CRUMB RUBBER MODIFIED BITUMEN

Civil Engineering

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MESSAGE

AN ACT OF GOODNESS IS AN ACT OF HAPPINESS. NO REWARD COMING AFTER THE EVENT CAN COMPARE THE SWEET REWARD THAT WENT WITH IT.

CERTIFICATE

This is to certify that the work entitled "**CRUMB RUBBER MODIFIED BITUMEN**" submitted by **YUVARAJ** (111619), **AKSHAY GARG** (111686), in partial fulfillment for the award of degree of Bachelor of Technology in Civil Engineering of Jaypee University of Information Technology has been carried out under my supervision. This work has not been submitted partially or wholly to any other University or Institute for the award of this or any other degree or diploma to the best of my knowledge.

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ACKNOWLEDGEMENT

This project report gives a detailed description of the study work done on the project topic "**CRUMB RUBBER MODIFIED BITUMEN**" for the partial fulfillment of the requirements for the degree of Bachelor of Technology in Civil Engineering, under the supervision of **DR. ASHISH KUMAR**.

We gratefully acknowledge the Management and Administration of Jaypee University of Information Technology, Waknaghat for providing us the opportunity and hence the environment to initiate and complete our project now.

We are very grateful to our Faculty Coordinator DR. ASHISH KUMAR for his help and able guidance regarding the project. We are also very grateful to the support and assistance provided by the team of talented and dedicated technical staff comprising Mr. Jaswinder Singh, Mr. Manvendra Singh, and Mr. Pradeep department of Civil engineering.

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ABSTRACT

The rapid utilization of crumb rubber in flexible pavements requires the better understanding of its effect on physical and rheological properties of rubberized bitumen binders. The properties of rubberized bitumen binder are influenced by the blending conditions and crumb rubber content.

The main objective of present study was to investigate the effect of crumb rubber content on the physical, rheological properties and rutting resistance of rubberized bitumen by varying the percentage of rubber content. The rubber used in the present study has natural rubber content equal to 34%. Laboratory tests were conducted to evaluate properties of bitumen binder with different rubber contents. The percentage of rubber content was varied from 0 to 16% (0, 2.5, 5, 7.5, 10, and 16). The tests undertaken comprise the Ductility test, Penetration test, Softening point and Marshal Stability test.

The results showed that the addition of crumb rubber has an effect on the physical properties of rubberized bitumen binders. Addition of crumb rubber decreased its penetration and ductility. The results indicated that the rubber content has the potential to resist rutting deformation that occurs in road pavement as result of increased traffic loading. The results of present study were also compared with previous study having natural rubber percentage as 60.

CHAPTER 1

INTRODUCTION

Introduction

The tyre is a complex and high-tech safety product representing a century of manufacturing innovation, which is still on-going. From the material point of view the tyre is made up of three main components materials: (i) elastomeric compound, (ii) fabric and (iii) steel. Tyre structure is shown in fig 1.1. The fabric and steel form the structural skeleton of the tyre with the rubber forming the ‘‘flesh’’ of the tyre in the tread, side wall, apexes, liner and shoulder wedge. This engineering process is necessary to transform natural rubber in a product able to ensure performance, durability and safety. In fact, natural rubber is sticky in nature and can easily deform when heated up and it is brittle when cooled down. In this state it cannot be used to make products with a good level of elasticity. The reason for inelastic deformation of not-vulcanized rubber can be found in the chemical nature as rubber is made of long polymer chains. These polymer chains can move independently relative to each other, and this will result in a change of shape. By the process of vulcanization cross-links are formed between the polymer chains, so the chains cannot move independently anymore. As a result, when stress is applied the vulcanized rubber will deform, but upon release of the stress the rubber article will go back to its original shape. Compounding is finally used to improve the physical properties of rubber by incorporating the ingredients and ancillary substances necessary for vulcanization, but also to adjust the hardness and modulus of the vulcanized product to meet the end requirement. Different substances can be added according to the different tyre mixtures; these include mineral oil and reinforcing fillers as carbon black and silica. In general, truck TR contains larger percentages of natural rubber compared to that from car tyres. To summarizes the general tyre composition of tyres used in cars and trucks in the EU. From the structural point of view, the main components of tyre are the tread, the body, side walls and the beads. The tread is the raised pattern in contact with the road. The body supports the tread and gives the tyre its specific shape. Beads are metal-wire bundles covered with rubber, which holds the tyre on the wheel. The inherent characteristics of the tyre are the same worldwide. They include: the resistance to mould, mildew, heat and humidity, retardation of bacterial development, resistance to sunlight, ultraviolet rays, some oils, many solvents, acids and other chemicals. Table 1 shows the effect of temperature on natural rubber.

S.No.	TEMPERATURE(˚C)	PROPERTY
1	-10	Brittle and Opaque
2	20	Soft, resilient and translucent
3	50	Plastic and sticky
4	120-160	Vulcanized when agents like sulphur are added
5	180	Break down as in the masticator
6	200	Decomposes

Table.1.1: Effect of Temperature on natural rubber

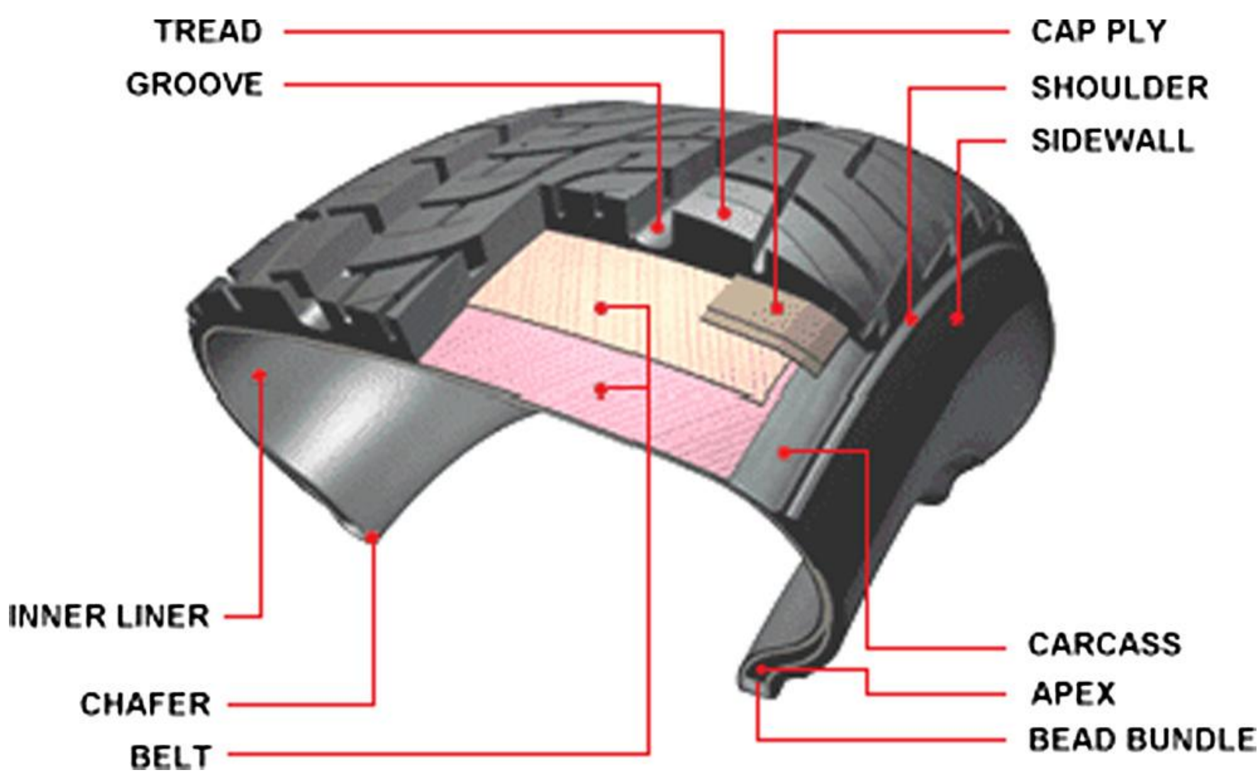

Fig.1.1: Tyre structure

(Reference: www.checkthatcar.com>;2013)

1.1. Ambient Grinding

Ambient processing is typically required to provide irregularly shaped, torn particles with relatively large surface areas to promote interaction with the paving bitumen. This is a mechanical grinding, performed by means of rotating blades and knives, in which the critical step is the separation of the fibers, amongst which are generally included steel fibers. Once separated from the metallic material, ambient grinding is able to produce rubber crumbs with grain size ranging from 5 to 0.5 mm. Figure 1.2 shows the working of ambient grinding.

