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Study on Tyre Rubber Modified Bitumens Mix for Road Asphalt Mixtures

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Abstract: In this study the strength & stability characteristics of bituminous mix for 80/100 grade bitumen is to studied and the effect of waste crumb rubber strength and stability characteristics in Bituminous mix and rubber bituminous mix is analyzed.
Keywords: voids in mineral aggregates (VMA), voids filled with bitumen (VFB) Method, Crumb rubber, Crumb rubber bituminous mix, stability, flow, Bulk Density.

I. INTRODUCTION

Roads are considered one of the most important aspects of infrastructure and play an important role in our daily lives. In the construction of road stones, the use of latex rubber in the conversion of bitumen binder is considered a viable sustainable development solution for waste recycling. And as the abundance and increase in dumping of waste tires is a major problem leading to environmental pollution. The rubble rubber found in the disposal of the discarded tires has been shown to improve the performance of clear bitumen from the 1840's. It can be used as a cheap and environmentally friendly conversion system to reduce road damage due to the increase in the number of service vehicles, the loading of the axes and the low-end maintenance services that have caused road construction to fail quickly. The use of rubbish rubber leads to good road health, driving comfort and low maintenance.

Bitumen is widely used as an ingredient in the construction of flexible roads. Different bitumen marks such as 30/40, 60/70 and 80/100 are available depending on their entry prices. The steady increase in the durability of vehicles in terms of commercial vehicles, as well as significant daily and seasonal variations, requires the improvement of road signs. Any improvement of binder material is a requirement. The preferred range of bitumen penetration in this study is 60/70 which is commonly used as Paving Grade Bitumen suitable for the construction of flexible corridors with high structures.

The potential for this should be improved by the construction of low-cost roads in different parts of our country. The necessary clarification should be made and efforts should be made to increase the use of waste materials in different parts of the road.

Garbage rubber is imported from a tire factory. It is in the form of black mice and is also used from used tiers. Crumb rubber is a recycled rubber obtained by mechanical grinding or grinding small cracked rubber tires. Tires are made of a variety of rubber chemicals. The main variations are rubber content, natural rubber content, total rubber hydrocarbon content, and acetone extraction. The ash and carbon content is generally similar to different rubber tire compounds.

In addition to the potential use, approximately 300 million tons of tires are produced annually in the United States alone, and about 13% of them dumped at European landfills produce 355 million tires annually, and millions of used tires are illegally disposed of or are maintained. Adequate disposal of tires can be extremely dangerous to human health and increase environmental hazards. Fortunately, these days, tire waste is used for many engineering purposes.

Advantages of crumb rubber bituminous mix modified bitumen can include following for road works.

1) Lower susceptibility to daily & seasonal temperature variations.
2) Higher resistance to deformation at elevated pavement temperature.
3) Better age resistance properties.
4) Higher fatigue life of mixes.
5) Better adhesion between aggregates & binder.
6) Prevention of cracking & reflective cracking.
7) Overall improved performance in extreme climatic conditions & under heavy traffic conditions.

II. LITERATURE REVIEW

R. A. Khan et. al. (2002) Author concluded that The thermal conductivity of the tire shreds is five times lower than the thermal conductivity of clay with a dry density of 1500 Kg/m3 and moisture content of 25 percent. Frost penetration in the tire shred embankment is larger than in the natural ground because of the low water content and presence of large voids in tire shreds and the difference in snow cover. It was observed that the surface deflection of the tire shred embankment is 15 to 25 mm, under 21000 Kg axle load. An average rebound of 11 mm and irrecoverable displacement of 7 mm were recorded after two passes of load. The elastic modulus of the tire shreds is proportional to the bulk density of the shreds. Non-linear elastic isotropic analysis gives a conservative estimate of the deflection of the tire shred embankments as compared to the linear elastic analysis. The design of road embankments with large-size tire shred layers can be made using the non-linear elastic analysis model presented in this paper. Large size tire shreds can be an economical alternative compared to the small size tire shreds in the construction of the tire shred embankment.

Justo et. al. (2002)Author have done the research work in the Centre lab for Transportation Engineering of Bangalore University on the possible use of the processed plastic bags as an additive material in bituminous concrete mixes. This properties of the modified bitumen were compared with ordinary bitumen. In the research it was observed that the penetration and ductility values of the modified bitumen decreased with the increase in proportion of the plastic additive, up to 12 % by weight. Due to this the life of the pavement surfacing course using the modified bitumen is also expected to increase substantially with comparison to the use of ordinary bitumen method.

Rokade S (2012) He conclude in study that on the use of LDPE (Low Density Polyethylene) and CRMB (crumb rubber modified bitumen) reveals that the Marshal Stability value, which is the strength parameter of SDBC has shown that it is increasing trend and the maximum values have increased by about 25 % by addition of LDPE and CRMB. The density of the mix has also increased in both the cases of LDPE and CRMB when compared with 60/70 grade bitumen. This will provide more stable and durable mix for the flexible pavements. The serviceability and resistance of road surface to moisture will also be better when compared to the conventional method of construction. The values of other parameters i.e Air Voids (Vv) , Voids in mineral aggregate (VMA) , Voids filled with bitumen(VFB)in both the cases LDPE and CRMB have found out to be within required specifications. This study not only constructively utilizes the waste plastic and tires in road construction industry but it has also effectively enhanced the important parameters which will ultimately have better and long living roads. From the results it is observed that the Marshal Stability Value are increased from 8% to 10% Crumb Rubber and then it is decreased i.e 10% of Crumb Rubber of the weight of bitumen is the optimum dose for getting enhanced strength characteristics of SDBC(Semi Dense Bituminous Concrete) mix. The bulk density of the sample also shows increasing trend from 8% to 12. The values of other parameters are also within the required specification limits.

Davide Lo Presti. (2013) The author believes that the widespread use of the RTR-MBs technologies within the road pavement industry is advisable. In fact the several benefits provided to the asphalt pavement performance, and to the overall sustainability of the infrastructure, are so evident that it is strongly advised to consider RTR-MBs technologies as a first option to the binders currently used in road pavements. Companies, road authorities, etc. have to evaluate if it is convenient to use the High Viscosity wet process technology, which proved widely to provide several benefits, in particular it allows highway designers to reduce pavement layer thickness due to the proven properties of rubberized bitumen, but presents some challenges as: the need for suitable blending and mixing equipment, the cost of such equipment and the degree of difficulty in preparing asphalt mix design. The other option is to choose the wet process-No-Agitation technology which solves several issues but leads to asphalts pavements. On the other hand, asphalts obtained by using High Viscosity RTR-MBs (Recycled Tire Rubber Modified Bitumen emulsions)have more performance history since this process started over in 1960s and they have been used successfully with many applications. With regards to asphalt mixtures, High Viscosity RTR-MB technology is very successful when used with Open- Graded surface courses, where the high air void content of the mix allows an aggregate coating with a much thicker film (36 lm) of high RTR content modified bitumen's (about 20%) which leads to an asphalt mix with significantly high binder content (about 7–9%) and with widely proven reduced oxidation, increased durability and increased resistance to reflective cracking. All these benefits are reduced when High Viscosity RTR-MBs is used for Dense-Graded hot mix projects since the dense gradation cannot adequately accommodate the rubber particle size, film thickness is reduced (9 micron) as well as acceptable binder content (about 5%) and the RTR-MBs needs to be produced with much lower rubber content (about 10%). The use of special equipment is not anymore justified by the significant benefits of a thicker coating, therefore in the case of Dense-Graded asphalt mixes the No-Agitation RTR-MBs are the most suitable.

