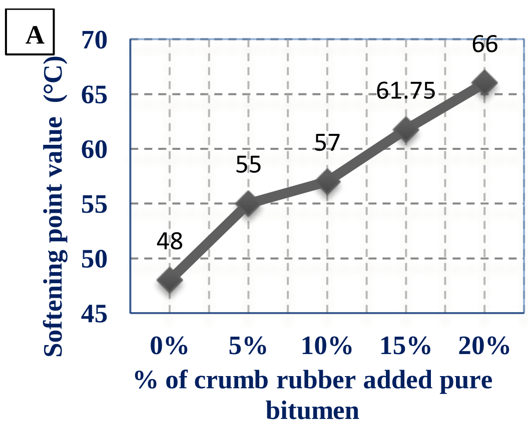
Figure 2(E) shows that the increase of percentage of waste crumb rubber content added is directly increases the gravity value of Crumb rubber modified bitumen. Specific gravity of 15% CRMB shows the properties of CRMB 60 grade and 5% and 10% CRMB shows the properties of CRMB 55 grade.

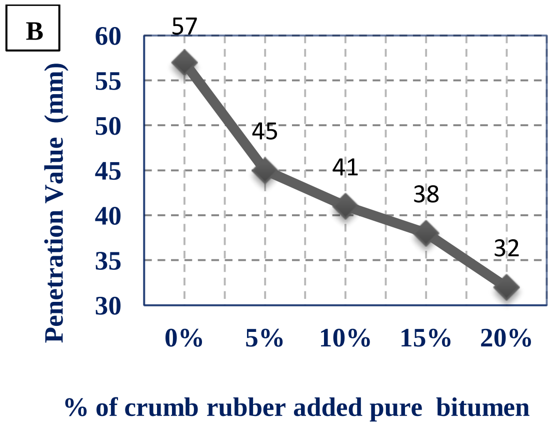
Different proportions of coarse aggregates 20mm, 12.5mm, 6mm and quarry dust was used in sieve analysis for obtaining the combined grain size distribution curve with aggregates and quarry dust using trial and error method to meet the required target range for surface layer as specified MORTH 5th Revision.

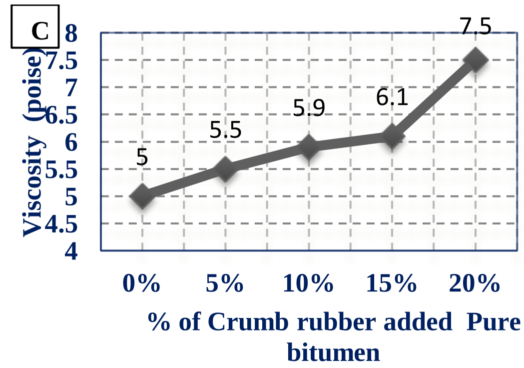
CRMB Bituminous Concrete Mix Marshall Observations and Voids Calculations (ASTM D6927-15)

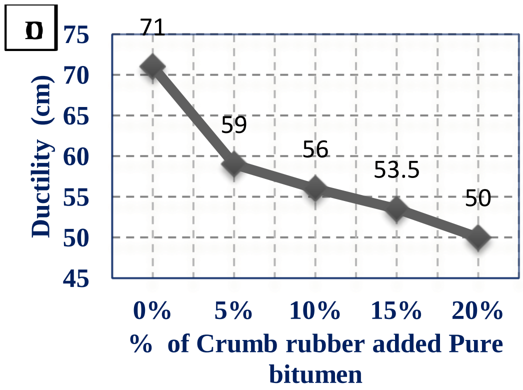
The Bituminous concrete mix was prepared by Marshall method using the VG-30 grade bitumen and CRMB 60. The variation of the (A) Marshal stability value, (B) Flow value, (C) Air Voids, (D) Voids in mineral aggregate (VMA), (E) Voids filled with bitumen(VFB), (F) Bulk Density for different percentages of mix of pure bitumen or 5%, 10%15% and 20% of CRMB as per specifications ASTM D6297-15 are shown in Table 3 and Figure 3.

Rubber has property of sound pollution, which also help in reducing the sound pollution of heavy traffic roads. The use of rubber can improve the durability of road. Use of discarded waste crumb materials and quarry dust in bituminous concrete mix may aid in minimizing the construction cost of the roads. We can save a certain bitumen quantity of bituminous mix. Moreover by adding of rubber with bitumen we can decrease the waste in environment, decrease the hazardous pollutions etc. and use of quarry dust in bituminous concrete mixes was reduces the air pollution and minimizing the waste in the environment.