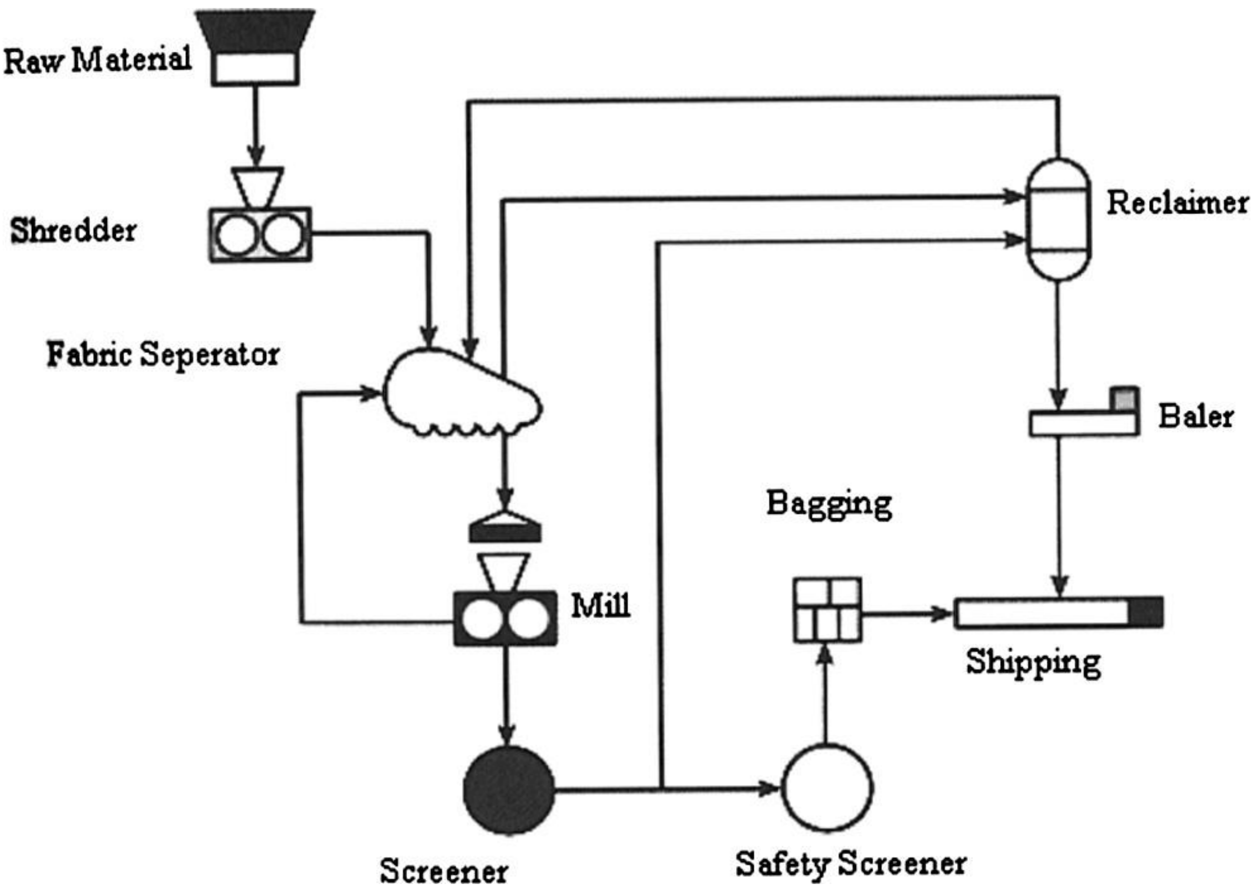

Fig.1.2: Schematic representation of ambient grinding.

(Reference: University of Nottingham, school of civil engineering; 2004.)

1.2. Cryogenic grinding.

This process uses liquid nitrogen to freeze the RTR (typically between 87 to 198 degree C) until it becomes brittle, and then uses a hammer mill to shatter the frozen rubber into smooth particles with relatively lower surface area than those obtained by ambient grinding. Oliver showed that several characteristics of the rubber granulate determine the elastic properties of the Crumb Rubber and those conferred on the final mix: they enhance with the decrease of specific gravity and particle size, and increase with the higher surface porosity of the granules.

1.3 Uses of CRMB

The recycled Tyre Rubber is being used in new-tyres, in tyre-derived fuel, in civil engineering application, in moulded rubber products, recreational and sports applications and in rubber modified asphalt applications. The benefits of using rubber modified asphalt are being more widely experienced and recognized, and the incorporation of tyres into asphalt is likely to increase. It is used in Flooring/Rubber mats, in Highway Construction and Repair, in Equestrian areas, in artificial athletic surfaces.

1.4 Brief Review:

An early investigation of the effects of addition of crumb rubber in bitumen was undertaken by Mahrez, (1999). They observed in their study that use of crumb rubber in bitumen modification leads to an increase in the softening point and viscosity as rubber crumb content increases.

A laboratory study by Nuha S. Mashaan, Asim H. Ali, Mohamed Rehan Karim and Mahrez Abdelaziz et al, (2011), also showed that addition of crumb in bitumen increases its softening point but decreases penetration and ductility which is taken as a reference for comparison for the present study.

1.5 Objective of study

In the present study following objectives are stipulated:

- ✓ To study the properties of ordinary bitumen and crumb rubber modified bitumen
- ✓ To find out the optimum percentage of crumb rubber in bitumen.
- ✓ To compare CRMB with high natural rubber content with CRMB of low natural rubber content.

In order to achieve the following objectives a series of laboratory experiments were conducted. The details of which are given in chapter 3 (Analysis of data and discussion of results).

1.6 Concluding remarks

Crumb rubber modifications of bitumen have improved the 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.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to literature review of CRMB:

A detailed review of research works carried out related to the present study is described as below. A number of studies are available on topic of "CRUMB RUBBER MODIFIED BITUMEN". They have utilized crumb rubber having percentage of natural rubber as 60. However latest study have been explained in this study.

The penetration is a measure of hardness or softness of bitumen binder which shows an effect by adding crumb rubber to bitumen binder; it decreases as rubber content is increased. The penetration shows lower values as rubber content increases at different mix conditions of rubberized bitumen binder, indicating that the binder becomes stiff and more viscous (Mashaan *et al.* 2011a). Mahrez (1999) investigated the properties of rubberized bitumen prepared by physical blending of bitumen 80 / 100 penetration grade with different crumb rubber content and various aging phases. The results of penetration values decreased over the aging as well as before aging by increasing the rubber content in the mix. Also, the modified binders have lower penetration values than unmodified binders.

2.2 Reviews

The softening point refers to the temperature at which the bitumen attains a particular degree of softening. The use of crumb rubber in bitumen modification leads to an increase in the softening point and viscosity as rubber crumb content increases (Mahrez, 1999; Mashaan et al, 20011a). Mahrezand Rehan (2003) claimed that there is a consistent relationship between viscosity and softening point at different aging phases of rubberized bitumen binder.

According to a study conducted by Lee *et al.* (2008), the higher crumb rubber content produced increased viscosity at 135°C and improved the rutting properties. It was also observed that the increased crumb rubber amount (fine crumb rubber) produced rubberized bitumen with higher viscosity and lower resilience. However, optimum crumb rubber content still needs to be determined for each crumb rubber size and asphalt binder. It is believed that a physicochemical interaction that occurs between the asphalt and the crumb rubber alters the effective size and physical properties of the rubber particle, thus influencing pavement performance (Huang *et al.*, 2007).

Becker *et al,* (2001) claimed that blend properties will be influenced by the amount of crumb rubber added to the bitumen. Higher amounts indicated significant changes in the blend properties. As rubber content generally increases, it leads to increased viscosity, increased resilience, increased softening point and decreases penetration at 25°C.

The mixture showed improved performance in dynamic stability, 48 h residual stability, flexural strength and strain value. Asphalt containing 0.2 and 0.4 mm size rubber indicated the best laboratory results (Souza and Weismann, 1994). The particles size disruption of crumb rubber influenced the physical properties of bitumen rubber blend. In general, small difference in the particles size has no significant effects on blend properties. However, the crumb rubber size can certainly make a big difference.

According to a study of Shen *et al*, (2009), the particle size effects of CRM on high temperature properties of rubberized bitumen binders was an influential factor on visco- elastic properties. The coarser rubber produced a modified binder with high shear modulus and an increased content of the crumb rubber decreased the creep stiffness which in turn showed significant thermal cracking resistance.

According to a study of Nuha S. Mashaan, Asim H. Ali, Mohamed Rehan Karim and Mahrez Abdelaziz *et al,* (2011), The performance properties of rubberized bitumen binder are influenced by the blending conditions and crumb rubber content. Addition of crumb rubber has an effect on the physical properties of rubberized bitumen binders, by increasing its elastic recovery and decreasing its penetration and ductility.

When crumb rubber is blended at high temperatures with bitumen to produce a modified binder (i.e. wet process), the two materials interact once bitumen components migrate into the rubber causing it swell (Bahia and Davies, 1994). Initially, the interaction between crumb rubber and bitumen is a nonchemical reaction, where the rubber particles are swollen by the absorption of the aromatic oils of bitumen (Heitzman, 1992).

2.3 Concluding remarks

Modified bitumen using crumb rubber showed an improvement in the performance of pavements over the base binders as a result of the interaction of crumb rubber with base binders. There are noticeable changes in the viscosity, physical and rheological properties of the rubberized bitumen binder (Airey *et al.* 2003; Bahla and Davies, 1995), leading to high resistance of rutting of pavements (Huang et al, 2007).

