TOUGHNESS CHARACTERISTICS OF MODIFIED BITUMEN FOR ROAD CONSTRUCTION[1]

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ABSTRACT

Conventional tests to characterise bituminous materials like, penetration, softening point, etc. are primarily empirical in nature and their applicability to modified binders remains doubtful. Several studies have been carried out on modified bitumen using modifiers which have resulted in improved properties of bitumen. Also there are many other materials that may be tried as modifiers in bitumen. Thispaper reports the results of an investigation, attempted to determine the strength characteristics of bituminous sample in terms of toughness values and compare the effects of modifier on bitumen. The toughness tests have been conducted for binders containing different percentages of Ethylene-Vinyl- Acetate (EVA), Crumb Rubber (CRM), Styrene-Butadiene-Styrene (SBS) and Waste Plastics (WP). For this purpose, existing Marshall Apparatus was modified to determine the toughness of plain and modified bitumen.

Keywords: *modifier, modified bitumen, toughness*

INTRODUCTION

Flexible pavements with bituminous surfacing are widely used in many parts of the world. The high intensity of traffic in terms of commercial vehicle and over loading of trucks and significant variation in daily and seasonal temperature of the pavement have been responsible for early development of distress symptoms like undulations, rutting, cracking and pot holing of bituminous surface. A factor which causes serious concern is varying climatic conditions at different periods of time. Under such conditions, flexible pavements tend to become soft in summer and brittle in winter.

Several investigation have revealed that properties of bitumen and bituminous mixes can be improved significantly to meet the requirements of pavement with incorporation of certain additives or blend of additives so that the early development of distress symptoms can be prevented and there by preventing pavement deterioration. The desirable properties of good bituminous mixes are stability, durability, cohesion, skid resistance and workability. If bituminous mix is poor in any of the above properties, then that mix ultimately result inpavement failure. A good mix is one which has got all the desirable properties.

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The properties of bitumen and bituminous mixes can be improved to meet the requirements of pavement with the incorporation of certain additives. These additives are called as bituminous modifiers and bitumen pre mixed with these modifiers is known as modified bitumen.

1.1 Need for modified bitumen for the pavement construction

Bitumen which is responsible for the viscous-elastic behavior characteristic of asphalt plays a large part in determining many aspects of road performance, particularly resistance to permanent deformation and cracking. In general, the proportion of any induced strain in asphalt that is attributable to viscous flow, which is non-recoverable, increases with both loading time and temperature.

One of the prime roles of a bitumen modifier is to increase the resistance of the asphalt to permanent deformation at high road temperatures without adversely affecting the properties of the bitumen or asphalt at other temperature.

In the construction of flexible pavements, bitumen plays the role of binding the aggregate together by coating over the aggregate. It also helps to improve the strength of the road. But its resistance towards water is poor. Anti-stripping agents are being used. A common method to improve the quality of bitumen is by modifying the rheological properties of bitumen by blending with organic and synthetic polymers like rubber and plastics.

The use of plastic materials such as carry bags, cups, etc. is constantly increasing. The consumption of plastics have increased from 4000 tons/annum (1990) to 4 million tons/annum (2001) and it is expected to rise 8 million tons/annum during the year 2009. Nearly 50 to 60% of the total plastics are consumed for packing. Once used, these plastic materials are generally thrown as waste. They do not undergo bio-decomposition. Hence, they are either land filled or incinerated. Both are not eco-friendly processes as they pollute the land and the air. Any method that can use this plastic waste for the purpose of construction is always welcomed.

Some of the properties of bituminous mixes that can be improved using polymers are: increased resistance to stripping[1]; reduce the effect of bleeding of binder during peak summer[1], Aging[1] and skid-resistance characteristics are improved; improvement in toughness[2]; increase in tenacity[3,4]; resistance to creep deformation[5, 6]; increase in indirect tensile strength[7] and compressive strength[7]; decrease the rutting rate [8, 9]; increase the fatigue resistance[10, 11, 12]; improve the temperature susceptibility; increase in Marshall stability[13, 14, 15], reduces the porosity, absorption of moisture and improves soundness; improvement in skid resistance characteristics[16]; increases the melting point[17]; improves the viscosity and elasticity of the materials tested[18]; improve the resistance to abrasion at low and high temperature; decrease thebrittleness[19].

Polymer Modified Bitumen is used due to its better performance. But in the case of higher percentage of polymer bitumen blend, polymer dispersion in bitumen, get separated on cooling. This may affect the properties and quality of the blend and also the road laid using such blend.

1.2 Desirable properties of modifiers-rubber and polymer

Polymer and rubber modified bitumen, often abbreviated as modified bitumen is obtained with the incorporation of selected thermoplastics and powdered rubber from discarded trucktires, natural rubber or any other suitable elastomers in bitumen. When used as bitumen modifier, selected polymers/rubber or blend should have few properties such as, it should be compatible with bitumen; resist degrading of bitumen at mixing temperature; be capable of being processed by conventional mixing and laying machinery; produce coating viscosity at application temperature; maintain premium properties during storage, application and in service; be cost effective on a life cycle cost basis.

Polymers are being increasingly used to modify bitumen and to enhance the properties of bituminous mixes. The polymer modified binders are highly suitable for special applications, where traffic is extremely high. However climatic and mixing temperature play important role in the preparation of polymer modifier binder.

Some of the polymers which are compatible with bitumen and which are easily available in market are Styrene-Butadiene-Styrene (SBS), Styrene-Butadiene-Rubber (SBR) and Ethylene Vinyl Acetate (EVA). The mix prepared with these modifiers shows a higher resistance to permanent deformation at higher temperature, increased fatigue life, improved temperature susceptibility and reduced cracking potential at lower temperature compared to the conventional bitumen.

The modified bitumen and the mixes prepared out of these modified bitumen should possess better strength characteristics compared to the mixes with plain bitumen. This aspect is studied in the present investigation.

The present study is aimed to determine the Toughness of 60/70 penetration bitumen with varying percentages of polymers such as Ethylene-Vinyl-Acetate (EVA), Crumb Rubber (CRM), Styrene-Butadiene-Styrene (SBS) and Waste Plastics (WP) at 0, 2, 4, 6, 8 and 10% at test temperatures of 10°, 20° and 30°C.

EXPERIMENTAL METHODOLOGY

2.1 Selection of bitumen and polymer for Toughness analysis

The Bitumen of 60/70 penetration grade which was supplied by Mangalore Refinery and Petrochemicals Limited (MRPL) was used.