On this regard, they are more likely to compete with polymer modified bitumen rather than High Viscosity RTR-MB. No-Agitation RTR-MBs have been successfully used for a much wider range of products as for instance chips seal applications, open graded and gap graded mixes and emulsions. Basically, RTR-MBs cannot be used wherever conventional asphalt mixes or asphalt surface treatments are needed. The lower viscosity of No-Agitation RTR-MB implies the usage of less binder per unit area (5–6% binder content) indicating less performance life than if High-Viscosity RTR-MB is used (8–10% binder content). In fact, the ability to inject more binder in the mix translates to better fatigue and reflective cracking performance.

Tomas Ucol- Ganiron J. (2013) Author concluded that Gradation of the asphalt mixture with scrap tire is lower in percentage retained 4.76 mm sieve than the conventional one for both marshall and immersion- compression tests. It was observed that bulk specific gravity of the design mixture has a lower result than the conventional for Marshall Test. Since scrap tire is not so hard as the crushed-stone aggregates, the Marshall stability values of the asphalt-aggregate-tire mixes were consistently lower as compare to control mixes without any scrap tire. It was also found that the tire which is cubical in shapes tend to absorb some of the energy imparted to compact a sample resulting in a weaker aggregate structure than a mix with no tire in it. For Marshall test The stability of the design mixture is twice lower than the conventional one, and constitutes a lower value in terms of flow. The density of the design mixture is lesser than the conventional. The stability of the mixture of asphalt depends on the grading of the aggregates, temperature and size of scrap waste tire. The advantages of scrap waste tires are: it mitigates roads noise and lessen the number of waste tires. In terms of Marshall Test, the longer rate of curing, the higher stability acquires. For Immersion-Compression test, the rate of curing by maximum 4 days will give the maximum value for water resistance for the road surface.

R S Deshmukh (2015) The Author concluded that, Strength of the road increased & Better soundness property. Better resistance to water & water stagnation. No stripping & have no potholes. Increased binding & better bonding of the mix. Optimum content of waste rubber tires to be used is between the range of 5% to 20%. Modifies the flexibility of sub surface layer Problem like thermal cracking and permanent deformation are reduce in hot temperature region after addition of waste tires as rubber aggregate.

Manoj Sharma. et al. (2016) Author concluded that the basic reason for using RTR-MB's is that it provides significantly improved engineering properties over conventional paving grade bitumen. The most important benefit is to withstand against the high climate, as generally in many parts of north India temperature reaches 40-60 ^{0}c. In these temperature RTR-MB's shows physical and rheological properties significantly different than those of neat paving grade bitumen likewise reduced several properties like fatigue, rutting, reflection cracking, and improved oxidation resistance, aging and better chip retention due to thicker binder films with additional increased viscosity that permit greater film thickness in mixed pave without bleeding and excessive drain down. It also shows that greater values of the elasticity and resilience especially at high temperature. This method proves to be very useful in Indian as the availability of waste rubber is in abundant and there is also no need of any special arrangement to prepare them for the use in road construction.

Prof. S. B. Patil. et al. (2016) Author concluded that Rubberized bitumen is used extensively in California, Arizona and Texas in the USA, in several countries of Western Europe, and in South Africa. It is also used to a lesser parts of Canada and in a dozen more states in the USA. Its benefits are many which including reduced long-term road maintenance and expense, significant noise reductions, improved traction and reduced accident rates in wet road conditions. Rubberized bitumen is a less expensive application when used as a thin top course over failed pavement that would otherwise need replacement. It is less expensive to maintain per lane-kilometer in years 6 through 15 of pavement life over conventional pavements, and the same in years 1 through 5. Rubber bitumen makes urban environments more habitable as it significantly reduces noise as opposed to concrete pavements, and also is quieter than bituminous pavements;. It significantly improves wet surface traffic safety. It creates less of a "heat island" effect than with concrete pavement at surface. In an Open Grade Friction Course it provides better surface road drainage. It is a hugely beneficial use for post-consumer waste tire materials, using about 1,000 waste passenger tires per lane mile.

H.T. Tai Nguyen et al. (2017) Author concluded that the dry process, CR is used in hot mix asphalt as a replacement for parts of coarse and fine aggregate, resulting in a preference for gap gradations, and aggregate does not appear in the dimensions of the added CR. Furthermore, the work of designing a gradation curve of aggregate corresponding to the added rubber powder is quite complicated because the melting of fine CR particles will occur at high temperatures. For example, the chunk rubber process could consume CR up to 12% by weight of the mixture. They have concluded after conducting various test on the bitumen sample like The CR contributes to the significant improvement in the Marshall stability and rutting resistance of asphalt concrete. The optimal CR content in mixtures of dense gradation and SMA gradation are 1.5% and 2%, respectively. And At the optimal content of CR, the rutting resistance of dry process asphalt mixtures is as good as that of SBS (Styrene-Butadiene- Stryrene). and CR modified asphalt mixtures using wet process.

Therefore, CR modified asphalt mixtures using dry process can be used in flexible pavement to mitigate rutting distress and, on the other hand, promote the recycling of waste tires, contributing to the protection of environment.

Olga Frolova et al. (2017) The paper was created in order to demonstrate the possibilities for reducing car noise levels by using low-noise asphalt pavement. asphalt mixture with the addition of crumb rubber from used tires showed good acoustic properties. Roughness of the mixtures was studied in in-situ conditions, on the wearing course of the experimental section (with crumb rubber) and the SMA (Stone Mastic Asphalt) section three years after the mixtures were laid. According to the results shown in this figure, the roughness of the CR mixture was lower than that of the SMA mixture. In recent studies it is find out that the use of crumb rubber modified binders produced higher stiffness modulus than the same binder without crumb rubber on mixtures sampled and compacted in the laboratory. According to the results, roughness could be potentially responsible for the higher sound emissions of SMA pavement. In order to achieve noise mitigation in overall noise emissions due to this surface property lower roughness values would be necessary. One of the aims of this work was to find out the existence of a good correlation between tire/pavement sound levels and the roughness surface characteristics in an in-service asphalt mixture with crumb rubber content.