The rubber particles are considered in their movement into the binder matrix to move about due to the swelling process which limits the free space between the rubber particles. Compared to the coarser particles, the finer particles swell easily thus, developing higher binder modification (Abedlrahman and Carpenter, 1999). Table 2.1, below shows the properties of crumb rubber modified bitumen. (IS: 15462: 2004)

Table.2.1: Properties of crumb rubber modified bitumen

S.No.	Characteristic	CRMB 50	CRMB 55	CRMB 60
1	Penetration at 25˚C,0.1mm,5s	<70	<60	<50
2	Softening Point,˚C,min	50	55	60
3	Flash Point,˚C,min	220	220	220
4	Elastic recovery of half thread in ductilometer at 15˚C,Min	50	50	50
5	Separation difference in softening point,˚C,Max	4	4	4
6	Viscosity at 150˚C,Poise	1-3	2-6	3-9

CHAPTER3

EXPERIMENT PROGRAMME AND SETUP

3.1 Introduction

Descriptions about the materials used are discussed in this chapter. As we know, specimen details and testing methods are essentials for an experimental investigation. Hence they are also described in detail in the following sections.

3.2 Experimental Investigation

Details of specimen

The broad objective of the present work was to study the effect of crumbed rubber when mixed with bitumen. So In order to fulfill above a controlled sets of experiments were conducted in the laboratory of Civil engineering of JUIT (Waknaghat). Table 3.1, 3.2 and 3.3 shows the details of physical and chemical properties of the materials bitumen and crumb rubber used.

Table 3.4 shows the details of the various test specimens. It is intended to find experimentally the effect of addition of crumb rubber on the properties of bitumen to be used for construction purpose. Hence the investigations are taken up to evaluate penetration, softening point, ductility and Marshal stability strength of plain and crumb rubber modified bitumen specimens as per standards.

Material used:

Bitumen

Crumb rubber

Bitumen

Table.3.1: Test on bitumen

S.No.	CHARACTERISTIC	VALUE
1	Penetration (0.1mm)	48
2	Softening point (˚C)	48
3	Ductility (cm)	75
4	Marshal stability (kN)	6

According to IS: 1203-1978, Indian standard methods for Testing Tar and Bituminous Materials: determination of penetration (First revision) bitumen used is of grade 40/50.

According to IS: 1208-1978, Indian standard methods for Testing Tar and Bituminous Materials: determination of Ductility (First revision) bitumen used is VG 10.

According to Ministry of road transport and highways, specification for road and bridge works, (Fourth revision) minimum marshal stability for bituminous mix is 3.4 kN and our result is 6 kN which indicates bitumen is quite good to proceed.

Crumb Rubber:

Specific gravity: Table 3.2 shows the details of specific gravity test on crumb rubber.

Table.3.2: Specific gravity of crumb rubber

S.No.	CHARACTERISTIC	WEIGHT(gm)
1	EMPTY BOTTLE	33.5
2	BOTTLE+.5CRMB	48.75
3	BOTTLE+WATER	91
4	CRMB+BOTTLE+WATER	91.5

SPECIFIC GRAVITY = ((W3-W1)/ (W2-W1)-(W4-W3))

= ((48.75-33.5)/(91-33.5)-(91.5-48.75)) = 1.03389

As specific gravity of crumb rubber is 1.03389 which is within the permissible limits as specified by IS: 15462-2004 (INDIAN STANDARD POLYMER AND BITUMEN MODIFIED BITUMEN) hence this crumb rubber is suitable for testing.

Sieve analysis: The fineness of crumb effects the physical and chemical properties of CRMB so sieve analysis was conducted and table 3.3 shows the details of sieve analysis on crumb rubber.

Table.3.3: Sieve analysis of crumb rubber

SIEVE	WEIGHT RETAINED(gm)	% WEIGHT RETAINED	CUMULATIVE WEIGHT(gm)	%CUMULATIVE WEIGHT(gm)	%PASSING
2.36	0	0	0	0	100
1	0.5	0.25	0.5	0.25	99.75
0.6	5	2.5	5.5	2.75	97.25
0.3	55.5	27.75	61	30.5	69.5
0.15	100.5	50.25	161.5	80.75	19.25
0.075	28.5	14.25	190	95	5
Pan	5.5	2.75	195.5	97.75	2.25

The fineness of crumb is as per as the technical guideline of south African asphalt academy TGI :2007

Table-3.4: Details of Experimental Specimen

S.No.	NAME OF TEST	SPECIMEN/APPARATUS	% of crumb added	NO OF SPECIMEN
1	Penetration (.1mm)	Diameter : 55mm Depth : 35mm	2.5 5 7.5 10 15 16	1 1 1 1 1 1
2	Softening point (˚C)	Steel balls : 2 Diameter : 9.5mm Brass ring : 2 Depth : 6.4mm Inside diameter at top : 17.5mm Inside diameter at bottom : 15.9mm Outside diameter : 20.6mm	2.5 5 7.5 10 15 16	1 1 1 1 1 1
3	Penetration (cm)	Length : 75mm Distance between clips : 30mm Width at mouth of clips : 20mm Area at min. width : 10.10mm	2.5 5 7.5 10 15 16	1 1 1 1 1 1
4	Marshal stability (kN)	Diameter : 101.6mm Height : 75mm	5 10 15	3 3 3
			Total	27

In all a total of 27 Experiments were conducted.

3.3 Testing Methods Details

The Penetration, Ductility, Separation test on Crumb, Softening Point, Sieve Analysis, Specific gravity, Marshal Stability tests are conducted in this study and testing methods details are given in detail in this chapter.

3.3.1 Penetration test

In this test we examine the consistency of a sample of bitumen by determining the distance in tenths of a millimeter that a standard needle vertically penetrates the bitumen specimen under known conditions of loading, time and temperature.

This is the most widely used method of measuring the consistency of a bituminous material at a given temperature. It is a means of classification rather than a measure of quality.

APPARATUS:

1. Penetration Apparatus

2. Needle

3. Container

4. Water Bath

5. Thermometer for Water Bath

6. Stop watch

Principle: It measures the hardness or softness of bitumen by measuring the depth in tenths of a millimeter to which a standard loaded needle will penetrate vertically in 5 seconds.

PROCEDURE:

Heat the sample until it becomes fluid. Pour it in a container to a depth such that when cooled, the depth of sample is at least 10mm greater than the expected penetration. Allow it to cool in an atmospheric temperature. Clean the needle and place a weight above the needle. Use the water bath to maintain the temperature of specimen. Mount the needle on bitumen, such that it should just touch the surface of bitumen. Then start the stop watch and allow the penetration needle to penetrate freely at same time for 5 seconds. After 5 seconds stop the penetration. Result will be the grade of bitumen. Take at least 5 reading.

Fig.3.1: Penetration setup

Figure 3.1, above shows the penetration setup for crumb rubber modified bitumen. The detailed results of Penetration test are shown in Appendix in tabular form.

3.3.2 Ductility Test

Ductility test is conducted to determine the amount CRMB will stretch at temperature below its softening point. A briquette having a cross sectional area of 1 in2 is placed in a tester at 77 °F. Ductility values ranges from 0 to over 150 depending on the type of bitumen.

APPARATUS:

1. Briquette apparatus

2. Scale

3. Water Bath

4. Thermometer for Water Bath

5. Ductility machine as per IS : 1208

PROCEDURE:

Ductility is the property of bitumen that permits it to undergo great deformation or elongation. Ductility Test Ductility is defined as the distance in cm, to which a standard sample or briquette of the material will be elongated without breaking. Dimension of the briquette thus formed is exactly 1 cm square. The bitumen sample is heated and poured in the mould assembly placed on a plate. These samples with moulds are cooled in the air and then in water bath at 27 °C temperature. The excess bitumen is cut and the surface is leveled using a hot knife. Then the mould with assembly containing sample is kept in water bath of the ductility machine for about 90 minutes. The sides of the moulds are removed, the clips are hooked on the machine and the machine is operated. The distance up to the point of breaking of thread is the ductility value which is reported in cm. The ductility value gets affected by factors such as pouring temperature, test temperature, rate of pulling etc.

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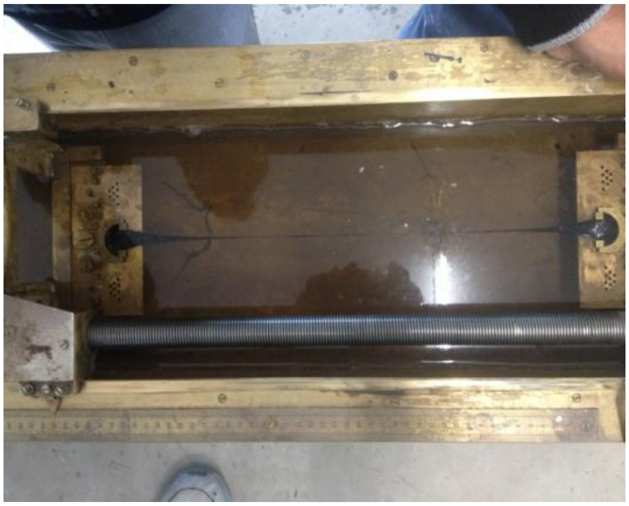
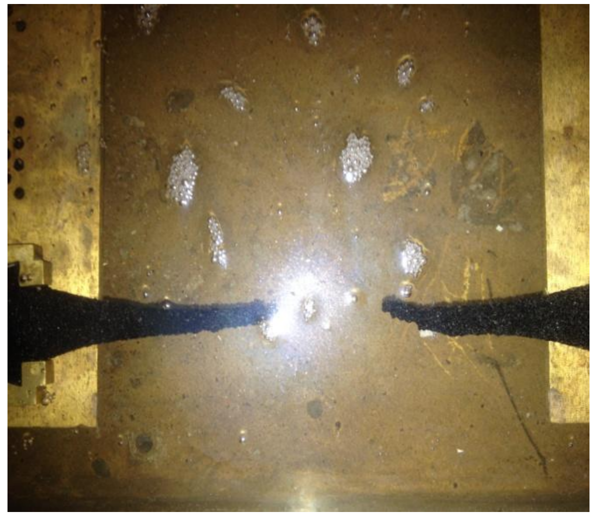


(a) Bitumen



(b) CRMB with 16 % crumb

Fig.3.2: Difference in ductility of bitumen and CRMB.