The polymers selected are Ethylene-Vinyl-Acetate (EVA), Styrene-Butadiene-Styrene (SBS) and Crumb Rubber which are available in the market and waste plastics supplied from KK plastics, Bangalore. These materials are blended with bitumen to form Polymer modified bitumen and waste plastic modified bitumen (WPMB).

2.2 Preparation of Modified Bitumen

The required quantity of 60/70 grade bitumen was heated up to 170°C in a container and EVA, SBS, Crumb rubber and waste plastics was added at different percentage by weight of bitumen to the heated bitumen and then stirred vigorously till a homogeneous material was formed. The heating was stopped after the mix reached 100° C. The procedure was repeated for each percentage of additives using 0%, 2%, 4%, 6%, 8% and 10% and for each trial fresh sampleof bitumen was taken.

.3 Preparation of Toughness Test Sample

The required quantity of 60/70 penetration bitumen was heated up to 170°C. The required quantity of polymer viz. EVA, SBS, Crumb rubber or waste plastic was weighed as percentage of weight of bitumen and mixed manually for two minutes. The mix was then agitated by a ¼ hp mechanical stirrer for about 20 minutes to get a uniform consistency.

The hemispherical cone unit was placed in the aluminium container at a fixed depth and at the central position and heated PMB was poured into the container up to the top of the hemisphere, with the help of a mark at the semicircular region. The prepared sample was cured in water bath for 1 hour at room temperature. Then it was conditioned for a period of 10 hours testing temperature [20].

The device was fabricated in the laboratory based on the detailing provided by Thompson[21] and ASTM-Standard method of test for determining toughness and tenacity of rubberized asphaltic materials Colorado procedure – Laboratory 2210- March 2007[22]. The experimental set-up used for the present investigation as shown in Figure 1.

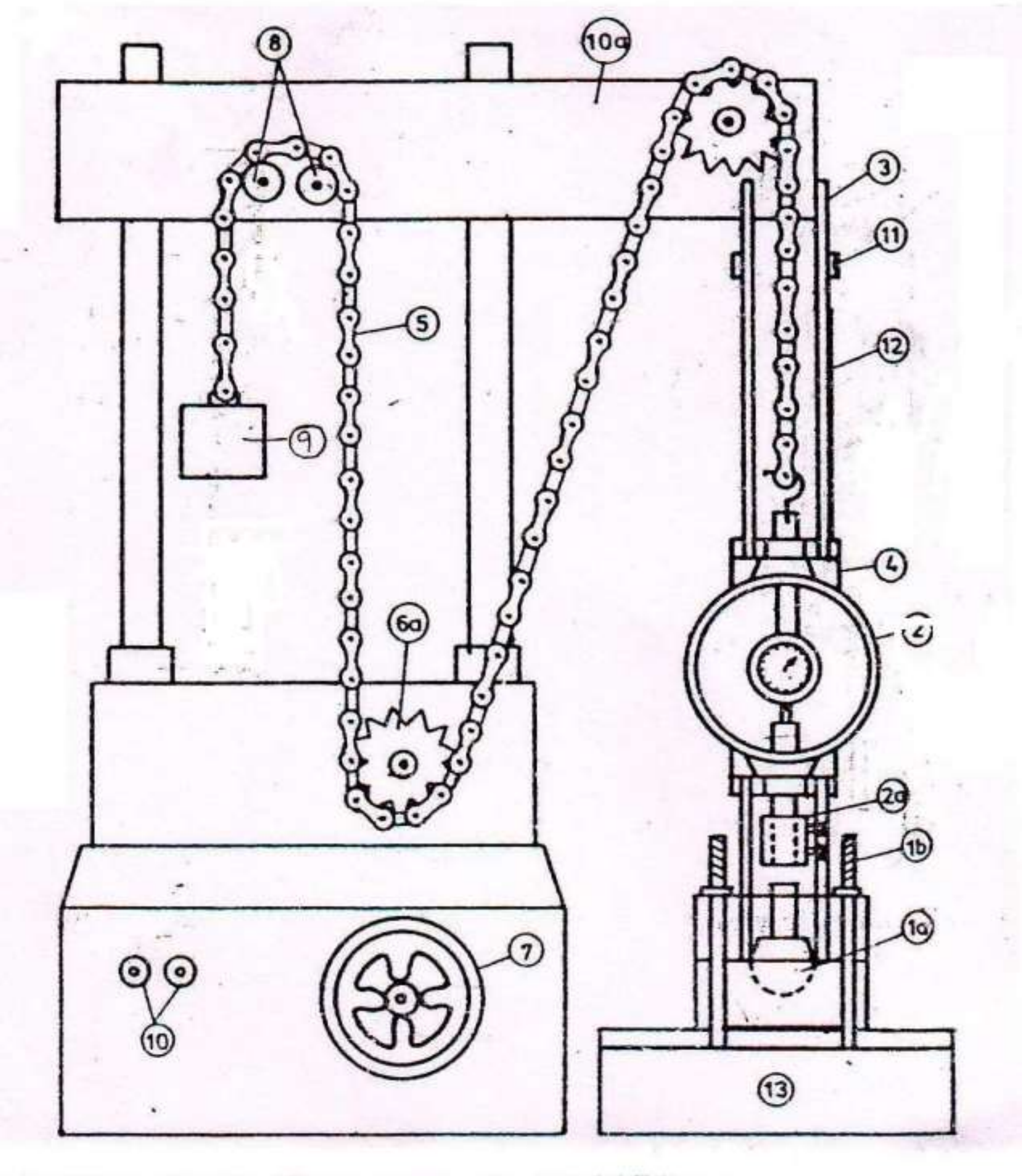

Figure 1: Experimental set-up

1a.PROBE 1b.SPECIMEN HOLDE 1.BITUMEN CONTAINER WITH PROBE ASSEMBLY 2.TENSION PROVING RING 2a.CONNECTOR 3.HORIZONTAL GUIDE 4.FRONT AND BACK GUIDE 5.CHAIN 6.SPROKET WITH BEARING 6a.SPROKET FITTED WITH THE GEAR SPINDLE 7.GEAR ARRANGEMENT FOR

SPEED SELECTION 8.CHAIN ROLLER 9.WEIGHT 10.ON/OFF SWITCH 10a. MAIN FRAME 11. VERTICAL STOPPER 12. STEEL SCALE 13. MASONRYFOUNDATION

EXPERIMENTAL PROCEDURE

The prepared sample was placed on the testing base and made to hold firmly to the base. All the controlling guides are checked after holding. The probe was pulled at the rate of 50 mm/min. The load was recorded from the tension proving ring and the corresponding displacements were noted from the steel scale during testing. Minimum 3 tests were conductedto get appropriate load-displacement data. Tests were carried out at 10°C, 20°C and 30°C. Temperature of 10°C and 20°C was maintained by placing the ice cubes around the specimen cup for about 30 minutes.