Nitu H. Deshmukh et.al.(2017)Author conducted the test which were done for normal bitumen and modified bitumen with 0%, 8%, 10%, 12%, and 14% of rubber waste content. From the result of the test, the penetration value for normal bitumen was 69 mm. The penetration value decreased with the increased amount of the rubber crumb waste added. Lower penetration value prove that grade of asphalt is harder, giving additional strength to the road and reduces water damage. Softening Point Test was done for normal bitumen and modified bitumen with 0%, 8%, 10%, 12%, and 14% of rubber waste content. From the result of test, the softening point for normal bitumen was 42.75˚c. Softening Point increased with the increased amount of the rubber waste added. The result showed that the bitumen becomes less susceptible to temperature changes as the content of rubber waste increased. Ductility test was done for both normal bitumen and modified bitumen with 0%, 8%, 10%, 12%, and 14% of rubber waste content. The result found that the rubber waste added will harden the bitumen. The bitumen becomes more viscous and harden, which would be useful to obtain stiffer bitumen asphalt.

III. MATERIAL USED

A. Aggregates

The coarse aggregates of varying size are sieved by passing through 26.5 mm and retained on a 2.36 mm sieve while fine aggregate should comprise 100% of fine crushed sand passing the 2.36 mm sieve and retained on 0.075mm sieve.

B. Mineral Fillers

Mineral fillers have substantial influence over the properties mix design. Filler should comprise of finally divided mineral such as rock dust or hydrated lime. The utilization of hydrated lime is encouraged because of its very good anti-stripping and anti-oxidant properties. Fillers used are lime and sand in bituminous mix specimen.

C. Bitumen

Bitumen is the by-product of petroleum and its grading depends upon its penetration value and viscosity grade for different climatic factor and nature of duty. It is utilized to build additional heavy duty bitumen pavement that need to persevere through considerable substantial traffic loads.

Fig Bitumen VG30

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D. Crumb Rubber

Crumb rubber is actually small pieces of waste tire scrapped from light motor vehicles and whose disposal is a serious menace. The annual available capacity for procured tires retreading is 4.8 million for bus and truck tires and 4.5 million for car and jeep tires. The crumb rubber is made by shredding scrap tire, which is a particular material free of fibre and steel. The rubber particle is graded and found in many sizes and shapes. The crumb rubber is described or measured by the mesh screen or sieve size through which it passes during the production process. To produce crumb rubber, generally, it is important to reduce the size of the tyres.

Fig. Crumb Rubber

III. EXPERIMENTAL PROGRAM

The Following tests were performed as per IRC Recommendation to find the various properties of mix are as follows:

1) Specific gravity test
2) Penetration index test
3) Softening point test
4) Ductility index test
5) Ductility index test
6) Marshall Stability test
7) Modification of Bitumen is done by two ways, they are;
a) Wet mix process
b) Dry mix process

IV. RESULTS

A. Physical Properties of Unmodified and Modified Samples:

S. No.	Experiment Name	(80/100) Unmodified Bitumen sample	Crumb Rubber type	% Crumb Rubber		
				10	15	20
1.	Penetration (1/10 mm)	91	Clean	61	56	54
			Unclean	62	55	54.5
2.	Softening Point (^{0} C)	42	Clean	47	48	49
			Unclean	47	49	50.5
3.	Ductility Value (cm)	98	Clean	67	61	58
			Unclean	59	55	46
4.	Elastic Recovery (%)	30.5	Clean	46.5	56	58
			Unclean	48.6	53.5	55
5.	Flash Point (^{0} C)	330	Clean	336	336	335
6.	Specific gravity	1.03	Clean	1.027	1.032	1.032

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Table : Marshall Properties of 80/100 Bitumen, Clean & Uncleaned Crumb Rubber

Binder	Binder/aggregate in mix	Density (gm/cc)	Stability (kN)	Flow (mm)
Clean				
	4.5	2.62	11.83	3.53
	5.0	2.63	11.96	3.36
	5.5	2.61	11.86	3.95
	6.0	2.60	9.23	5.31
	6.5	2.60	8.70	5.73
Unclean				
	4.5	2.59	11.32	4.43
	5.0	2.60	10.80	4.48
	5.5	2.60	10.15	5.25
	6.0	2.61	9.35	5.45
	6.5	2.60	9.22	5.70
80/100				
	4.5	2.60	12.17	3.30
	5.0	2.60	12.65	3.47
	5.5	2.61	9.47	2.92
	6.0	2.63	9.77	4.37
	6.5	2.59	8.85	6.18

Table: Marshall Properties of 80/100 Bitumen, Clean & Uncleaned Crumb Rubber

Binder	Binder %	VMA %	VA %	VFB %
Clean				
	4.5	14.91	7.45	50.31
	5.0	14.52	6.26	57
	5.5	14.38	5.40	62.65
	6.0	14.99	5.35	64.50
	6.5	14.60	4.23	70.99
Unclean				
	4.5	14.90	7.47	50.17
	5.0	14.80	6.60	55.60
	5.5	14.50	5.57	61.67
	6.0	14.40	4.73	67.17
	6.5	14.57	4.27	70.83
80/100				
	4.5	15	7.27	50.63
	5.0	14.57	6.27	56.80
	5.5	15.27	5.83	60.57
	6.0	14.60	4.87	66.57
	6.5	14.97	4.43	69.70

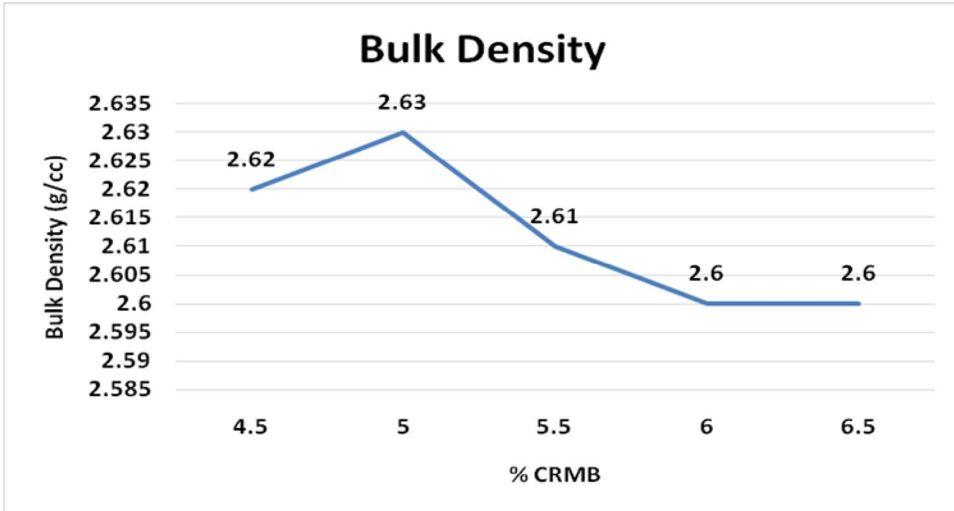

Fig.: Bulk Density of the samples with different proportion of clean crumb rubber bitumen