Figure 3.2 clearly shows the decrease in ductility with the increase of crumb rubber in bitumen. The detailed results of Ductility test are shown in Appendix in tabular form.

3.3.3 Separation Test on CRMB

SIGNIFICANCE AND USE

Purchasers of crumb rubber need to be given guidelines on proper storage and handling procedures to maintain the integrity of material they have purchased. This practice provides a significant tool for understanding the characteristics of these materials as well as comparing various sources of supply.

SCOPE

1. This practice describes a laboratory procedure for determining the tendency of crumb rubber to separate from CRMB under static heated storage conditions. The results of testing on material prepared according to this practice may be used as a guideline when formulating products or to establish field handling procedures. Large differences in test results between top and bottom specimens indicate that there is a degree of incompatibility between the crumb rubber and the base asphalt.

2. The values stated in SI units are to be regarded as the standard. No other units of measurement are included in this standard.
3. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.

3.3.4 Softening Point

The principle behind this test is that softening point is the temperature at which the substance attains a particular degree of softening under specified condition of the test.

APPARATUS

i) Ring and ball apparatus

ii) Thermometer – Low Range : -2˚ to 80˚C, Graduation 0.2˚C – High Range : 30˚ to 200˚C, Graduation 0.5˚C

PROCEDURE

A) Materials of softening point below 80˚ C:

1. Assemble the apparatus with the rings, thermometer and ball guides in position.
2. Fill the beaker with boiled distilled water at a temperature 5.0˚ ± 0.5˚C per minute.
3. With the help of a stirrer, stir the liquid and apply heat to the beaker at a temperature of 5.0˚ ± 0.5˚C per minute.
4. Apply heat until the material softens and allow the ball to pass through the ring.
5. Record the temperature at which the ball touches the bottom, which is nothing but the softening point of that material.

(a) Placing of samples

(b) Ring and ball apparatus

Fig.3.3: Softening point

Figure 3.3, above shows the placing of samples and apparatus for softening point. The detailed results of Softening point test are shown in Appendix in tabular form.

3.3.5 Sieve Analysis on CRMB.

NEED AND SCOPE:

The grain size analysis is widely used in classification of soils. The data obtained from grain size distribution curves is used in the design of filters for earth dams and to determine suitability of soil for road construction, air field etc. Information obtained from grain size analysis can be used to predict soil water movement although permeability tests are more generally used.

APPARATUS REQUIRED:

1. Stack of Sieves including pan and cover

2. Balance (with accuracy to 0.01 g)

3. Mechanical sieve shaker

TEST PROCEDURE:

Take a representative crumb rubber that weighs about 200 g.

If crumb rubber particles are lumped or conglomerated crush the lumped and not the particles using the pestle and mortar.

Determine the mass of sample accurately. Wt (g)

Prepare a stack of sieves. Sieves having larger opening sizes (i.e. lower numbers) are placed above the ones having smaller opening sizes (i.e. higher numbers). The very last sieve is #200 and a pan is placed under it to collect the portion of soil passing #200 sieves.

Fig.3.4: Sieve shaker

Figure 3.4 shows the sieve shaker used for gradation. The test results for sieve analysis are tabulated in table 3.3 above.

3.3.6 Specific Gravity of CRMB

Specific gravity is defined as the ratio of the mass of a given volume of the bituminous material to the mass of an equal volume of water, the temperature of both being specified as 270C.

APPARATUS

1. Specific gravity bottle of 50 ml capacity, ordinary capillary type with 6 mm diameter neck or wide mouthed capillary type bottle with 25 mm diameter neck
2. Balance having least count of 1g
3. Specific gravity bottles.

PROCEDURE

1. The specific gravity bottle is cleaned, dried and weighed along with the stopper.
2. Empty specific gravity bottle with stopper is now weighed.
3. Specific gravity bottle with half filled with crumb rubber is now weighed.
4. Specific gravity bottle is filled with water and stopper placed and weighed.
5. Specific gravity bottle is filled with half crumb rubber and rest with water and stopper placed and weighed.

3.3.7 Marshal Stability

Marshal stability is defines as the maximum load carried by a compacted specimen at a standard test temperature of 60˚C.

APPARATUS REQUIRED

1. Mold Assembly: cylindrical moulds of 10 cm diameter and 7.5 cm height consisting of a base plate and collar extension

2. Sample Extractor: for extruding the compacted specimen from the mould

3. Compaction pedestal and hammer.

4. Breaking head.

5. Loading machine

6. Flow meter, water bath, thermometers

PROCEDURE

In the Marshall Test method of mix design three compacted samples are prepared for each binder content. At least four binder contents are to be tested to get the optimum binder content. All the compacted specimens are subject to the following tests:

- Bulk density determination.
- Stability and flow test.
- Density and voids analysis.

PREPARATION OF TEST SPECIMENS

The coarse aggregate, fine aggregate, and the filler material should be proportioned so as to fulfill the requirements of the relevant standards. The required quantity of the mix is taken so as to produce compacted bituminous mix specimens of thickness 63.5 mm approximately. 1200 gm of aggregates and filler are required to produce the desired thickness. The aggregates are heated to a temperature of 175° to 190°C the compaction mould assembly and rammer are cleaned and kept pre-heated to a temperature of 100°C to 145°C. The bitumen is heated to a temperature of 121°C to 138°C and the required amount of first trial of bitumen is added to the heated aggregate and thoroughly mixed. The mix is placed in a mould and compacted with number of blows specified. The sample is taken out of the mould after few minutes using sample extractor. The design of bituminous mix for Marshal Stability is given in appendix D.

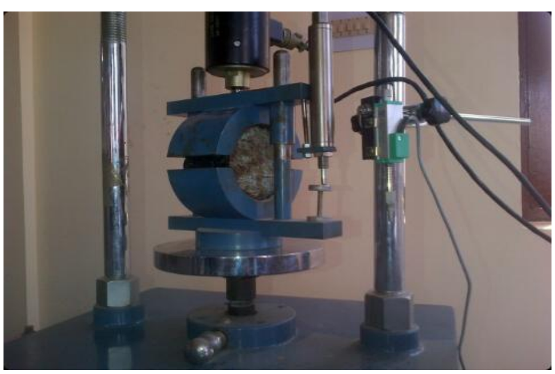


Fig.3.5: Marshal Stability apparatus

Figure 3.5 above shows the arrangement of Marshal Stability test.

3.4 Concluding Remarks

All the above listed experiments were performed in laboratory and results of the so performed experiments are tabulated in appendix A, B, C, D and E.

CHAPTER 4

ANALYSIS OF DATA AND DISCUSSION OF RESULTS

4.1 Introduction

Particularly four tests i.e. Penetration, Softening Point, Ductility and Marshal Stability tests were conducted by us in the Concrete Lab of Civil Engineering Department of Jaypee University of Information Technology, Waknaghat (H.P). The results are analyzed and discussed as under.

4.2 Properties of bitumen

The mechanical properties of plain bitumen such as penetration, Softening Point, Ductility and Marshal Stability tests were observed by various tests in highway laboratory. These results are shown below in tabular form.

Table 4.1: Results of various tests on bitumen

S.No.	CHARACTERISTIC	VALUE	REMARK
1	Penetration (0.1mm)	48	40-50
2	Softening point (˚C)	48	VG-30
3	Ductility (cm)	75	VG-10
4	Marshal stability (kN)	6	$\geq$ 3.4

From the above table 4.1 we conclude that bitumen used is meeting the required standard of marshal stability and is VG-30, VG-10 for Softening point and Ductility respectively and is 40-50 grade bitumen. Now in the following section, we will discuss and compare the results of plain and crumb rubber bitumen with varying percentage of crumb in detail.

4.2.1 Properties of bitumen on adding crumb rubber

As explained earlier that Penetration test is used examine the consistency of a sample of bitumen by determining the distance in tenths of a millimeter that a standard needle vertically penetrates the bitumen specimen under known conditions of loading, time and temperature. So, in laboratory we performed the Penetration test once for conventional bitumen and bitumen with different percentage of crumb and got the following penetration values as result.