EXPERIMENTAL RESULTS

4.1 Load - Deformation Characteristic of Modified Bitumen

The experimental results from the direct tension test using the above equipment has yielded the data for 60/70 bitumen with various percentages of polymers, crumb rubber and waste plastic. The typical load-deformation curve under tension is given in Figure 2 which shows a typical tensile load- deformation characteristic plot with added creep after reaching the failure load at which the hemispherical cone is pulled out of the bitumen.

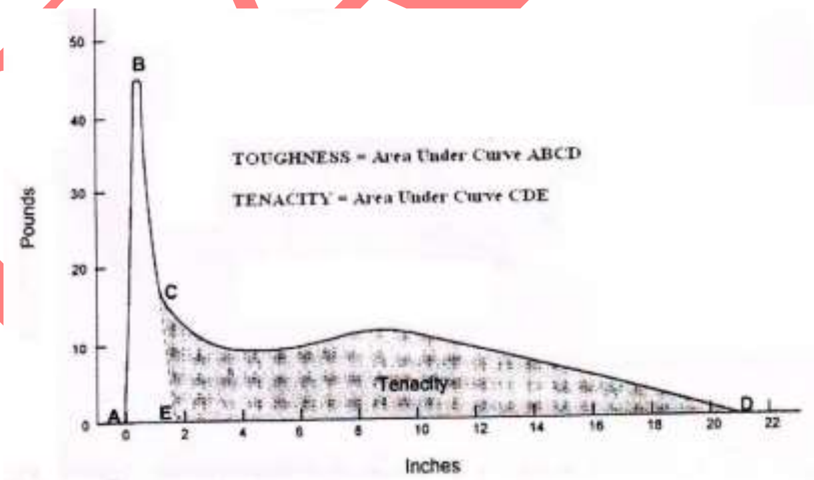

Figure 2: Typical Stress- Strain Curve for Rubberized Asphalt

The toughness and tenacity of the modified bitumen are calculated as given below.

Toughness = Area under curve ABCD

Tenacity = Area under curve CDE

TABLES AND GRAPHS

The summary of experimental results of load and deformation values of 60/70 grade bitumen with various modifiers (WP, CRM EVA and SBS) at different temperatures as obtained from the modified pull test (Toughness Test Machine) and direct tensile test are shown in the Tables 1 to 12.

Table 1: Load and Deformation values of 60/70 grade bitumen with WP at 10◦ C

Test Temperature	10˚ C					
Deformation in mm	Percentage of plastic added					
	0	2	4	6	8	10
	Load in kgs					
0	0	0	0	0	0	0
2	64.90	97.35	110.33	116.82	110.33	51.92
4	90.86	136.29	149.27	162.25	142.78	77.88
6	123.31	175.23	188.21	188.21	175.23	97.35
8	136.29	201.19	214.17	227.15	207.68	116.82
10	162.25	214.17	233.64	246.62	253.11	142.78

Table 2: Load and Deformation values of 60/70 grade bitumen with WP at 20˚ C

Test Temperature	20˚ C					
Deformation in mm	Percentage of plastic added					
	0	2	4	6	8	10
	Load in kgs					
0	0	0	0	0	0	0
2	38.94	58.41	32.45	77.88	97.35	51.92
4	58.41	64.90	58.41	123.31	142.78	71.39
6	71.39	90.86	77.88	149.27	175.23	90.86
8	84.37	116.82	103.84	181.72	201.19	103.84
10	97.35	136.29	136.29	207.68	233.64	129.80

Table 3: Load and Deformation values of 60/70 grade bitumen with WP at 30˚ C

Test Temperature	30˚ C					
Deformation in mm	Percentage of plastic added					
	0	2	4	6	8	10
	Load in kgs					
0	0	0	0	0	0	0
2	12.98	19.47	12.98	32.45	45.43	19.47
4	19.47	25.96	25.96	51.92	58.41	32.45
6	25.96	32.45	32.45	64.90	77.88	38.94
8	32.45	45.43	38.94	77.88	97.35	58.41
10	38.94	51.92	45.43	84.37	123.31	64.9

Table 4: Load and Deformation values of 60/70 grade bitumen with CRM at 10˚ C

Test Temperature	10˚ C					
Deformation in mm	Percentage of CRM added					
	0	2	4	6	8	10
	Load in kgs					
0	0	0	0	0	0	0
2	64.90	71.39	51.92	136.29	129.80	97.35
4	90.86	84.37	84.37	175.23	155.76	123.31
6	123.31	103.84	116.82	188.21	194.70	149.27
8	136.29	116.82	129.80	214.17	233.64	175.23
10	162.25	129.80	155.76	259.60	272.58	188.21

Table 5: Load and Deformation values of 60/70 grade bitumen with CRM at 20˚ C

Test Temperature	20˚ C					
Deformation in mm	Percentage of CRM added					
	0	2	4	6	8	10
	Load in kgs					
0	0	0	0	0	0	0
2	38.94	32.45	45.43	64.90	51.92	32.45
4	58.41	58.41	64.90	84.37	77.88	45.43
6	71.39	77.88	84.37	103.84	103.84	64.90
8	84.37	97.35	110.33	136.29	129.80	90.86
10	97.35	116.82	129.80	162.25	149.27	123.31

Table 6: Load and Deformation values of 60/70 grade bitumen with CRM at 30˚ C

Test Temperature	30˚ C					
Deformation in mm	Percentage of CRM added					
	0	2	4	6	8	10
	Load in kgs					
0	0	0	0	0	0	0
2	12.98	6.49	19.47	25.96	19.47	12.98
4	19.47	12.98	32.45	45.43	32.45	25.96
6	25.96	25.96	38.94	51.92	38	32.45
8	32.45	32.45	45.43	58.41	58.41	45.43
10	38.94	38.94	51.92	64.90	71.39	51.92

Table 7: Load and Deformation values of 60/70 grade bitumen with EVA at 10˚ C

Test Temperature	10˚ C					
Deformation in mm	Percentage of EVA added					
	0	2	4	6	8	10
	Load in kgs					
0	0	0	0	0	0	0
2	64.90	51.92	71.39	116.82	51.92	19.47
4	90.86	71.39	97.35	149.27	77.88	25.96
6	123.31	97.35	116.82	188.21	97.35	32.45
8	136.29	116.82	136.29	220.66	129.80	38.94
10	162.25	136.29	162.25	259.60	162.25	