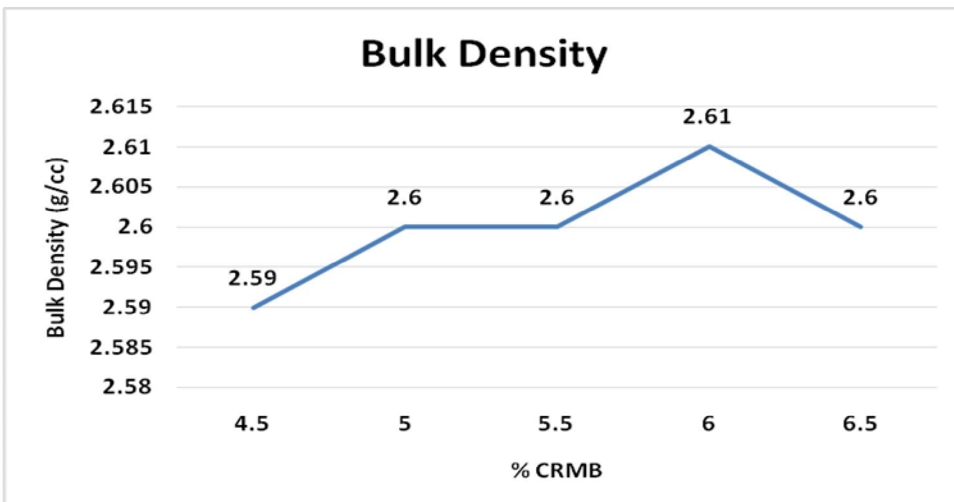

Fig.: Bulk Density of the samples with different proportion of unclean crumb rubber bitumen

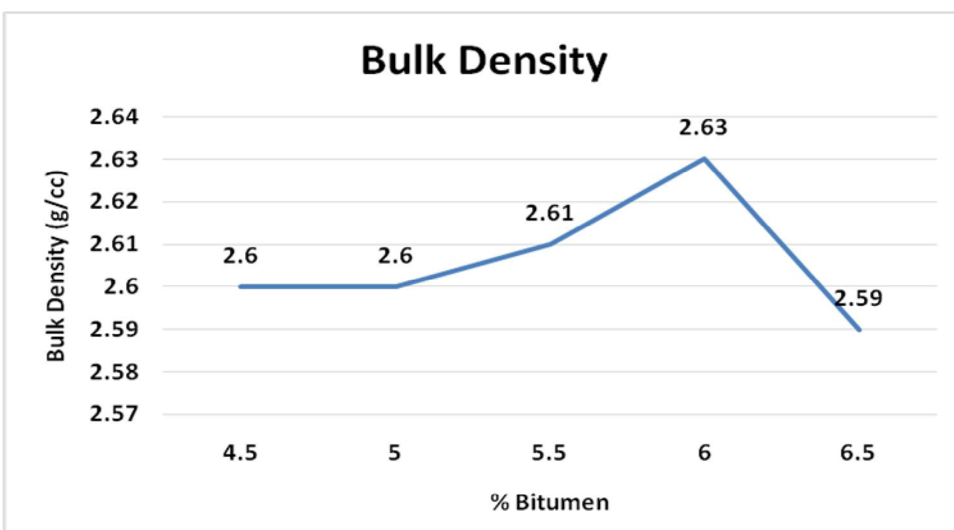

Fig.: Bulk Density of the samples with different proportion of bitumen

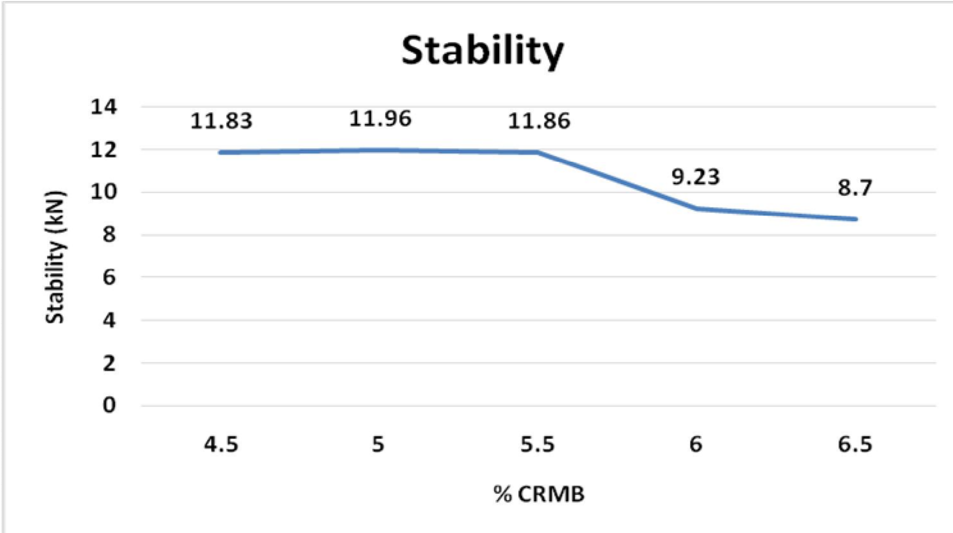

Fig.: Stability of the samples with different proportion of clean crumb rubber bitumen

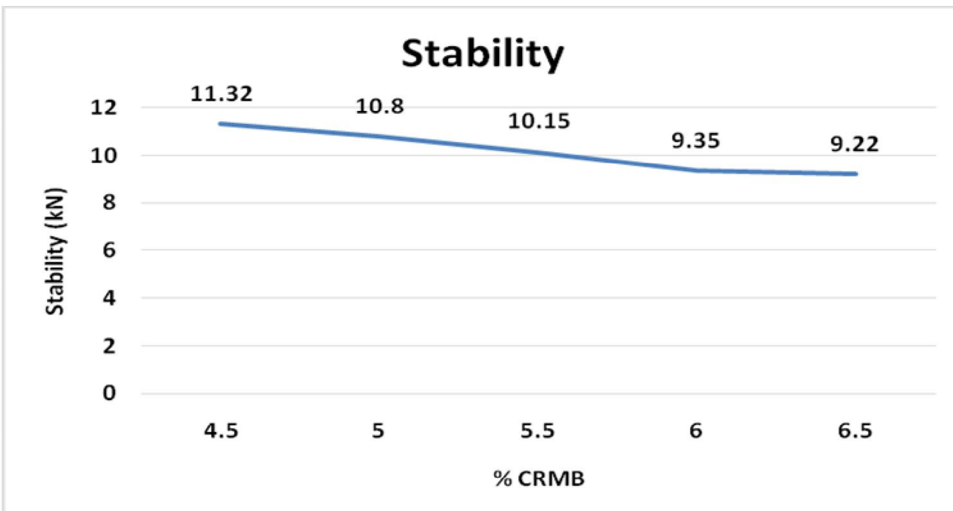

Fig.: Stability of the samples with different proportion of unclean crumb rubber bitumen