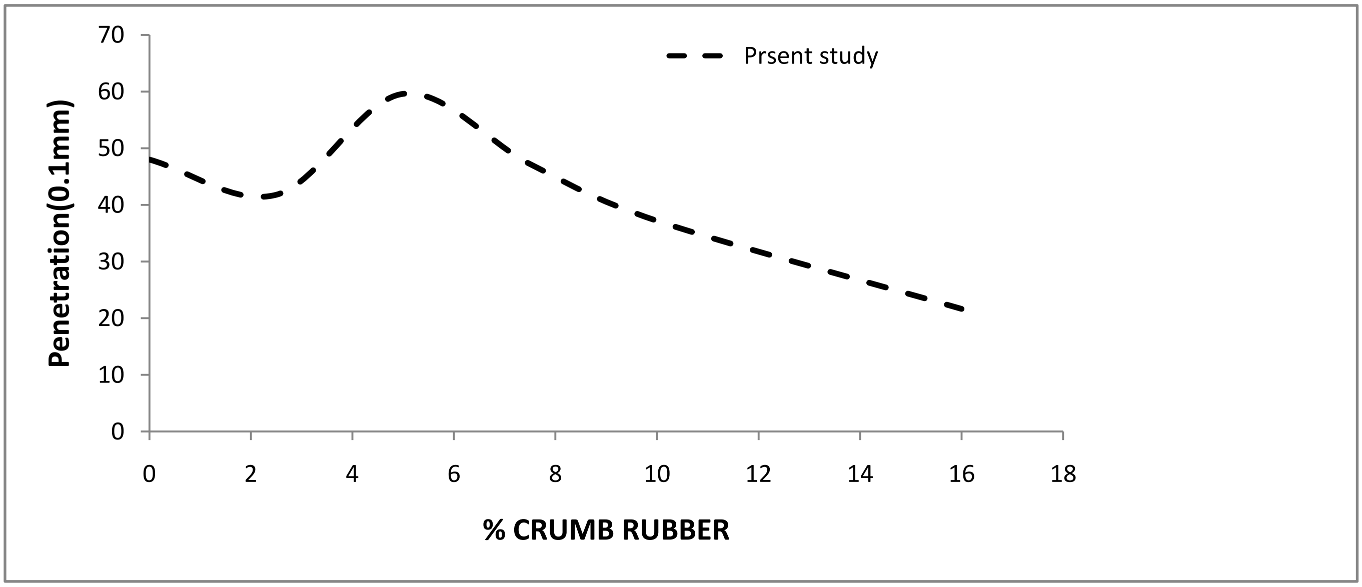


Fig.4.1: Penetration vs. Percentage crumb rubber

It can be seen in fig 4.1 that as the value of crumb rubber increases the value of penetration first increases and then decreases with the further increase in percentage of crumb.

W e also observe that as the percentage of crumb rubber increases value of penetration first increases reach to maximum value of 59.6 at 5 Percentage of CRMB and then decreases respectively with increase in further percentage of crumb in bitumen 21.66 at 16 Percentage of CRMB.

The crumb rubber content has a strong effect on reducing the penetration value by increasing the stiffness of crumb rubber bitumen binder, thus, would make the binder less temperature susceptible and lead to high resistance to permanent deformation like rutting. Test results are shown in table in appendix A.

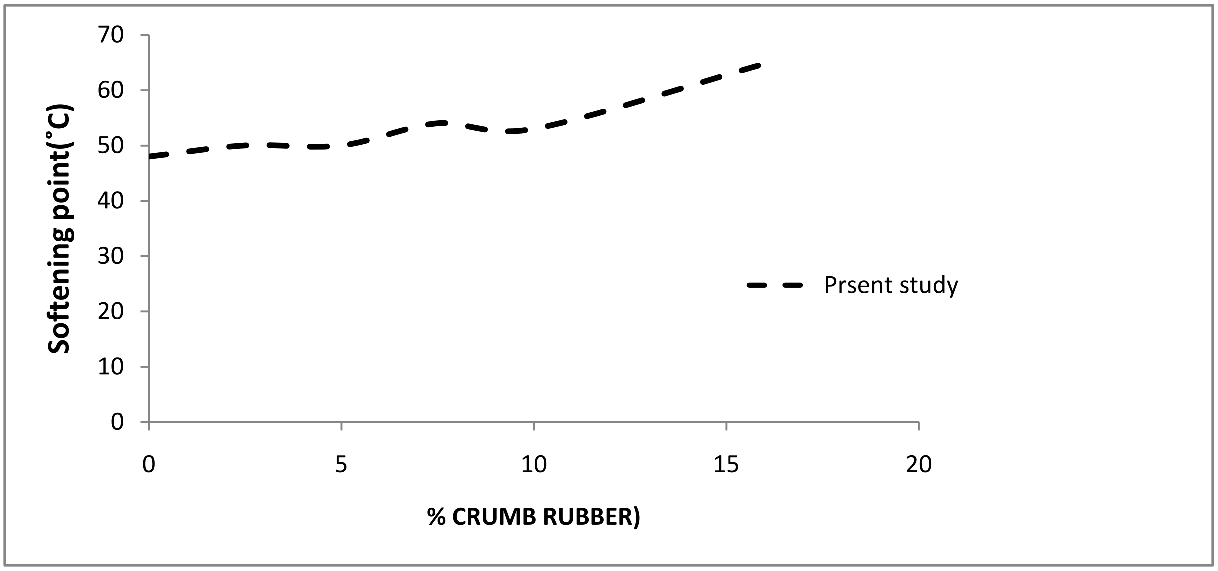


Fig.4.2: Softening Point vs. Percentage of crumb rubber

Figure 4.2 above shows that as the percentage of crumb in bitumen increases the value of softening point increases also it indicates that CRMB has a good potential at hot climates like Rajasthan where temperature rises to 55-60˚C .

We also observe that as the percentage of crumb rubber increases, value of Softening Point first keep on increasing due to the fact that penetration also decreases and it becomes brittle. Test results of this are tabulated in appendix B.

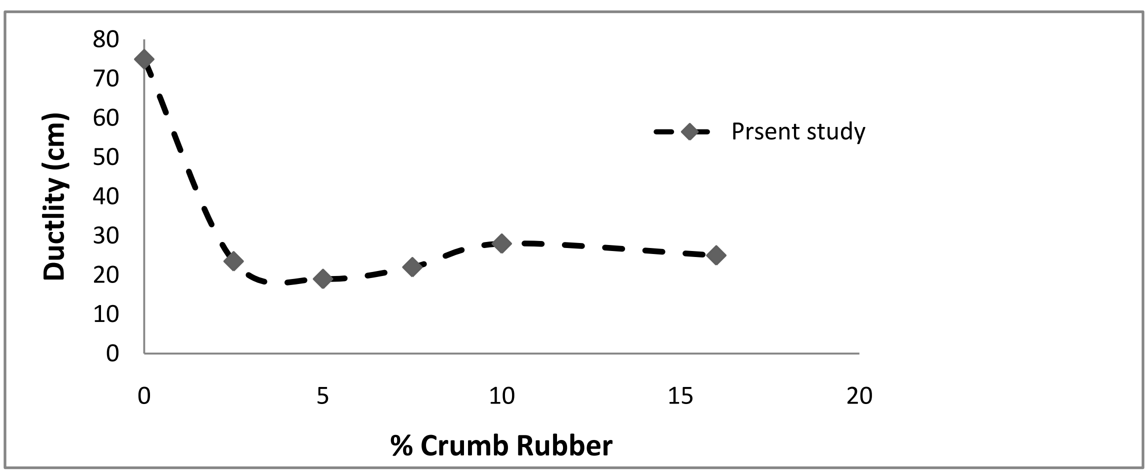


Fig.4.3: Ductility vs. percentage of crumb rubber

In figure 4.3 we observe that as the percentage of crumb rubber increases value of Ductility keep on decreasing up to 5 percentage of crumb in conventional bitumen and then increases reaches maximum value of 28 at 10 percentage of crumb and again starts to decrease with further increase of crumb and attains a value of 25 at 16 percentage of crumb in bitumen.

This can also be inferred that as the softening point increases and penetration decreases with increase in percentage of crumb rubber as a result of which it is becoming brittle and hence we see the decline in the ductility value as a result of which we conclude that it is not a good binder when higher percentage of crumb rubber is added.

Accordingly, an increase in binder mass could make the binder more elastic, stiff and highly resistant to pavement rutting. Meanwhile, the decrease in ductility value could be attributed to the oily part of the bitumen absorbed into the rubber powder and the increase in mass of the rubber particles. In effect, the modified binder became thicker compared with the unmodified bitumen samples. Test results of this are tabulated in appendix C.