Table 8: Load and Deformation values of 60/70 grade bitumen with EVA at 20˚ C

Test Temperature	20˚ C					
Deformation in mm	Percentage of EVA added					
	0	2	4	6	8	10
	Load in kgs					
0	0	0	0	0	0	0
2	38.94	32.45	64.90	71.39	45.43	12.98
4	58.41	45.43	77.88	103.84	64.90	19.47
6	71.39	64.90	90.86	116.82	84.37	32.45
8	84.37	97.35	103.84	142.78	97.35	45.43
10	97.35	110.33	129.80	181.72	110.33	58.41

Table 9: Load and Deformation values of 60/70 grade bitumen with EVA at 30◦ C

Test Temperature	30˚ C					
Deformation in mm	Percentage of EVA added					
	0	2	4	6	8	10
	Load in kgs					
0	0	0	0	0	0	0
2	12.98	19.47	32.45	32.45	25.96	12.98
4	19.47	32.45	45.43	45.43	38.94	32.45
6	25.96	45.43	51.92	64.90	51.92	45.43
8	32.45	58.41	64.90	77.88	64.90	58.41
10	38.94	64.90	97.35	116.82	71.39	64.90

Table 10: Load and Deformation values of 60/70 grade bitumen with SBS at 10˚ C

Test Temperature	10˚ C					
Deformation in mm	Percentage of SBS added					
	0	2	4	6	8	10
	Load in kgs					
0	0	0	0	0	0	0
2	64.90	51.92	64.90	84.37	103.84	77.88
4	90.86	77.88	103.84	123.31	142.78	97.35
6	123.31	116.82	129.80	162.25	175.23	116.82
8	136.29	136.29	155.76	188.21	201.19	136.29
10	162.25	149.27	181.72	214.17	246.62	162.25

Table 11: Load and Deformation values of 60/70 grade bitumen with SBS at 20˚ C

Test Temperature	20˚ C					
Deformation in mm	Percentage of SBS added					
	0	2	4	6	8	10
	Load in kgs					
0	0	0	0	0	0	0
2	38.94	25.96	19.47	32.45	38.94	25.96
4	58.41	32.45	32.45	45.43	71.39	45.43
6	71.39	38.94	51.92	64.90	90.86	58.41
8	84.37	45.43	64.90	84.37	123.31	77.88
10	97.35	51.92	71.39	103.84	149.27	97.35

Table 12: Load and Deformation values of 60/70 grade bitumen with SBS at 30° C

Test Temperature	30° C					
Deformation in mm	Percentage of SBS added					
	0	2	4	6	8	10
	Load in kgs					
0	0	0	0	0	0	0
2	12.98	12.98	19.47	12.98	19.47	12.98
4	19.47	12.98	25.96	19.47	25.96	19.47
6	25.96	19.47	32.45	25.96	38.94	32.45
8	32.45	25.96	38.94	32.45	51.92	38.94
10	38.94	32.45	51.92	45.43	71.39	58.41

The Toughness values obtained for 60/70 grade bitumen with various percentages of modifiers at different temperature are given in Table 13.

Table 13: Toughness values of various Modified Bitumen

Temperature °C	Percent of Modifier in binder	Toughness kg-mm			
		WP	CRM	EVA	SBS
10	0	50.13	50.13	50.13	50.13
	2	51.71	55.69	56.88	53.11
	4	58.15	66.04	69.85	67.69
	6	67.82	80.06	92.76	56.86
	8	69.78	121.74	53.49	53.84
	10	72.21	98.34	35.69	54.85
20	0	44.32	44.32	44.32	44.32
	2	45.57	50.13	45.18	42.09
	4	49.57	51.87	59.41	42.21
	6	52.73	55.69	84.07	46.52
	8	57.72	56.22	64.21	54.28
	10	66.21	56.86	20.58	30.07

30	0	22.19	22.19	27.9	22.19
	2	35.83	27.9	33.12	22.66
	4	39.9	31.81	43.62	23.05
	6	42.41	33.42	80.76	28.1
	8	45.96	34.12	43.62	34.62
	10	57.15	35.24	13.93	18.04

The load-deformation curve for various percentages of modifiers (like WP, CRM, EVA and SBS) added to 60/70 penetration bitumen is plotted taking load in kg and deformation in mm for different temperatures as shown in Fig 3 to 14.

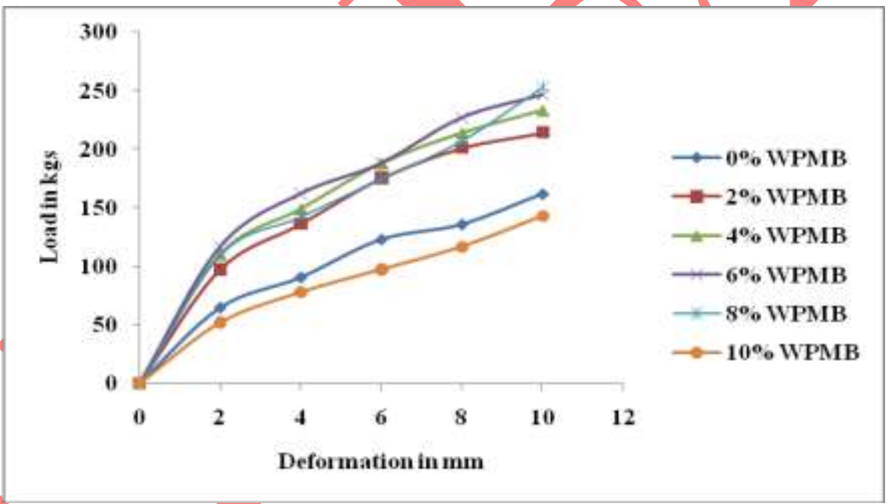

Figure 3: Load-Deformation curve for various percentages of Waste Plastic added to 60/70 Penetration Bitumen at 10° C