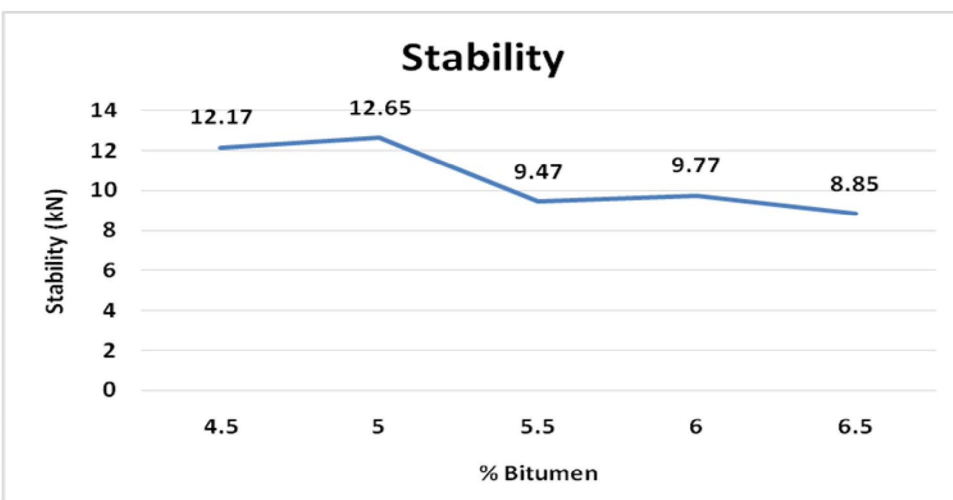

Fig.: Bulk Density of the samples with different proportion of bitumen

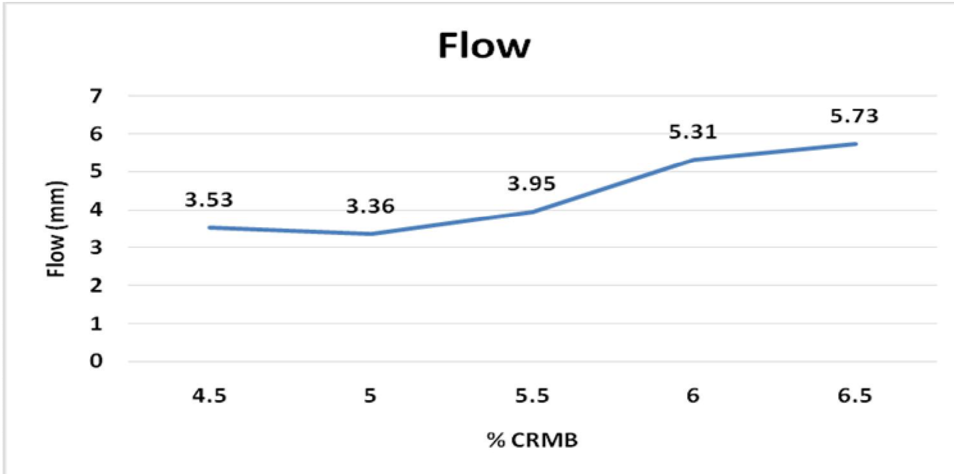

Fig.: Flow value of the samples with different proportion of clean crumb rubber bitumen

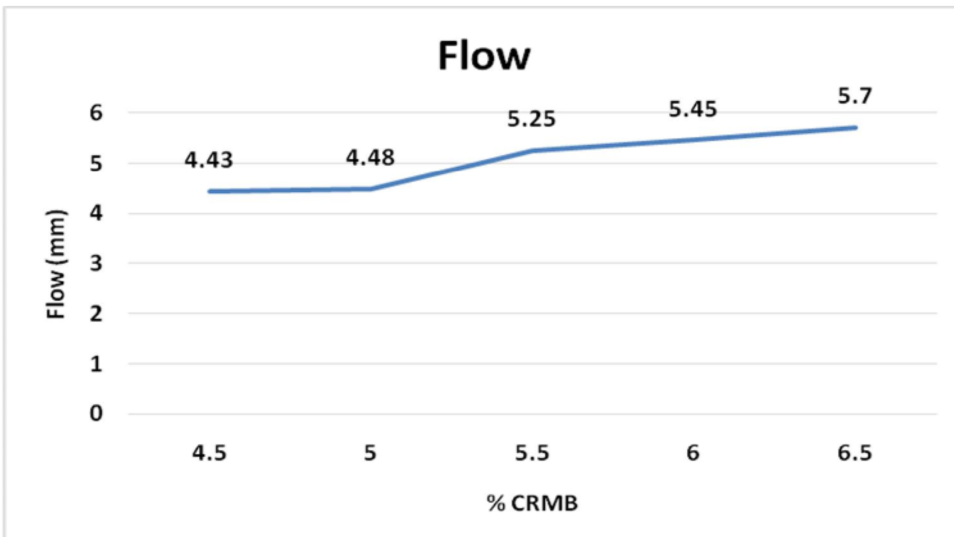

Fig.: Flow value of the samples with different proportion of unclean crumb rubber bitumen