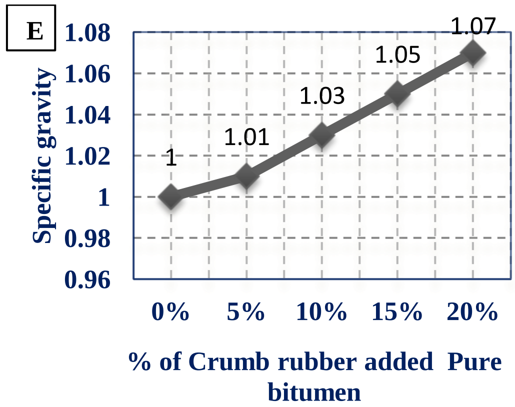


Figure 2: Variation of physical properties for varying percentages of CRM to the Pure bitumen (A) softening point value (°C), (B) Penetration value (mm), (C) Viscosity value (poise), (D) Ductility value (cm) and (E) Specific gravity value

Table 1: Test results obtained on Aggregates (IS: 2386 part 1- part 5, 1963)

S. NO	Aggregate physical properties	Result	Test method	IS:2386 code specifications	MORTH 5th revision
1	Aggregate crushing value (%)	24.21	IS:2386-part 4	<30	<30
2	Aggregate Impact value (%)	17.18	IS:2386-part 4	<30	<27
3	Los Angeles Abrasion value (%)	23.98	IS:2386-part 4	<30	<35
4	Water Absorption value for 20 mm aggregate (%)	0.73	IS:2386-part 3	0.1-2.0	<2
5	Water Absorption value for 12.5 mm aggregate (%)	0.5	IS:2386-part 3	0.1-2.0	<2
6	Specific gravity of 20 mm aggregate	2.64	IS:2386-part 3	2.5-3	2-3
7	Specific gravity of 12.5 mm aggregate	2.66	IS:2386-part 3	2.5-3	2-3
8	Specific gravity of 6 mm aggregate	2.55	IS:2386-part 3	2.5-3	2-3
9	Specific Gravity of quarry dust	2.69	IS:2386-part 3	2.5-3	2-3
10	Combined Flakiness Index & Elongation Index (%)	28.85	IS:2386-part 1	<35	<35
11	Aggregate stripping value (%)	98	IS:6241-1971	-	Min 95

Table 2: Blending of aggregates for bituminous concrete Mix (MORTH 5th revision 500-17 table)

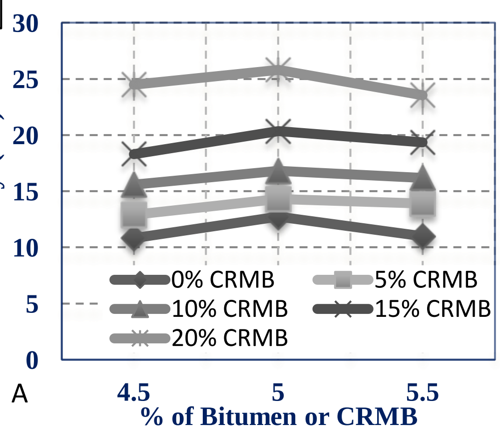
Sieve Size (mm)	%Passing The sieve				combined	Target Range (MORTH 5th revision 500-17 table)
	20mm	12.5mm	6mm	Quarry dust		
26.5	100	100	100	100	100	100
19	16.2	100	100	100	91.5	90-100
13.2	0	61.5	100	100	75.4	59-79

9.5	0	12.3	97.8	100	62.8	52-72
4.75	0	5.4	0.3	96.0	44.6	35-55
2.36	0	0	0.6	79.7	35.8	28-44
1.18	0	0	0	47.3	21.2	20-34
0.6	0	0	0	37.6	16.9	15-27
0.3	0	0	0	27.0	12.2	10-20
0.15	0	0	0	18.3	8.2	5-13
0.075	0	0	0	9.4	4.5	2-8
Proportion (%)	15	25	15	45		

Table 3: Pure bituminous and crumb rubber modified bitumen concrete mix Marshall Observations and Voids calculations (ASTM D6927-15)

