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Utilization of Rubber Waste in Construction of Flexible Pavement

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ABSTRACT

The growth rate of vehicles is the backbone of economic development of any country. India is the second fast growing automobile industry in the world. In today's era, solid waste management is the thrust area. On the other side, the traffic intensity is also increasing. As a result amount of waste tyres is also increasing. The increasing consumption of waste tire has generated many problems such as increasing landfill space, environmental pollution and causing health hazards. Parallel to this is the increasing of roads construction as a result of heavy traffic on roads. This study reviews to the use of crumb rubber (waste tires in powder form) in bitumen using the wet process. The study focuses on the crumb rubber as a replacement to the total weight of bitumen. The design or life span for all highways and urban roads is 10 – 20 years. Unfortunately, damages or distresses on pavements are still occurring before reaching the maximum period of the designed road serviceability. Among the major influencing factor that is contributing to this distress is the repeated heavy traffic loading on the road surfaces. Moreover, the use of waste crumb rubber in road construction as a pavement surface has a better skid resistance, fatigue crack resistance and increased rut resistance. The review includes physical tests that are used to determine the physical properties of bitumen and modified crumb rubber mix. The physical tests involve penetration test, softening point test, and ductility test. The expectations from the study are to develop bitumen with waste crumb rubber that would minimize the costs of bitumen and providing better physical properties compared to the convention bitumen based on the tests that was conducted.

Keywords: Waste Tyre Rubber, Bitumen, Crumb Rubber, Wet Process, Flexible Pavement, etc.

1. INTRODUCTION

In India, over 15 million waste tires are generated annually. Not only are these tire mounds eyesores, they are also environmental and health hazards. The little pools of water retained by whole waste tires create an ideal breeding ground for mosquitoes. Aside from the persistent annoyance, mosquitoes have been shown to spread various dangerous diseases. Equally hazardous are tire fires, which pollute the air with large quantities of carbon smoke, hydrocarbons, and residue. These fires are virtually impossible to extinguish once started. Currently, the only large scale methods to use waste tires are through burning for electric power generation, production of cement in cement kilns, energy to run pulp and paper mills, and recycling at tires-to-energy facilities.

In 1990, the Environmental Protection Agency (EPA) estimated that out of the 242 million waste tires generated that year, 78% of the tires were either stockpiled, a land filled, or illegally dumped. While some states burn waste tires this is only a temporary solution because of the tires, in many cases, tend to float back up to the surface. Land filling waste tires has also become more and more expensive as landfill space has decreased.

Asphalt acting as a binder for aggregates is a very important ingredient affecting the life cycle and travel comfort on roads. It has been an established fact that normal bituminous course cannot cope up with the following problems:

i. Increasing traffic on road / overloading of vehicles leading to undulations, rutting, cracking, deformations, potholing, and shortening of the life of asphaltic pavements.
ii. High range of temperatures causing pavements to become softer in summer and brittle in winter.
iii. Rains/water causing extensive stripping problems in asphaltic pavements.

To overcome the above problems in the entire world it has become a regular practice to use modifier as additives to strengthen the asphalt for making longer lasting asphalt mixes. This has been a very important development in the last 3 decades and has led not only to huge saving by delaying the maintenance cycles of the road but also its importance has been felt in countries where aggregates and asphalt are in short supply.

Natural asphalt is a naturally occurring hydrocarbon mineral that is high in asphaltense and high in the Nitrogen. When crumb rubber added to asphalt it dramatically increases the asphalt's viscosity, lowering penetration while increasing the softening point. The chemically treated crumb rubber and besides have been designed to rapidly blend into asphalt. The addition of rubber gives the additional binding strength, increasing elasticity and softening point of the asphalt. Carbon present in rubber acts as an anti-oxidant and prevents asphalt from ageing and oxidization.