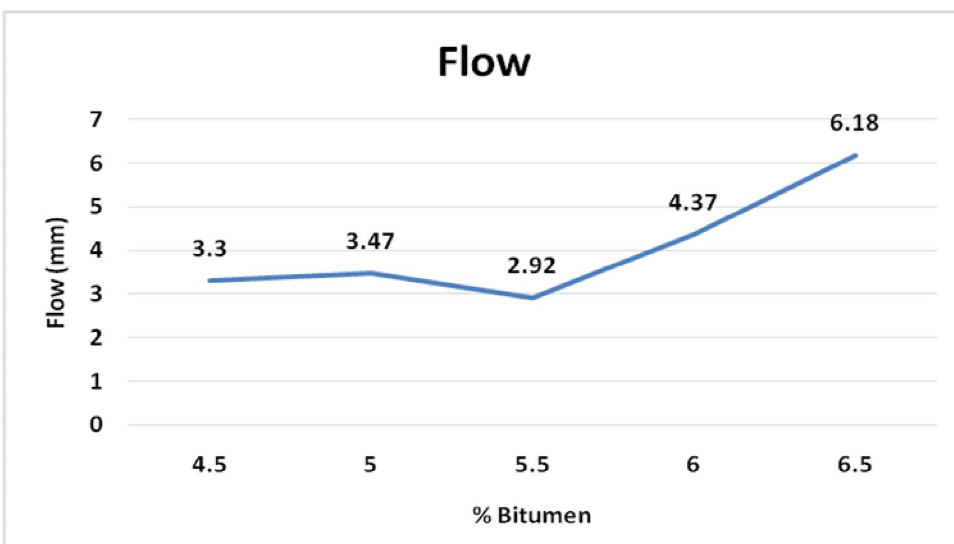

Fig.: Flow value of the samples with different proportion of bitumen

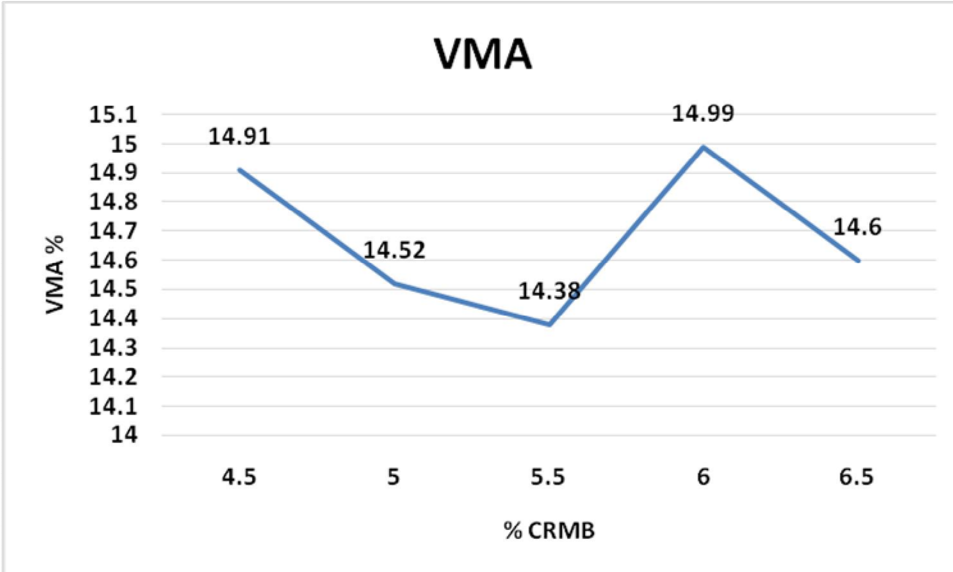

Fig.: VMA of the samples with different proportion of clean crumb rubber bitumen

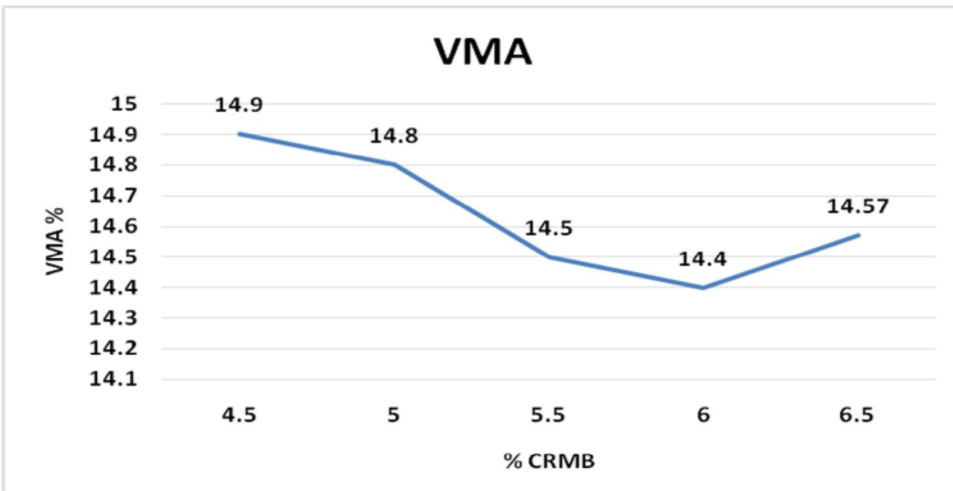

Fig.: VMA of the samples with different proportion of unclean crumb rubber bitumen

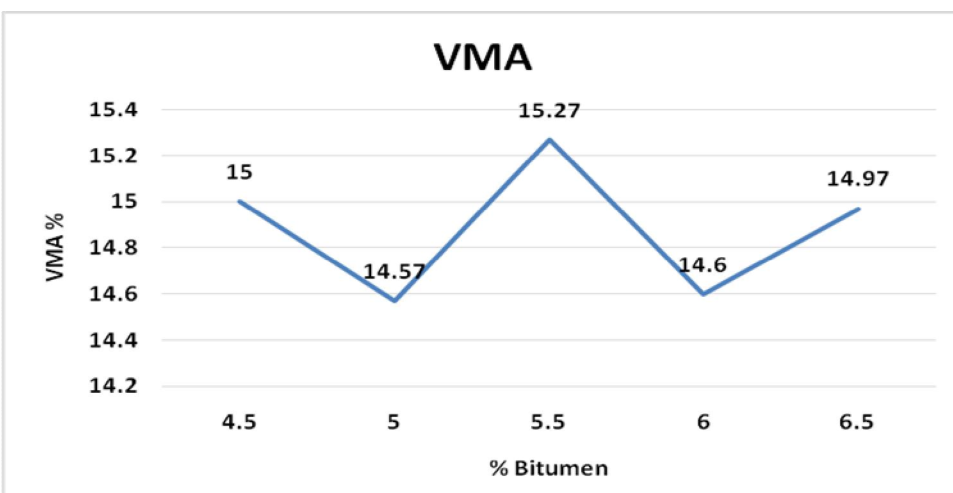

Fig.: VMA of the samples with different proportion of bitumen

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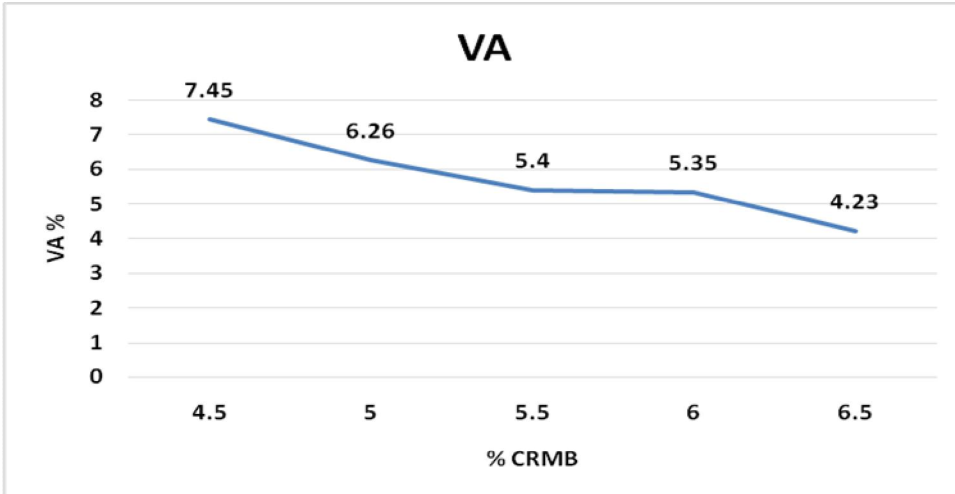