S. No.	Bituminous Mix Properties	Pure Bitumen	5% Replacement	10% Replacement	15% Replacement	20% Replacement	MORTH 5th revision
1	Bulk density, g/cc	2.401	2.38	2.363	2.378	2.365	-
2	Stability, KN	12.73	14.32	16.8	20.35	25.8	>12KN
3	Flow, mm	3.26	2.5	2.8	3.15	4.1	2-4
4	Air Voids %	3.7	3.6	3.8	4.0	4.6	3-5%
5	VMA %	16.1	14.4	14.6	14.8	15.3	>12%
6	VFB %	77.2	74.9	73.4	72.8	70.1	65-75%

A



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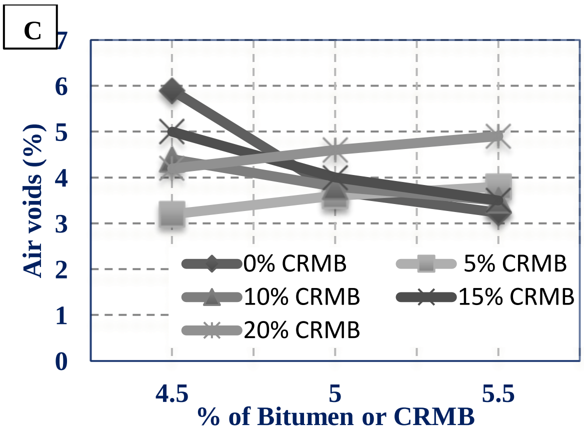

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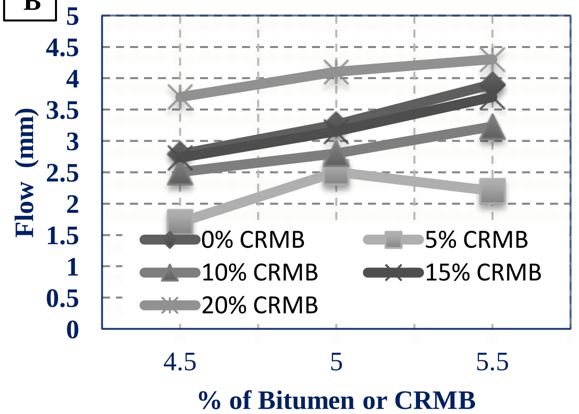

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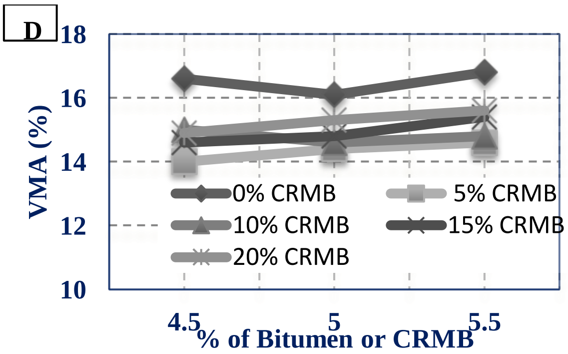

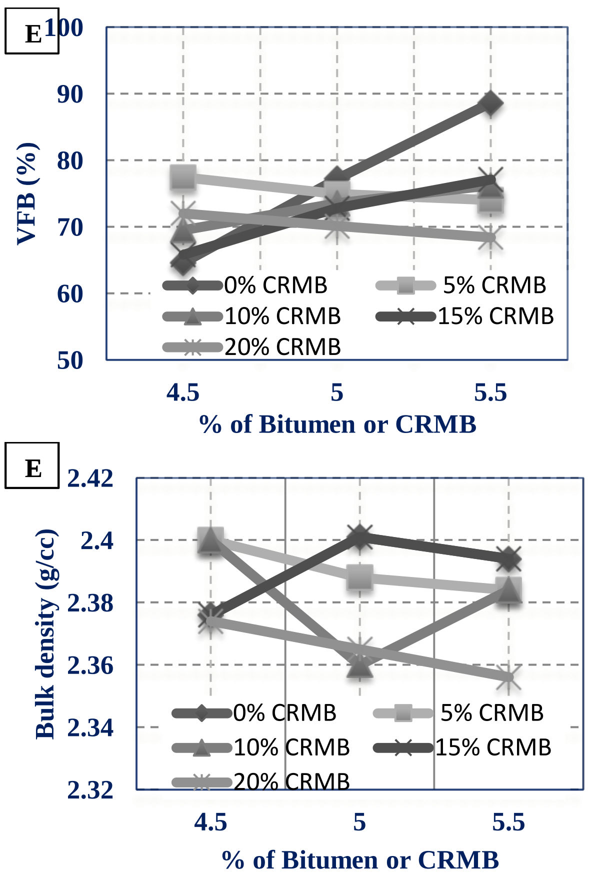

Figure 3: Variation of Marshall Results (A) stability (kN), (B) Flow (mm), (C) Air voids (%), (d) VMA (%), (E) VFB (%) and (F) Bulk density (g/cc) for different percentages of mix of pure bitumen or 5%, 10%15% and 20% of CRMB