1.1 Hazards of Tyre Waste

1) This waste tyres are produced carbon by burning process.
2) This amount of tyres is very large manner so it becomes dangerous as well as uncomfortable to placing, because of Land problems to our country.
3) Potentially harmful substances were found exposed to highly acidic solutions.
4) Aside from the persistent annoyance, mosquitoes have been shown to spread various dangerous diseases.
5) Equally hazardous are tyre fires, which pollute the air with large quantities of carbon smoke, hydrocarbons, and residue.
6) Not only are this tyre mounds eyesores, they are also environmental and health hazards. The little pools of water retained by whole waste tyres create an ideal breeding ground for mosquitoes.
7) These fires are virtually impossible to extinguish once started.

2. LITERATURE REVIEW

Many types of research were carried out by many scholars and professors of civil engineering in this field, to find the ways and crumb rubber mix in conventional bitumen to improve in engineering properties of bitumen.

2.1 Nabin Rana Magar, (2014) investigates the performance of crumb rubber modified bitumen by varying the sizes of crumb rubber. The test results of common laboratory test on plain bitumen and crumb rubber modified bitumen shows that the penetration values and softening points of plain bitumen can be improved significantly by modifying it with the addition of crumb rubber which is a major environmental pollutant. The best size to be used for crumb rubber modification is suggested as (0.3-0.15mm) size for commercial production of CRMB.

2.2 Siddharth Rokade, (2012) The Crumb Rubber was added to 60/70 grade bitumen in varying percentage. The mix was prepared with 5 % bitumen and the varying percentages of Crumb Rubber. The bitumen, when mixed with Crumb Rubber, is termed as Crumb Rubber Modified Bitumen (CRMB). The results observed that the Marshal Stability Value is increased from 4% to 12% Crumb Rubber and then it is decreased 15% of Crumb Rubber of the weight of bitumen is the optimum dose for getting enhanced strength characteristics of the mix.

2.3 Nuha S.Mashaan, (2012) In their study presented the application of crumb rubber modifier in the asphalt modification of flexible pavement. From the results of the previous study, it aspires to consider crumb rubber modifier in hot mix asphalt to improve resistance to rutting and produce pavement with better durability by minimizing the distresses caused in hot mix asphalt pavement. Hence, road user would be ensured of safer and smoother roads.

2.4 Mashaan et al, (2011a) 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 vicious

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.

2.5 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.

2.6 Abedlrahman and Carpenter, (1999) From the study he determines that the various properties of CRMB vary with blending temperature and blending time. The optimum blending temperature and blending time found out 175ºC and 45 minutes respectively for preparing high-quality CRMB.

3. MATERIALS AND MIX DESIGN

This chapter provides a background on the materials used in crumb rubber modified bitumen and the specifications for those materials. Specific topics will include a discussion of the production and properties of CRM, the shipping and handling of CRM, the properties of the asphalt cement as they relate to asphalt rubber.

3.1 Bitumen

Bitumen is a black, highly viscous and very sticky liquid or semi-solid, found in some natural deposits. It is also the by-product of the fractional distillation of crude petroleum. Generally in India bitumen used in road construction of flexible pavement is of grades 60/70 or 80/100 penetration grade.

3.2 Crumb Rubber

The major component of crumb rubber modifier (CRM) is scrap tire rubber which is primarily natural and synthetic rubbers and carbon black. Automobile tires have more synthetic rubber than truck tires. Truck tires contain a higher percentage of nature rubber than automobile tires. Advances in tire manufacturing technology have decreased the difference in chemical composition between the types of tire rubber. The typical bulk CRM produced in today's market is uniform in composition. The average car tire contains ten types of synthetic rubber, four types of natural rubber, four types of carbon black, steel cord, bead wire, and 40 kinds of chemicals, waxes, oils, pigments, etc.