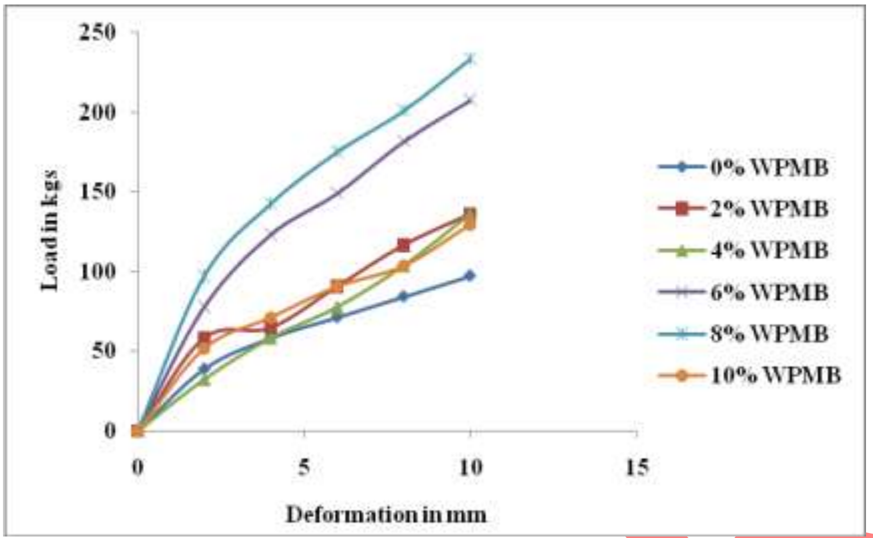

Figure 4: Load-Deformation curve for various percentages of Waste Plastic added to 60/70 Penetration Bitumen at 20˚ C

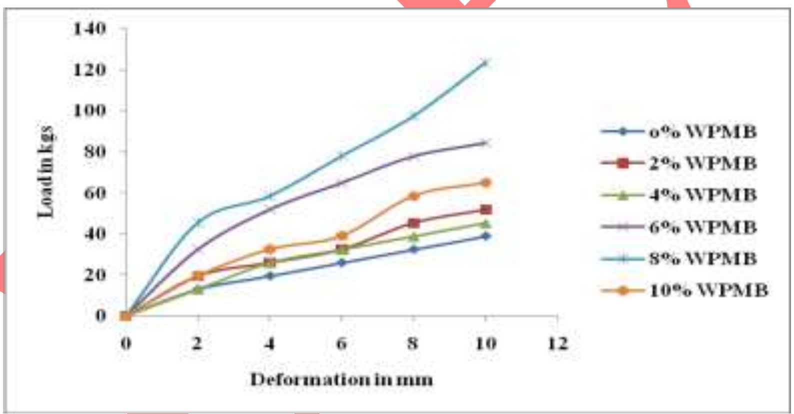

Figure 5: Load-Deformation curve for various percentages of Waste Plastic added to 60/70 penetration Bitumen at 30˚ C

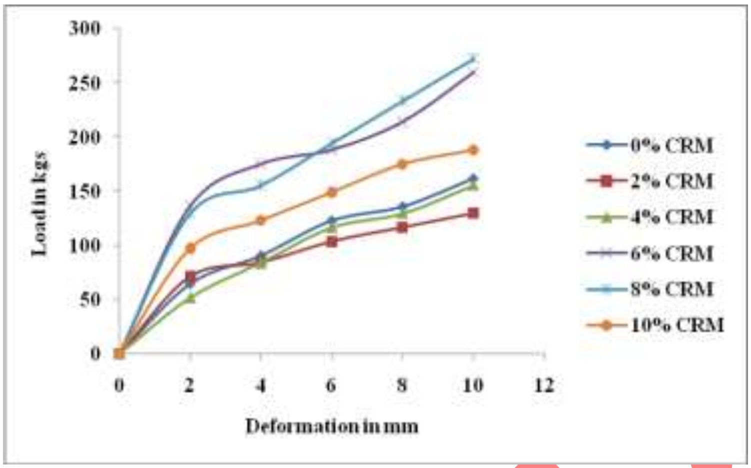

Figure 6: Load-Deformation curve for various percentages of CRM added to 60/70 penetration Bitumen at 10˚ C

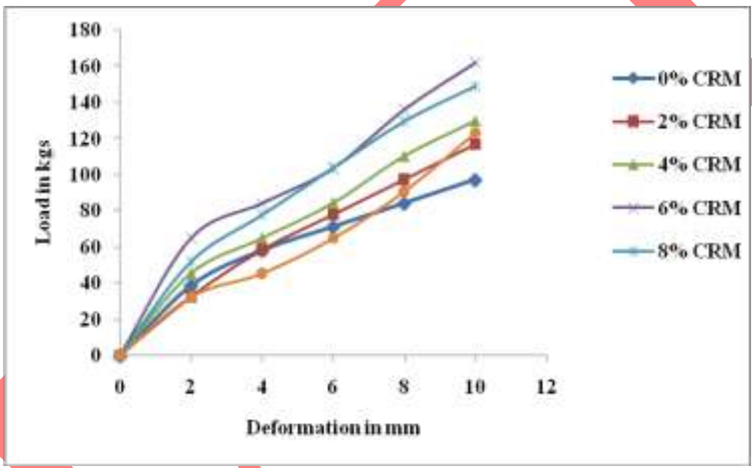

Figure 7: Load-Deformation curve for various percentages of CRM added to 60/70 penetration Bitumen at 20˚ C

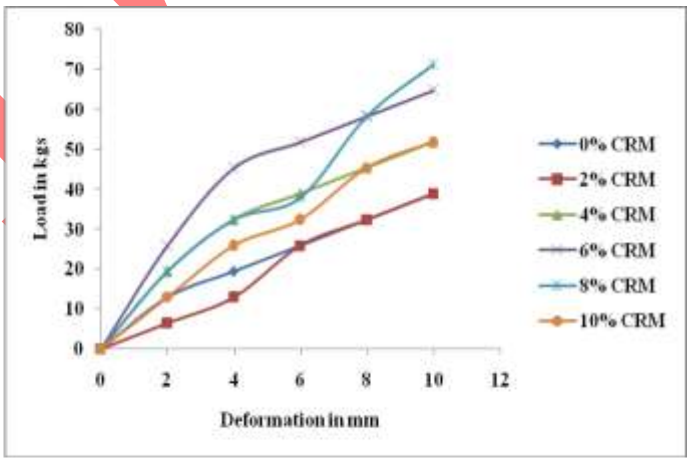

Figure 8: Load-Deformation curve for various percentages of CRM added to 60/70 penetration Bitumen at 30˚ C

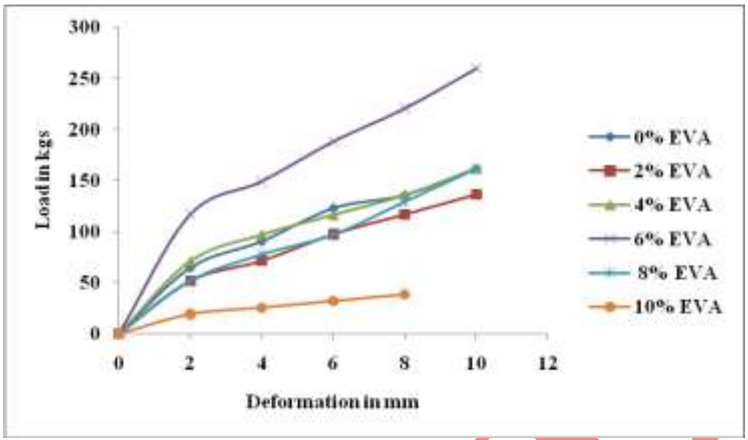

Figure 9: Load-Deformation curve for various percentages of EVA added to 60/70 penetration Bitumen at 10˚ C