Fig .: VA of the samples with different proportion of clean crumb rubber bitumen

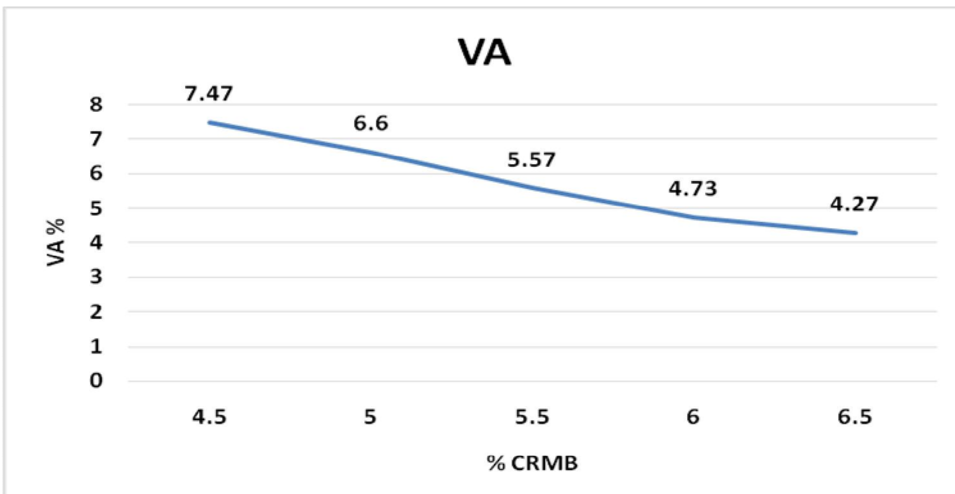

Fig .: VA of the samples with different proportion of unclean crumb rubber bitumen

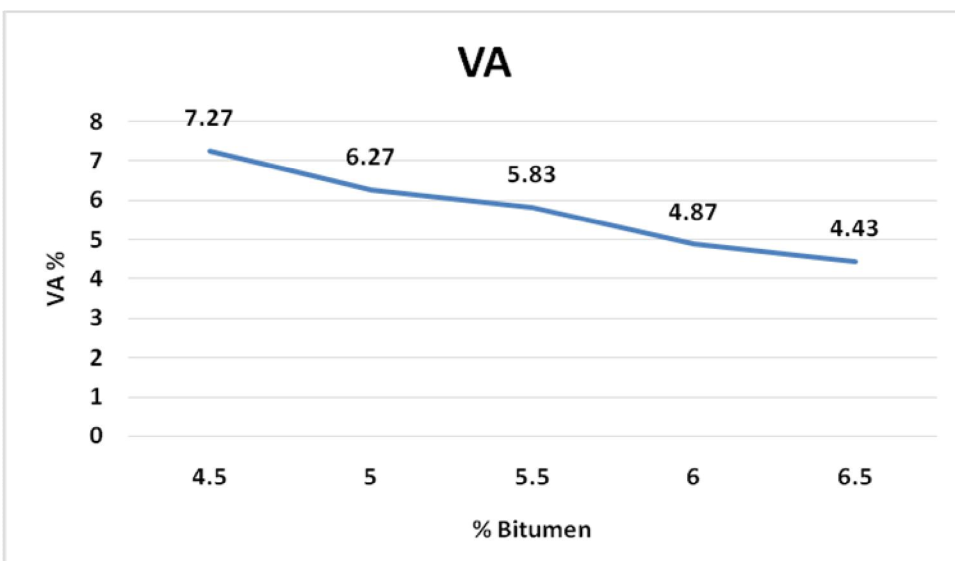

Fig.: VA of the samples with different proportion of bitumen

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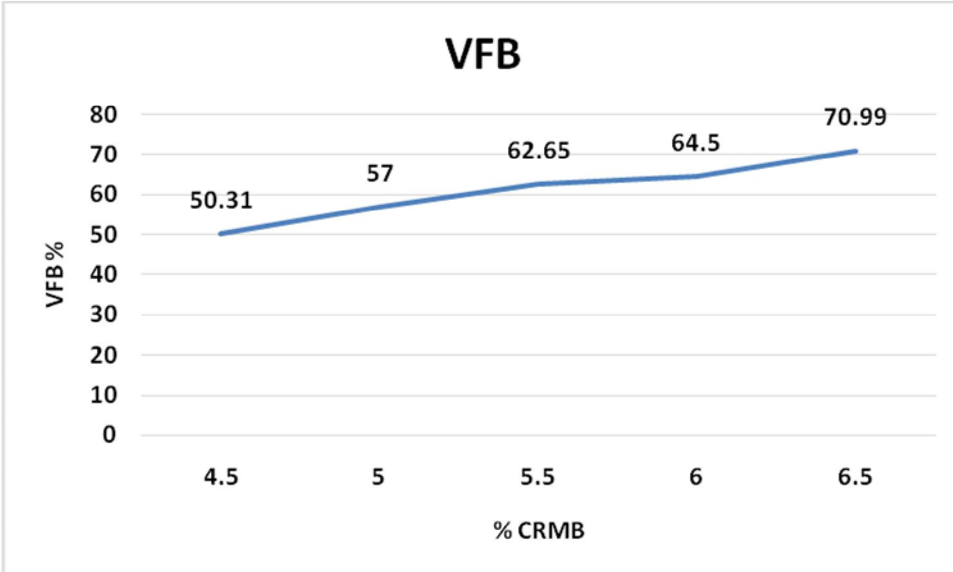

Fig.: VFB of the samples with different proportion of clean crumb rubber bitumen

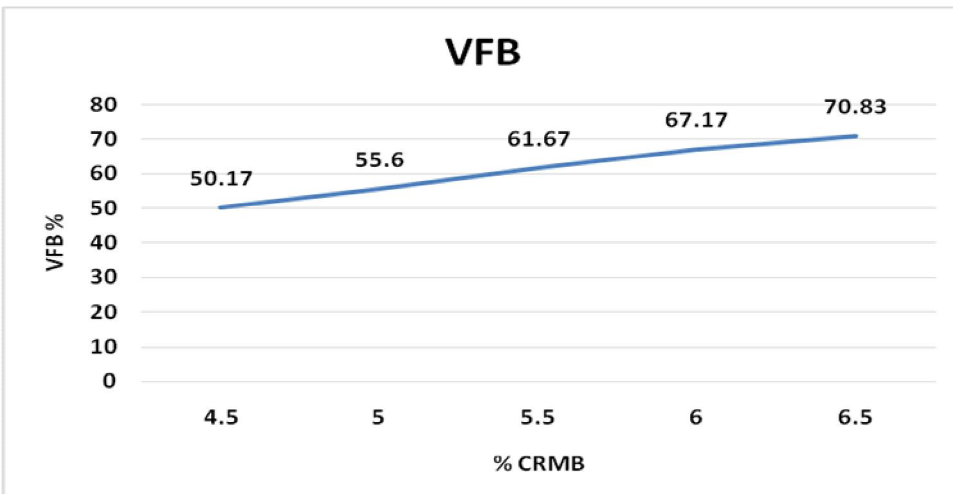

Fig.: VFB of the samples with different proportion of unclean crumb rubber bitumen