FIG-1: WASTE TYRE RUBBER CHIPS (CRM)

The scrap tires are delivered to a processing plant as a whole, cut, or shredded tires or buffing waste. CRM is produced using one or more combinations of the four processes:

a. Cracker Mill

The most common method is the cracker mill process. The scrap tires are pre-processed by shredding to remove steel cord and bead wire. Rotating corrugated steel drums are used to tear the scrap tires into smaller ground CRM. The ground CRM has irregular torn shapes with large surface areas and sizes ranging from 4.75 mm to 425 µm (No. 4 to No. 40 sieve).

b. Granulator

In the granulator process, steel cord and bead wire are removed and close tolerance revolving steel plates are used to cut the scrap tires into granulated CRM. The granulated CRM is cubical, uniformly shaped with a low surface area with sizes ranging from 9.5 mm to 2.0 mm (3/8 inch to No. 10 sieve).

c. Wet grinding

In the wet-grinding process, ground or granulated CRM is mixed with water and forced between rotating discs to reduce the CRM to sizes ranging from 425 µm to 75 µm (No. 40 to No. 200 sieve). Before the material is processed in the wet grinding process, it must be reduced in size using another process.

d. Cryogenic Process

In the cryogenic process, the pre-chipped scrap tires are cooled with liquid nitrogen. The brittle tire rubber is easily fractured with a hammer mill. The process uses a cooler to chill tile material, a grinder, appropriate screens and conveyors and steel and fiber separation systems. Usually, the cryogenic process is used as a preliminary step to the other processes which will reduce the particles to the desired size.

3.3 Crumb Rubber Modified Bitumen (CRMB)

Crumb rubber is also used to modify bitumen in an appropriate manner, so that its resistance to temperature, water etc is better. This modified bitumen is one of the important construction materials for flexible Road pavement. The rubber waste/crumb rubber modified bitumen show better properties for road construction.

Preparations to make Crumb Rubber Modified Bitumen blend

The studies on the behavior and binding property promoted a study on the preparation of rubber waste-bitumen blend. It's bituminous properties are found. These properties are compared with Normal Bitumen. Then its suitability as a blend for road construction is investigated. Scrap tire rubber can be incorporated into asphalt paving mixes using two different methods, which are referred to as the wet process and the dry process. In the wet process, crumb rubber acts as an asphalt cement modifier, while in the dry process, granulated or ground rubber and/or crumb rubber is used as a portion of the fine aggregate.

CRMB is produced by the so-called wet process in which crumb rubber is added to hot bitumen of temperature around 150 -160 degree C and the mixture is agitated mechanically until there is a “reaction” between the bitumen and crumb rubber. The “reaction” is not a chemical process but rather a diffusion process that includes the physical absorption of aromatic oils from the bitumen into the polymer chain of the rubber. The rubber particles swell as they absorb oils, which cause the viscosity of the CRMB to increase during the first hour or so. After the “reaction” and associated swelling is over the viscosity of the blend levels off.

4. EXPERIMENTAL STUDIES

4.1 Mixing Of Crumb Rubber with Plain Bitumen

In preparing the modified binders, about 500 gm of the bitumen was heated to a fluid condition in a 1.5-litre capacity metal container. For the blending of crumb rubber with bitumen, it was heated to a temperature of 160 °C and then crumb rubber was added. For each mixture sample 0%, 8%, 10%, 12%, and 14% of crumb rubber by weight is used. The blend is mixed manually for about 3-4 minutes. The mixture is then heated to 160 °C and the whole mass was stirred using a mechanical stirrer for about 50 minutes. Care is taken to maintain the temperature between 160 °C to 170 °C. The contents are gradually stirred for about 55 minutes. The modified bitumen is cooled to room temperature and suitably stored for testing.