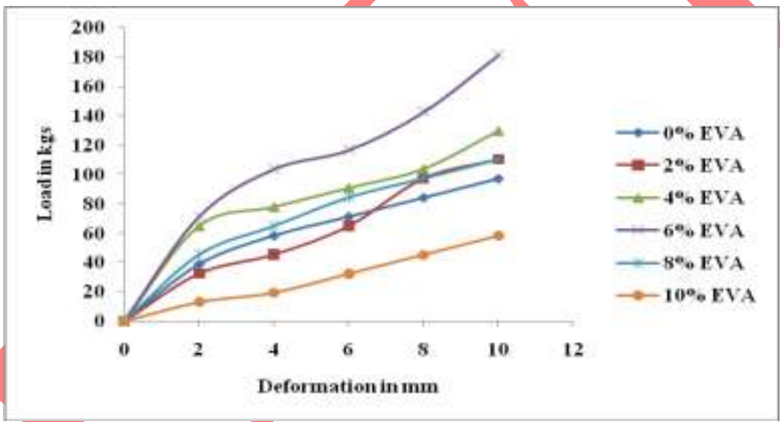

Figure 10: Load-Deformation curve for various percentages of EVA added to 60/70 penetration Bitumen at 20˚ C

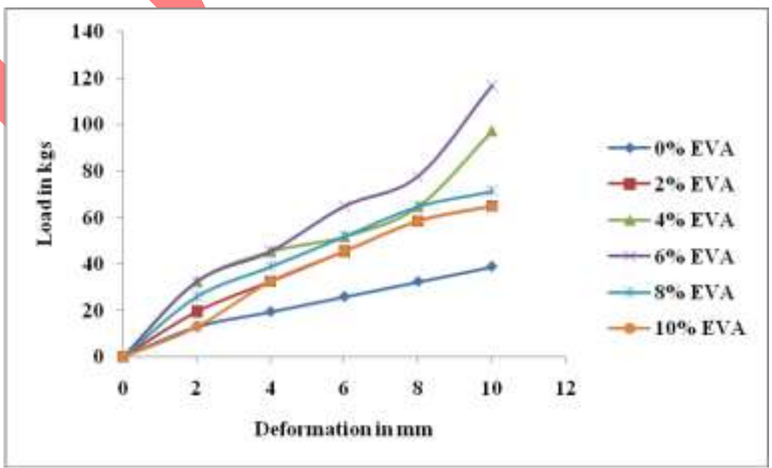

Figure 11: Load-Deformation curve for various percentages of EVA added to 60/70 penetration Bitumen at 30˚ C

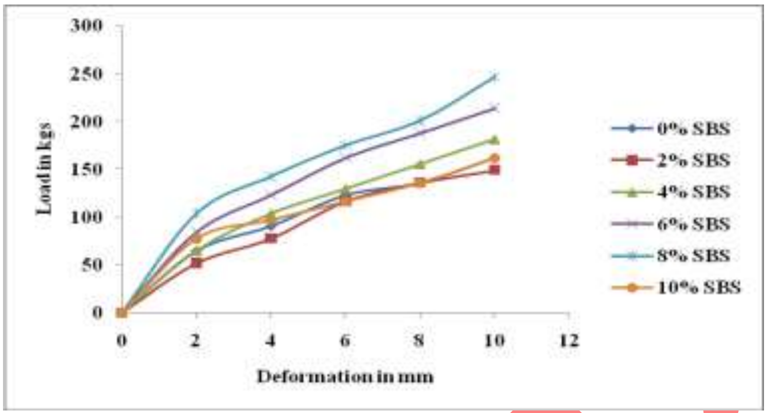

Figure 12: Load-Deformation curve for various percentages of SBS added to 60/70 penetration Bitumen at 10˚ C

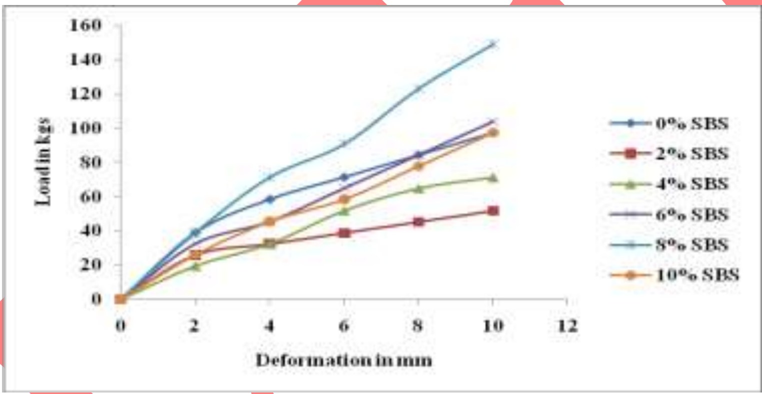

Figure 13: Load-Deformation curve for various percentages of SBS added to 60/70 penetration Bitumen at 20˚ C

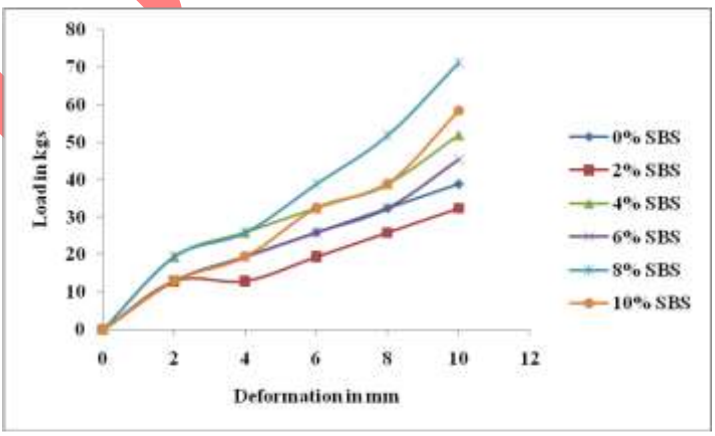

Figure 14: Load-Deformation curve for various percentages of SBS added to 60/70 penetration Bitumen at 30˚ C

A plot showing variation of Toughness and percent of polymers such as EVA, CRM, SBS and WP added to 60/70 penetration bitumen is as shown in Fig. 15 to 18.