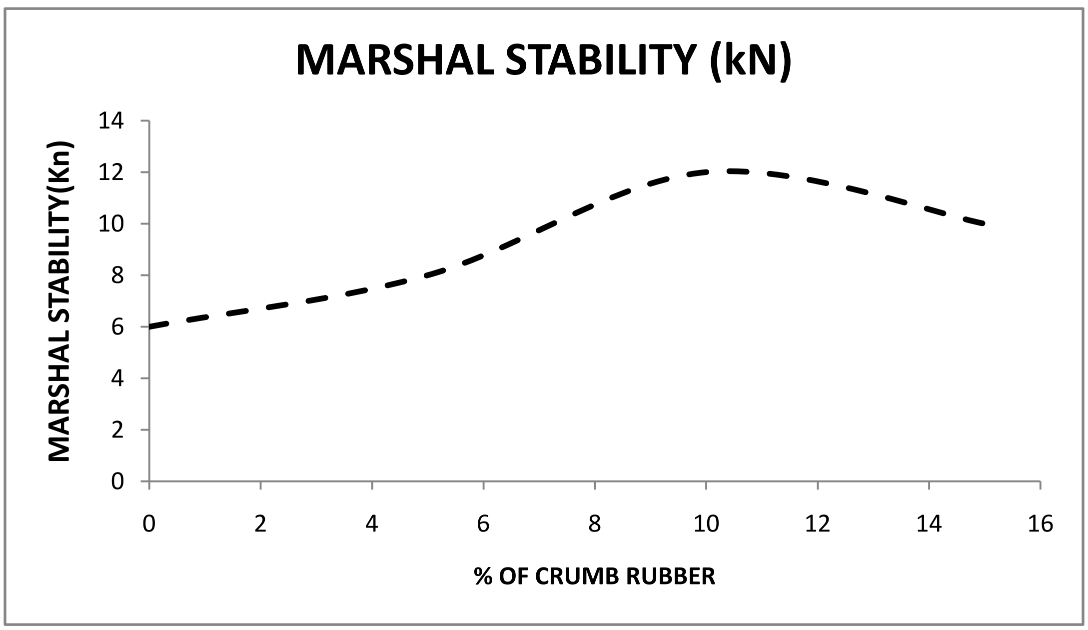
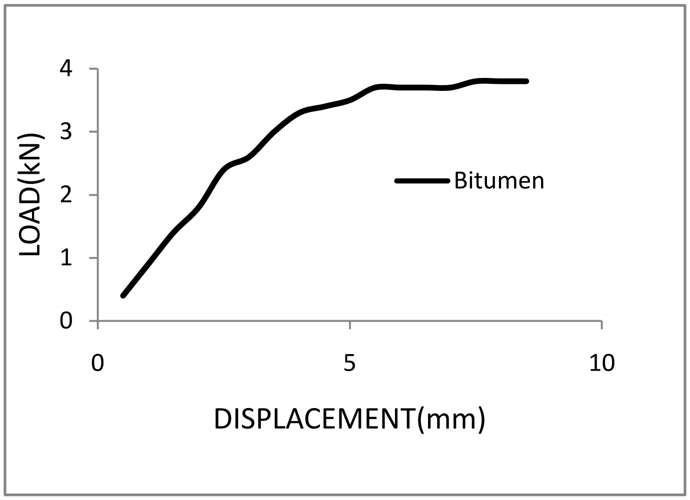


Fig.4.4: Marshal Stability vs. Percentage of crumb rubber

From figure 4.4, we can observe as the percentage of crumb increases in the range of 0-5 percentage value of Marshal Stability increases up to 25% and 50% for 0-10 percentage increase in crumb in bitumen with a maximum value of 12kN and then starts to decrease with a higher percentage of crumb in bitumen. Test results of this are tabulated in appendix D.



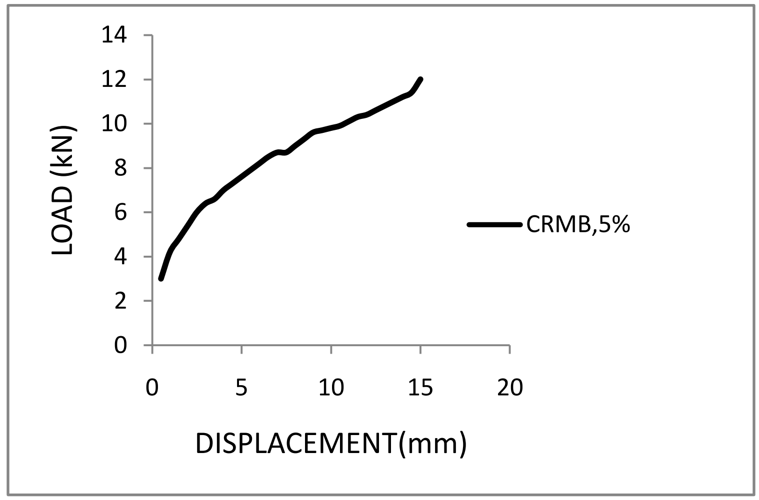


Fig. 4.5: load vs. displacement for bitumen

Fig. 4.6: load vs. displacement for CRMB

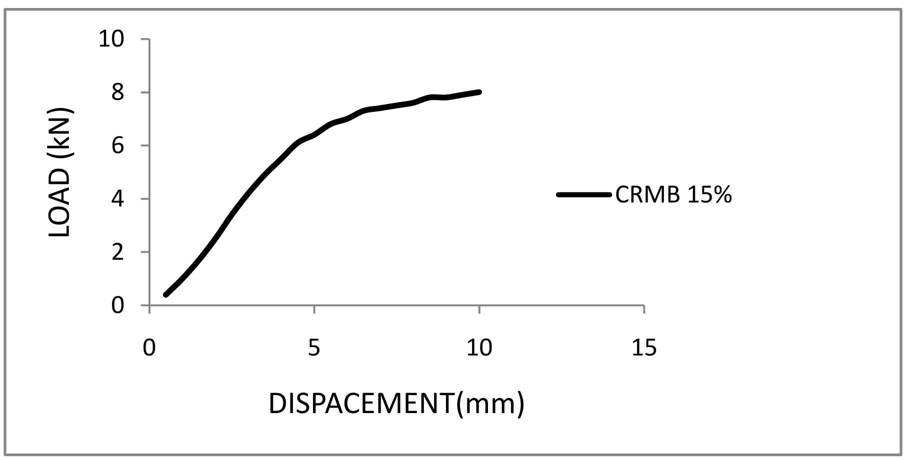


Fig. 4.7: load vs. displacement for CRMB

Figures 4.5, 4.6, 4.7 above shows the load vs. displacement curves for conventional bitumen and CRMB. Test results are tabulated in appendix E.

As we can see the increase in load value for CRMB is more and less for bitumen for the same displacement hence the load carrying capacity for CRMB is superior to that of bitumen.

4.3 Comparison of Results with Previous Studies

In order to compare the effect of crumb rubber addition in bitumen, the results of Nuha S. Mashaan, Asim H. Ali, Mohamed Rehan Karim and Mahrez Abdelaziz et al, (2011) on the same test are also complied. Figure 10, 11, 12, 13, 14, 15 depicts the comparison in these studies

The data collected in the present study are analyzed in this chapter. Here we showed the comparison of CRMB (Present Study) with CRMB (Nuha S. Mashaan, Asim H.Ali, Mohamed Rehan Karim and Mahrez Abdelaziz et al, (2011)) by plotting graphs.

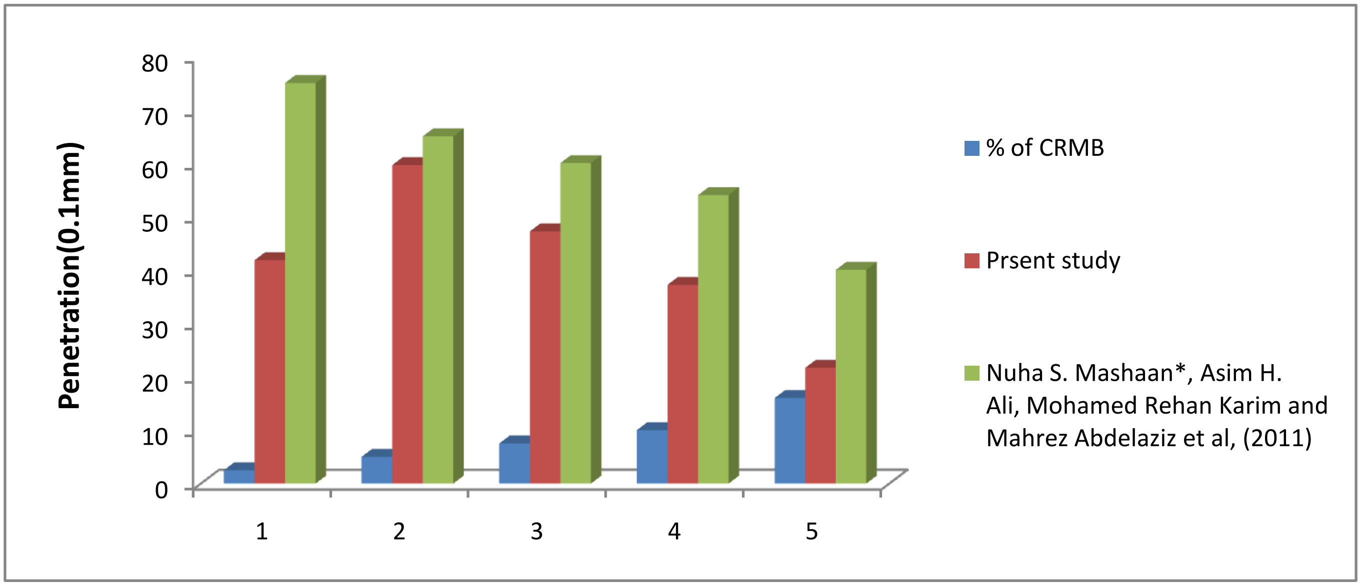


Fig .4.8: Comparison of different CRMB on the basis of penetration

Figure 4.8 shows the variation of penetration (0.1mm) by increasing the percentage of crumb in bitumen for CRMB (Present Study) and CRMB (Nuha S. Mashaan, Asim H. Ali, Mohamed Rehan Karim and Mahrez Abdelaziz et al, (2011).