4.2 Physical Properties

Table 1: Physical Properties of Crumb rubber

Sr. No.	Properties of Crumb rubber	Test Result
1	Specific gravity	1.015
2	Moisture content	0.71%

4.3 Penetration test

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. BIS had standardized the equipment and test procedure. The penetrometer consists of a needle assembly with a total weight of 100g and a device for releasing and locking in any position. The bitumen is softened to a pouring consistency, stirred thoroughly and poured into containers at a depth at least 15 mm in excess of the expected penetration. The test should be conducted at a specified temperature of 25o C. It may be noted that penetration value is largely influenced by any inaccuracy with regards to pouring temperature, the size of the needle, weight placed on the needle and the test temperature. A grade of 40/50 bitumen means the penetration value is in the range 40 to 50 at standard test conditions. In hot climates, a lower penetration grade is preferred.

Record of Observation:

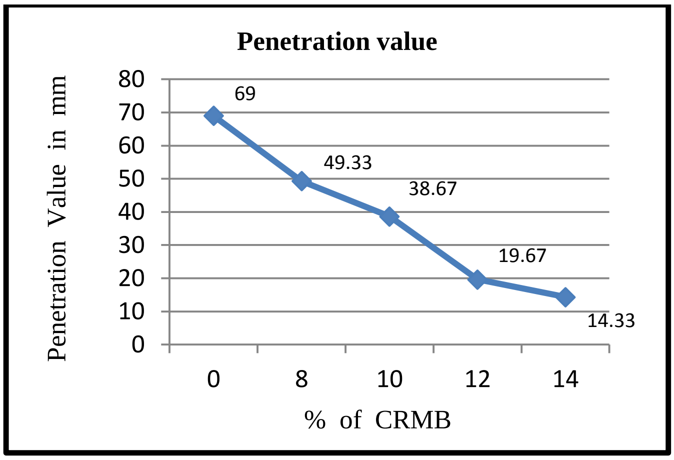
Actual test temperature = 25˚ c

Table 2: Penetration Test Result

% Of CRMB	Reading	Trial			Average. Value In mm
		1	**2**	**3**	
0% of CRMB	Initial	0	0	0	**69**
	Final	64	69	75	
Penetration Value		**64**	**69**	**75**	
8% of CRMB	Initial	0	0	0	**49.33**
	Final	44	48	56	
Penetration Value		**44**	**48**	**56**	
10% of CRMB	Initial	0	0	0	**38.67**
	Final	33	37	47	
Penetration Value		**33**	**37**	**47**	
12% of CRMB	Initial	0	0	0	**19.67**
	Final	19	20	20	
Penetration Value		**19**	**20**	**20**	
14% of CRMB	Initial	0	0	0	**14.33**
	Final	14	14	15	
Penetration Value		**14**	**14**	**15**	

Result Penetration

Test were done for normal bitumen and modified bitumen with 0%, 8%, 10%, 12%, and 14% of rubber waste content. The result was shown in Table 2. From the result of the test, the penetration value for normal bitumen was 69 mm. Penetration value decreased with the increased amount of the rubber waste added. Lower penetration value making harder grade of asphalt, giving additional strength to the road and reduces water damage.