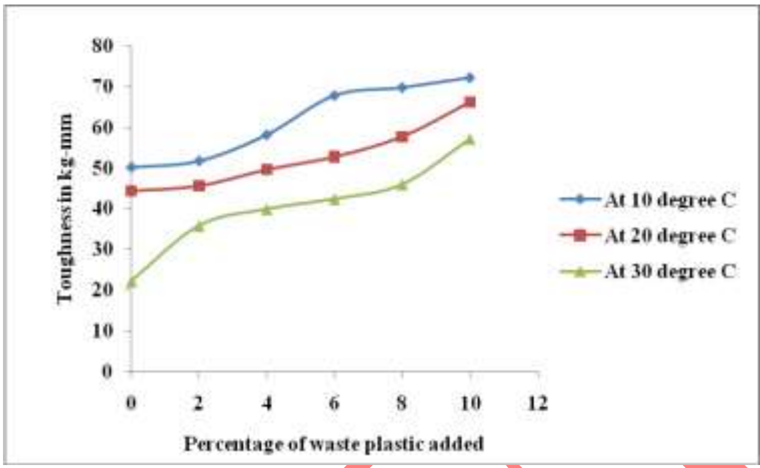

Figure 15: Toughness Vs Percentage of waste plastic added at different temperatures

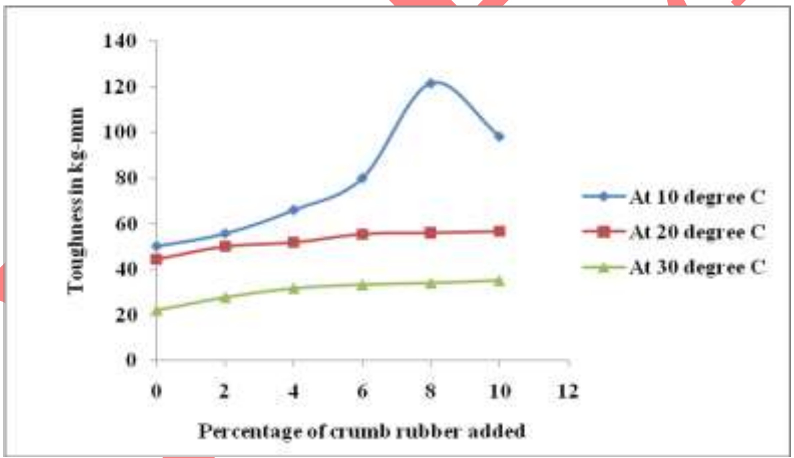

Figure 16: Toughness Vs Percentage of crumb rubber added at different temperatures

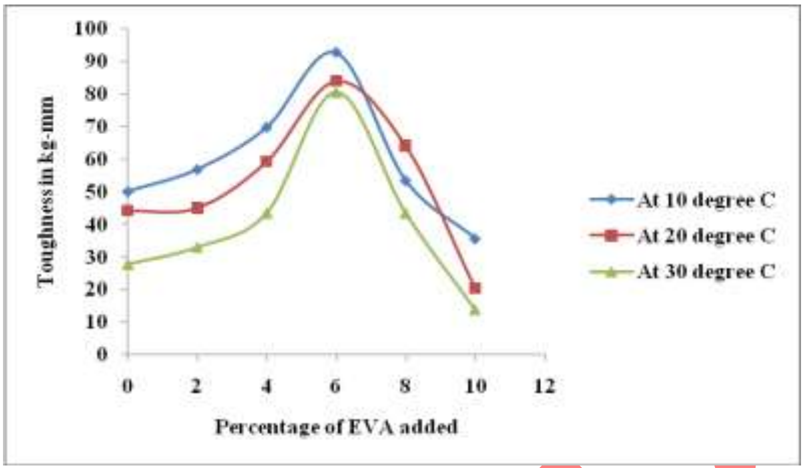

Figure 17: Toughness Vs Percentage of EVA added at different temperatures

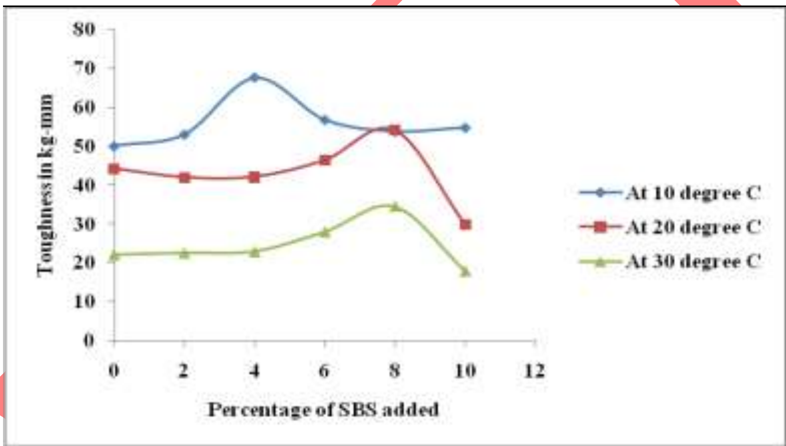

Figure 18: Toughness Vs Percentage of SBS added at different temperatures

DISCUSSION

The test results obtained from the bitumen 60/70 modified with polymers viz. PMB (SBS70), Crumb rubber, waste plastics and EVA were analysed for toughness. This parameter is the indicator of the performance of bitumen in the field. In light of usefulness of addition of different types of modifiers, the following discussions are presented.

5.1 Load Deformation characteristic of the Modified Bitumen

The Load deformation results obtained from the modified pull out test for toughness are given in Tables 1 to 12 and the load deformation curves are presented in Fig 2 to 13 at different temperatures ranging from 10° to 30° C. The general trend of the curves illustrates the elastic nature of the modified bitumen with a tendency to creep at higher deformations. The effect of the temperature is indicated by decrease in loads at 30°C compared to at 10°C. In all the cases 6 to 8% modifier content by weight of bitumen has given higher load-deformation characteristics.

5.2 Effect of Modifiers on the Toughness of Bitumen

Generally the addition of polymers/plastics to the bitumen should increase its toughness consequently increasing the softening point, flow resistance and decrease the penetration. The exact percentage of addition of modifier at which the transition of the bitumen from elastic to plastic state can be obtained from Toughness and Tenacity tests. Table 13 and Figs 15 to 18 indicate that with increase in percentage of modifier the toughness increases up to maximum value and then decreases. This is highly predominant in EVA polymer modified bitumen with 80kg-mm toughness at 6% EVA at 10°C where as CRM has shown the higher at 120kg-mm at 8% crumb rubber added at 10°C. At higher temperatures no such trend is observed. For waste plastic, the increase in toughness with the addition of modifier is mild and indicates a maximum value of 60kg-mm at 6% at 10°C. Whereas for the SBS modifier, at 4% SBS a higher value of 65kg-mm is indicated at 10°C. At higher temperatures, it is observed that this trend shifts to 8% addition of modifier.