V. CONCLUSION

Based on above observations, it is concluded that 5% and 10% CRMB shows the properties of CRMB 55 grade and 15% CRMB shows the properties of CRMB 60 grade. 5% CRMB is recommended in cold climate zones due to its high penetration value and 15% CRMB is recommended in hot climate zones due its lower ductility and higher stiffness of pavements. The Marshall Stability results of pure bitumen, 5%, 10%, 15% and 20% CRMB bituminous concrete mixes conclude that the increased stability value decreased flow value (deformation) and decreased air voids compared to pure bituminous concrete mix at optimum bitumen content of 5%. 5% CRMB of Marshall stability results shown the increased stability compared to pure bituminous concrete mix and is suitable for cold climate zones due to high penetration of 5% CRMB compared to 10 % CRMB. 15% CRMB of Marshall stability results shown the increased stability compared to pure bituminous concrete mix and is suitable for hot climate zones. The properties of 20% CRMB are failed due to high content of waste rubber and could not able to obtain any grade as per specifications of IS: 15462 hence not used for flexible pavement mixes.

REFERENCES

1. Ángel Vega-Zamanilloa, Pedro Lastra-Gonzáleza , Miguel A. Calzada-Péreza, Daniel Castro-Fresnoa, EvelioTeijón-López-Zuazo, (2018) "Bituminous mixtures with low percentage of natural aggregates and rubber modified bitumen with wax," *Transportation Research Procedia, 33,* pp. 91–98.
2. Goodrich J.L., (1998). "Bitumen and polymer modified Bitumen properties related to the performance of Bitumen concrete mixes," *Journal of the Association of Bitumen Pavement Technologists*, Volume 57, pp.116-160.
3. IBEF (2019), Road Network In India: National Highways, Projects, Government Initiatives.
4. IRC SP-53 (2010), "Guidelines on use of modified bitumen in road construction".
5. IS 15462 (2004), "*Specifications of Modified bitumen*".
6. IS 73 (2013) "Bureau of Indian Standards, Paving Bitumen Specification*"*.
7. MORTH 5th revision (2013) Specifications for road and bridge works.
8. Nabin Rana Magar (2014). "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.
9. Niraj D. Bariaya (2013) "Use of waste rubber tyres in constructions of bituminous roads-An Overview," *International Journal of Application or Innovation in Engineering & Management (IJAIEM)* , Volume 2, Issue 7, ISSN 2319 – 4847.
10. Nitish Kumar K., H N Rajakumara, 2016, "Study of Using Waste Rubber Tyres in Construction of Bituminous Road," *International Journal of Scientific & Engineering Research*, Volume 7, Issue 5, ISSN 2229-5518.
11. Nitu H. Deshmukh, D. Y. Kshirsagar, 2017, "Utilization of Rubber Waste in Construction of Flexible Pavement" *International Journal of Advance Research and Development*, Volume 2, Issue 7.
12. Nuha S. Mashaan, Asim Hassan Ali, Mohamed RehanKarim and MahrezAbdelaziz (2012) "An overview of crumb rubber modified asphalt," *International Journal of the Physical Sciences*, 7(2), pp. 166 – 170.
13. Rokade S (2012). "Use of Waste Plastic and Waste Rubber Tyres in Flexible Highway Pavements," *International Conference on Future Environment and Energy IPCBEE*, Volume 28, IACSIT Press, Singapore.
14. Shubham B., Anil Kumar M., Purnima B. (2017). "Evaluation of modified bituminous concrete mix developed using rubber and plastic waste materials" *International Journal of Sustainable Built Environment*, pp. 442–448.
15. Vasudevan, R (2007). "Utilization of crumb rubber for flexible pavement and easy disposal of crumb rubber" *International conference on sustainable solid waste management, Chennai, India*, pp.105- 111.
16. Vishal Rasal, L Nokfho K, P. M. Wale, Mrunalini Kasar, Anjali Thorat, Raunak Solanki, Ishan Dharmadhikari (2018) "Experimental Study on Modified Bituminous Mix Using Waste High Density Polyethylene And Crumb Rubber" *International Journal of Innovative Research in Science, Engineering and Technology*, Volume 7, Issue 5, ISSN- 2319-8753.