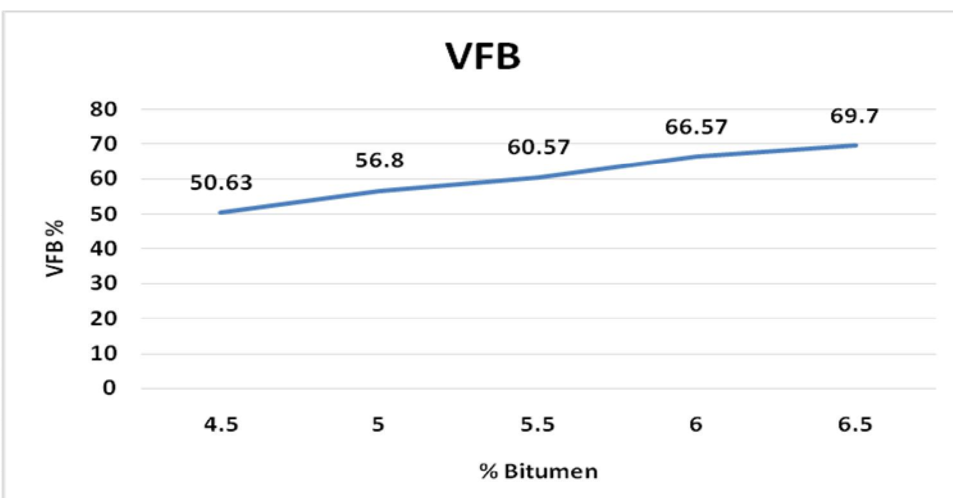

Fig.: VFB of the samples with different proportion of bitumen

VI. CONCLUSIONS

A. There is little improvement in the flash point and specific gravity values of the modified binder, compared to the neat bitumen
B. Marshall stability values of mixes with clean modified binder are slightly greater than those of mixes with 80/100 bitumen, even though the flow values decreased for mixes with clean modified binder compared to 80/100 binder no fixed trend was observed.
C. Optimum blending time was found to be ¼ hr. mixing + 1 hr. reaction + ½ hr. mixing , for mixing temperature of 165 °C, tire shred size of 1cm X 1cm (and tire shred concentration of 15%).
D. 15% tire shred concentration was found to be optimum, as the improvement in the binder properties beyond this (15%) is not significant for mixing temperature of 165 °C and blending time of ¼ hr. mixing + 1 hr. reaction + ½ hr. mixing.

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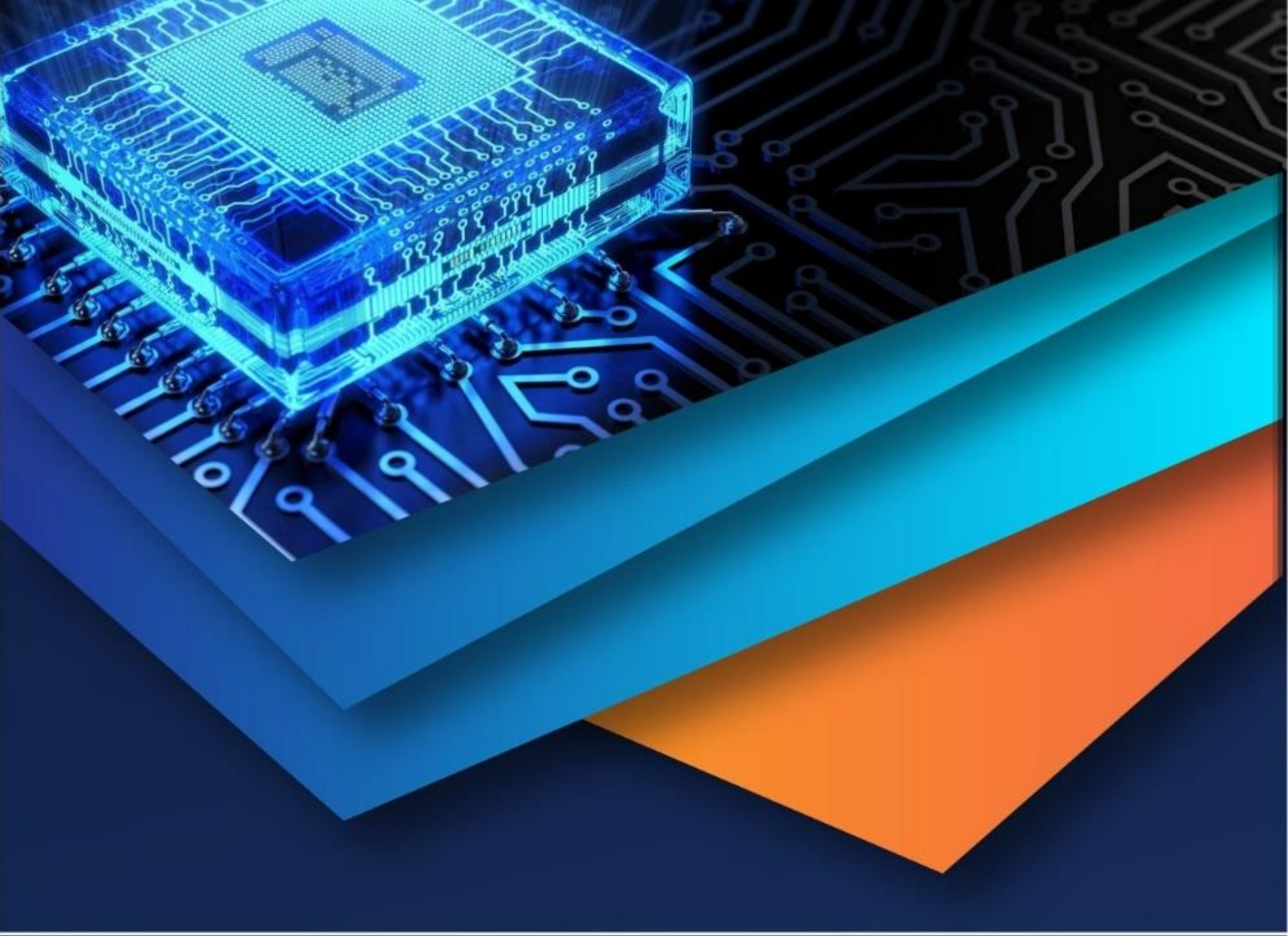

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