5.3 Variation of Toughness of Modified bitumen with Temperature

In general for all the modifiers, with increase in temperature the toughness decreases. The higher decrease in toughness is observed for CRM for 8% addition as shown in Table 3 where in the decrease occurs from 121.74 kg-mm at 10˚C to 34.12kg-mm at 30˚C. The decrease was minimum for EVA at 8%, dropping from 53.49 at 10˚C to 43.62 at 30˚C.

CONCLUSION

From the results of the tests conducted on the 60/70 bitumen modified with various percentages of waste plastic, crumb rubber, EVA and SBS-70 polymers, using pull out test on modified Marshall equipment, the following conclusions are drawn.

i. The toughness measured from the modified equipment is highest at 8% addition for CRMB.
ii. The addition of CRMB thus has given higher toughness value when compared with the toughness obtained by the addition of Plastics and Polymers, thus contradicting the general opinion that the polymers and plastics make bitumen tougher.
iii. The crumb rubber modified bitumen has shown superior toughness characteristics, when compared with toughness of bitumen modified by EVA, SBS and Waste Plastics.

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REFERENCES

[1] Abdelaziz Mahrez., and Mohamed Rehan Karim, (2003); Rheological Evaluation of Aging Properties of Rubber Crumb Modified Bitumen, *Journal of the Eastern Asia Society for Transportation Studies*, Vol.5.

[2] Jyh-Dong Lin, Shih-Huang Chen, Pei Liu, & Jian-Neng Wang, (2004); Modified Toughness used to Evaluate the Effect of Polymer Modified Asphalt on Stonic Mastic Asphalt, *Journal of the Chinese Institute of Engineers*, vol. 27, No. 7, pp. 1013-1020.

[3] Benson, J.R, (Apr 1955); New Concepts for Rubberized Asphalts Roads and Streets.

[4] Robinson, H.L., Taylor, M.B. and Tosh, D.J, (Jan 1991); Toughness and Tenacity Analysis of Bitumen, *Highways*, U.K.

[5] Madzlan B.Napiah, Ibrahim Kamaruddin, Yasreen Gasm, (2010); The Creep Performance of Base and Polymer Modified Bituminous Mixes Containing Different Types of Sand as Fine Aggregate, *Journal of the Eastern Asia Society for Transportation Studies*, Vol. 8.

[6] H. U. Bahia., D. I. Hanson., M. Zeng., H. Zhai., M. A. Khatri., and R. M. Anderson, (2001); *Characterization of Modified Asphalt Binders in Superpave Mix Design*, Transportation Research Board, National Research Council, National Academy Press Washington, D.C. Vol. 459.

[7] Bindu C.S & Dr. K.S.Beena, (2010); Waste Plastic as a Stabilizing additive in Stone Mastic Asphalt, *International Journal of Engineering and Technology* Vol.2 (6), 379-387.

[8] V. S. Punith and A. Veeraragavan, (1 June 2007); Behavior of Asphalt Concrete Mixtures with Reclaimed Polyethylene as Additive, *Journal of Materials in Civil Engineering*, Vol. 19, No. 6.

[9] Punith.V.S and Veeraraghavan.A (2004); Fatigue Characteristics of Recycled Plastic Modified Bituminous Concrete Mixes, *Highway Research Bulletin*, No.70, and Page 11-29.

[10] H. Von Quintus., J. Mallela., and M. Buncher, (2007); Quantification of the Effect of Polymer Modified Asphalt on Flexible Pavement Performance, in *Proceedings of 86thAnnual Meeting, Transportation Research Board*, Washington DC, pp.21-25.

[11] Taher Baghaee Moghaddam, Mohamed Rehan Karim and Mahrez Abdelaziz, A review on fatigue and rutting performance of asphalt mixes, Available online at http://www.academicjournals.org/SRE

[12] Denning.J.H and Carswell.J (1981); *Improvements in Rolled asphalt Surfacing by the addition of Organic Polymers*, Department of the Environment, Report LR989, Transportation Road Research Laboratory (TRRL), Crowthrone.

[13] Sabina, Tabrez A Khan, Sangita, D K Sharma and B. M Sharma (Nov 2009); Performance Evaluation of Waste plastic/Polymer Modified Bituminous Concrete Mixes, *Journal of Scientific & Industrial Research*, Vol.68, pp. 975-979.

[14] Ministry of Road Transport and Highway (MoRTH): Specifications of Road and Bridges Works (Third Revision), IRC; New Delhi, 2001.

[15] Ayman M. Othman, Incorporation of White Cement Dust on Rubber Modified Asphalt Concrete Mixtures, *International Journal of Civil & Environmental Engineering IJCEE*,Vol.9, No. 10, pp.40-51.

[16] R. Vasudevan, S.K. Nigam, R. Velkennedy, A. Ramalinga Chandra Sekar and B. Sundarakannan (5-7 Sep 2007); Utilization of Waste Polymers for Flexible Pavement and Easy Disposal of Waste Polymers, *Proceedings of the International Conference on Sustainable Solid Waste Management*, India, pp. 105-111.

[17] S.S. Verma, (Nov 2008); Roads from Plastic Waste, *Indian Concrete Journal*, pp. 43-44

[18] Scott Shuler, James H. Collins and John P. Kirkpatrick, (1987), Polymer Modified Asphalt Properties Related to Asphalt Concrete Performance, Asphalt Rheology Relationship to Mixture, *ASTM*, STP 941, O.E.Briscoe Ed. ASTM, Philadelphia.

[19] IRC: SP: 53-2002, Tentative Guidelines on use of Polymer and Rubber Modified Bitumen in Road Construction.

[20] S.K.Palit, M.Pandai & M.Mazumdar (1996); Toughness and Tenacity of Bitumen and Polymer Modified Bitumen, I.R.C. - Highway Research Board No.55.

[21] Thompson, D.C. and Hagman, J.F, (1958); The Modification of Asphalt with Neoprene, Association of Asphalt Pavement Technologists.

[22] ASTM: Standard Method of Test for Determining Toughness and Tenacity of Rubberized Asphaltic Materials Colorado procedure- Laboratory 2210- March 2007.