The penetration decreased as the amount of rubber increases up to 37% for CRMB (Nuha S. Mashaan, Asim H. Ali, Mohamed Rehan Karim and Mahrez Abdelaziz et al, (2011) and 18% for (Present Study) for 5% increase in rubber content. It shows that CRM content has a significant effect on penetration value. The crumb rubber content has a strong effect on reducing the penetration value by increasing the stiffness of crumb rubber bitumen binder, thus, would make the binder less temperature susceptible and lead to high resistance to permanent deformation like rutting.

The average reduction in penetration value of modified binder is 59% and 47% for CRMB (Present Study) and CRMB (Nuha S. Mashaan, Asim H. Ali, Mohamed Rehan Karim and Mahrez Abdelaziz et al, (2011) for crumb rubber content 16% respectively.

This behavior is justified because the rubber addition turns the bitumen more viscous. This increase in rubber content lead to enhanced the particle size of the rubber. This was due to the increase in rubber mass through the interaction and swelling of the rubber into the bitumen during the blending process, which led to the decrease in the penetration of rubberized bitumen. Thus, indicate that the rubberized bitumen binder will be less susceptible to high temperature change and more resistance to rutting. The test results are tabulated in appendix A.

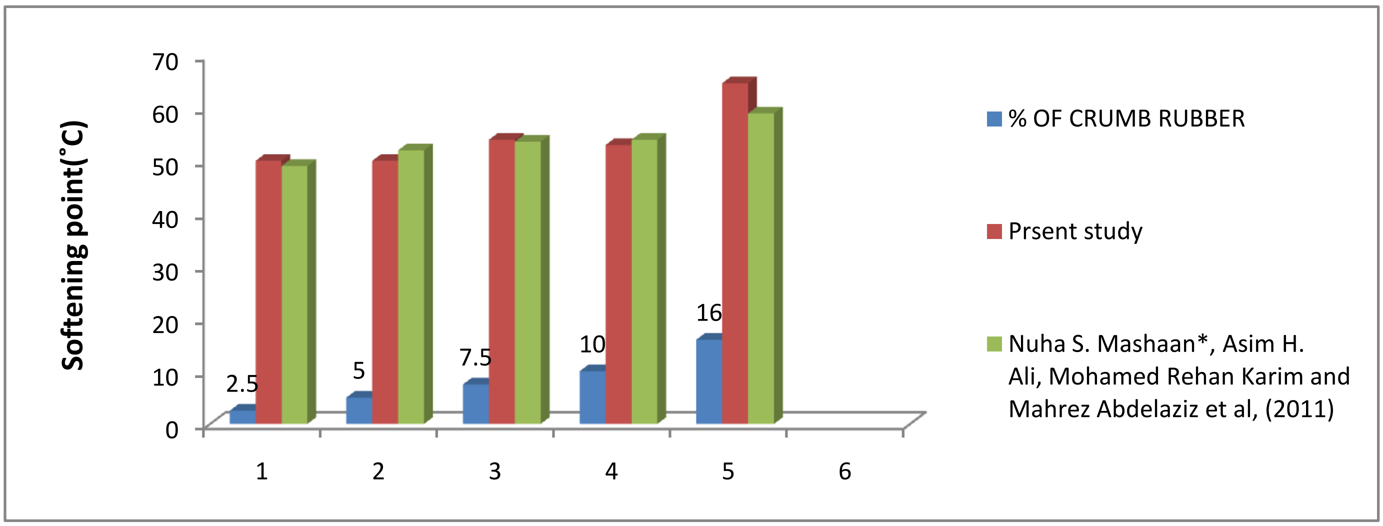


Fig.4.9: Comparison of different CRMB on the basis of Softening Point

Figure 4.9 shows the variation of Softening Point (˚C) by increasing the percentage of crumb in bitumen for CRMB (Present Study) and CRMB (Nuha S. Mashaan, Asim H. Ali, Mohamed Rehan Karim and Mahrez Abdelaziz et al, (2011).

It also shows the effect of crumb rubber concentration on Softening Point (˚C). The Softening Point increased as the amount of rubber increases up to 4% for CRMB (Present Study) and 8 % for

(Nuha S. Mashaan, Asim H. Ali, Mohamed Rehan Karim and Mahrez Abdelaziz et al, (2011) for 5% increase in rubber content.

It also shows there in not much difference in the softening point values with the increase in percentage of crumb for CRMB (Present Study) and CRMB (Nuha S. Mashaan, Asim H. Ali, Mohamed Rehan Karim and Mahrez Abdelaziz et al, (2011) as the two graphs are overlapping.

The average increase in softening point value of modified binder is 26% and 22% for CRMB (Present Study) and CRMB (Nuha S. Mashaan, Asim H. Ali, Mohamed Rehan Karim and Mahrez Abdelaziz et al, (2011) for crumb rubber content 16% respectively.

The increase in blending temperature led to an increase in rubber mass through the interaction and swelling of the rubber into the bitumen during the blending process. This in turn led to the increase in the softening point values of rubberized bitumen samples. The increase of rubber content in the mix could be co-related to the increase in the asphaltene/resins ratio which probably enhanced the stiffening properties, making the modified binder less susceptible to temperature changes. Test results are tabulated in appendix B.

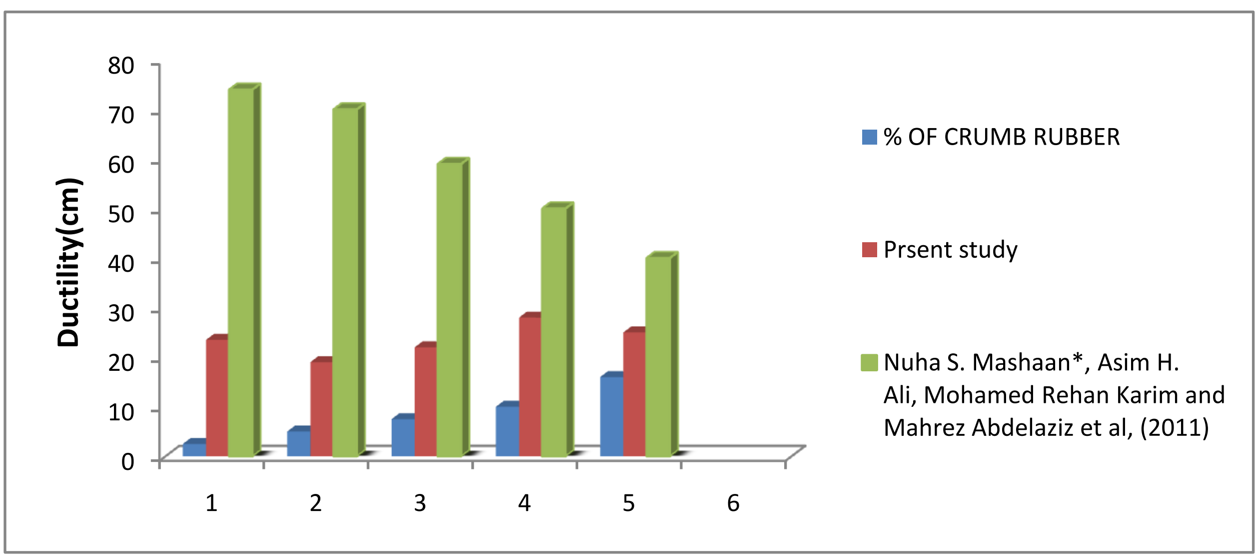


Fig.4.10: Comparison of different CRMB on the basis of ductility

Figure 4.10, shows the variation of Ductility (cm) by increasing the percentage of crumb in bitumen for CRMB (Present study) and CRMB (Nuha S. Mashaan, Asim H. Ali, Mohamed Rehan Karim and Mahrez Abdelaziz et al, (2011).

It shows the effect of crumb rubber concentration on ductility. The ductility decreased drastically as the amount of rubber increases up to 75% for CRMB (Present study) and 20% for (Nuha S. Mashaan, Asim H. Ali, Mohamed Rehan Karim and Mahrez Abdelaziz et al, (2011) for 5% increase in rubber content. It shows that CRM content has a significant effect on ductility value.

This also shows that as the content of natural rubber in crumb increases, ductility reduces to a great extent in comparison with crumb containing less content of natural rubber.

The average reduction in penetration value of modified binder is 66% and 50% for CRMB (Present study) and CRMB (Nuha S. Mashaan, Asim H. Ali, Mohamed Rehan Karim and Mahrez Abdelaziz et al, (2011) for crumb rubber content 16% respectively.

The decrease in ductility value could be attributed to the oily part of the bitumen absorbed into the rubber powder and the increase in mass of the rubber particles. In effect, the modified binder became thicker compared with the unmodified bitumen samples. Test results are tabulated in appendix C.

4.4 Concluding Remarks

CRMB (Present Study) and CRMB (Nuha S. Mashaan, Asim H. Ali, Mohamed Rehan Karim and Mahrez Abdelaziz et al, (2011)) showed variations in the ductility and penetration values due the fact that increasing natural rubber content increases the stiffness of the binder and hence decreasing penetration and ductility respectively.

By studying the test results of common laboratory tests on plain bitumen and crumb rubber modified bitumen it is concluded that the penetration values and softening points of plain bitumen can be improved significantly by modifying it with addition of crumb rubber which is a major environment pollutant.

CHAPTER 5

CONCLUSIONS AND DISCUSSION

5.1 Introduction

The main objective of the present study was to study the variation of CRMB (Nuha S. Mashaan, and Mahrez Abdelaziz et al, (2011)) and CRMB (Present study) in the properties through a systematically conducted series of laboratory experiments. The experimental data of Nuha S. Mashaan, Asim H. Ali, Mohamed Rehan Karim and Mahrez Abdelaziz (2011) were also used, combined with the data of present study, for the purpose of analysis. On the basis of experimental observations and analysis, the following main conclusions are drawn from the present study.

5.2 Conclusion and Discussion

- As crumb rubber meets the guidelines mentioned in the code, examples specific gravity in n the range 1-1.15 and percentage finer so we decided to perform further experimentation with the same.
- Separation test was successfully done hence it ensured proper mixing.
- From the experiment conducted with different percentage of crumb rubber with bitumen on Penetration, Softening point, Ductility, Marshal Stability we arrive at:

✓ It showed minimum penetration when percentage of Crumb rubber used was in the range of 10-16 percentages.

✓ It showed maximum softening point when percentage of Crumb rubber used was in the range of 7.5-16 percentages.

✓ It showed maximum ductility when percentage of Crumb rubber used was specifically 10 percentages.

✓ It showed maximum Marshal stability when percentage of Crumb rubber used was specifically in the range of 0-5 percentage.

✓ As Marshal Stability and Ductility are the key parameters for determining optimum percentage of crumb in bitumen.

So we conclude that optimum % of crumb rubber in CRMB (60% Natural rubber) is from 5-10%.

- With the increase in temperature beyond 220 degree C test results were badly affected due to depolymerisation of rubber.
- Increasing content of natural rubber in crumb affects the properties of binder adversely making the binder stiffer and hence not suitable for highway construction.

CHAPTER 6

REFERENCES

References

1. “Crumb rubber modifier design procedures and construction practices,” Workshop Notes FHWA-SA-93-011, Design procedure and construction practices,USDepartment of Transportation,Federal Highway Administration, 1993.
2. D. Lo Presti, G. Airey, and P. Partal, “Manufacturing terminal and field bitumen-tyre rubber blends: the importance of processing conditions,” Procedia, vol. 53, pp. 485–494, 2012.
3. D. X. Cheng and R. G. Hicks, “Summary of Rubber Modified Asphalt Product Specifications from around the World,” Ontario Tire Stewardship, pp. 1–218, 2012.
4. Hindawi Publishing Corporation Advances in Materials Science and Engineering Volume 2013, Article ID 415246.
5. International journal of structural and civil engineering research.Vol. 1, No. 1, November 2012 2012 IJSCER.
6. IS 15462 (2004): Polymer and Rubber Modified Bitumen.
7. IS: 1203-1978, Indian standard methods for Testing Tar and Bituminous Materials.
8. IS: 1208-1978, Indian standard methods for Testing Tar and Bituminous Materials.
9. Ministry of road transport and highways, specification for road and bridge works, (Fourth revision).
10. M. Attia and M. Abdelrahman (2009), “Enhancing the performance of crumb rubber-modified binders through varying the interaction conditions,” International Journal of Pavement Engineering, vol. 10, no. 6, pp. 423–434.
11. Nuha S. Mashaan, Asim H. Ali, Mohamed Rehan Karim and Mahrez Abdelaziz et al, (2011),”Investigating the Rheological Properties of Crumb Rubber Modified Bitumen and its Correlation with Temperature Susceptibility
12. “The Effects of digesting Crumb Rubber in Modified Binders,” The University of Wisconsin—Madison Asphalt Research Group in collaboration with the Recycled Materials Resource Center, pp. 1–13, 2011.
13. T. C. Billiter, J. S. Chun, R. R. Davison, C. J. Glover, and J. A. Bullin (1997), “Investigation of the curing variables of asphalt rubber binder,” Petroleum Science and Technology, vol. 15, no. 5-6, pp. 445–469.

14. Zhu, J., Birgisson, B., Kringos, N. (2014) Polymer modification of bitumen: Advances and challenges. European Polymer Journal, 54: 18-38.

APPENDIX A

PENETRATION (ONE TENTH OF MM)		
PERCENTAGE OF CRUMB RUBBER	**CRMB(PRESENT STUDY)**	**BITUMEN**
0	-	48
2.5	41.8	48
5	59.6	48
7.5	47.2	48
10	37.2	48
16	21.66	48

PENETRATION (ONE TENTH OF MM)		
PERCENTAGE OF CRUMB RUBBER	**CRMB(Nuha S. Mashaan, and Mahrez Abdelaziz et al, (2011))**	**BITUMEN**
0	-	81
2.5	75	81
5	65	81
7.5	60	81
10	54	81
16	40	81

APPENDIX B

SOFTENING POINT(˚ C)		
PERCENTAGE OF CRUMB RUBBER	**CRMB(PRESENT STUDY)**	**BITUMEN**
0	48	48
2.5	50	48
5	50	48
7.5	54	48
10	53	48
16	64.75	48

SOFTENING POINT(˚ C)		
PERCENTAGE OF CRUMB RUBBER	**CRMB(Nuha S. Mashaan, and Mahrez Abdelaziz et al, (2011))**	**BITUMEN**
0	-	48
2.5	49	48
5	52	48
7.5	53.625	48
10	54	48
16	59	48

APPENDIX C

DUCTILITY(cm)		
PERCENTAGE OF CRUMB RUBBER	**CRMB(PRESENT STUDY)**	**BITUMEN**
0	75	75
2.5	23.5	75
5	19	75
7.5	22	75
10	28	75
16	25	75

DUCTILITY(cm)		
PERCENTAGE OF CRUMB RUBBER	**CRMB(Nuha S. Mashaan, and Mahrez Abdelaziz et al, (2011))**	**BITUMEN**
0	-	90
2.5	74	90
5	70	90
7.5	59	90
10	50	90
16	40	90

APPENDIX D

NOMINAL AGGREGATE SIZE	**19MM**		
LAYER THICKNESS	**50-65MM**		
SIEVE SIZE, MM	**% PASSING , BY WEIGHT**	**WEIGHT PASSING(gm)**	**WEIGHT RETAINED(gm)**
26.5	100	1200	0
19	89.5	1074	126
13.2	69	828	246
9.5	62	744	84
4.75	45	540	234
2.36	36	432	108
1.18	27	324	108
0.6	21	252	72
0.3	15	180	72
0.15	9	108	72
0.075	5	60	48
		TOTAL	1170
BITUMEN CONTENT, % BY WEIGHT OF TOTAL MIX	5-6		
WEIGHT OF BITUMEN IN (gm	60-72		

MARSHAL STABILITY(kN)				
S.No.	**% OF BITUMEN**	**% OF CRUMB**	**STABILITY(kN)**	**TEMPERATURE(˚C)**
1	7	0	3.4	30
2	7	5	12	30
3	7	10	10	30
4	7	15	8	30

APPENDIX E

CRUMB RUBBER,0%	
DISPLACEMENT,MM	**LOAD(KN)**
0.5	1.3
1	2
1.5	2.6
2	3.2
2.5	3.6
3	3.9
3.5	4.3
4	4.5
4.5	4.8
5	4.9
5.5	5.1
6	5.3
6.5	5.5
7	5.7
7.5	5.8
8	5.9
8.5	5.9

CRMB 15%	
DISPLACEMENT	**LOAD(KN)**
0.5	0.4
1	1
1.5	1.7
2	2.5
2.5	3.4
3	4.2
3.5	4.9
4	5.5
4.5	6.1
5	6.4
5.5	6.8
6	7
6.5	7.3
7	7.4
7.5	7.5
8	7.6
8.5	7.8
9	7.8
9.5	7.9
10	8

CRMB,5%	
DISPLACEMENT	**LOAD (KN)**
0.5	3
1	4.2
1.5	4.8
2	5.4
2.5	6
3	6.4
3.5	6.6
4	7
4.5	7.3
5	7.6
5.5	7.9
6	8.2
6.5	8.5
7	8.7
7.5	8.7
8	9
8.5	9.3
9	9.6
9.5	9.7
10	9.8
10.5	9.9
11	10.1
11.5	10.3
12	10.4
12.5	10.6
13	10.8
13.5	11
14	11.2
14.5	11.4
15	12