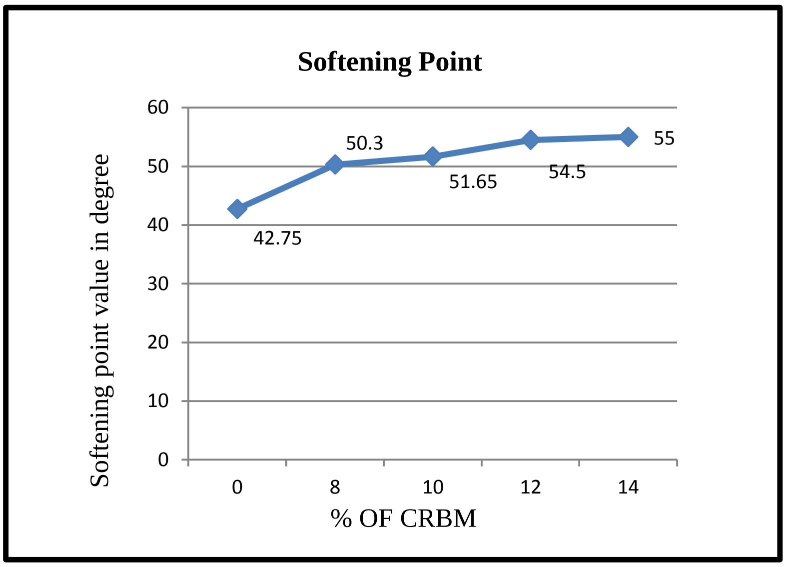
Graph 1: Penetration Value v/s CRMB %

4.4. Softening Point Test

Softening point denotes the temperature at which the bitumen attains a particular degree of softening under the specifications of test. The test is conducted by using Ring and Ball apparatus. A brass ring containing test sample of bitumen is suspended in liquid like water or glycerin at a given temperature. A steel ball is placed upon the bitumen sample and the liquid medium is heated at a rate of 5ºC per minute. Temperature is noted when the softened bitumen touches the metal plate which is at a specified distance below. Generally, higher softening point indicates lower temperature susceptibility and is preferred in hot climates.

Record of Observation:

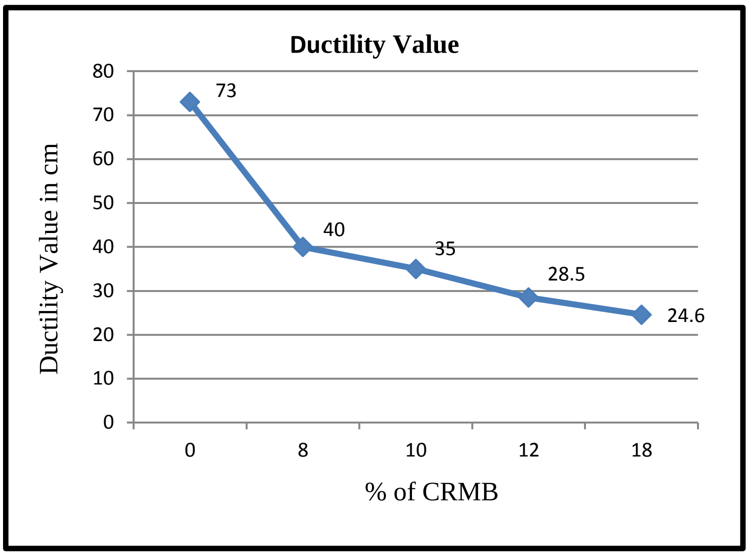
Table 3: Softening Point Test Result



	%Of CRMB	Reading 1 in Degree	Reading 2 in degree	Mean value in Degree
Temperature at which bitumen softens and touches the bottom plate by sinking of ball	0% of CRMB	42.4	43.1	42.75
	8% Of CRMB	49.1	51.5	50.3
	10% Of CRMB	51.4	51.9	51.65
	12% Of CRMB	54.1	54.9	54.5
	14% Of CRMB	54.2	55.8	55

Result

Softening Point Test was done for normal bitumen and modified bitumen with 0%, 8%, 10%, 12%, and 14% of rubber waste content. The result was shown in Table 3. From the result of the test, the softening point for normal bitumen was 42.75˚c. Softening Point increased with the increased amount of the rubber waste added. This showed that the bitumen becomes less susceptible to temperature changes as the content of rubber waste increased.



Graph 2: Softening Point value v/s CRMB %

4.5 Ductility Test

Ductility is the property of bitumen that permits it to undergo great deformation or elongation. Ductility is defined as the distance in cm, to which a standard sample or briquette of the material will be elongated without breaking.

Record of Observation:

Table 4: Ductility Test Result

% of CRMB	Sample Reading in cm			Average
	Reading 1	Reading 2	Reading 3	
0 % of CRMB	71	73	75	73
8 % of CRMB	39	40	41	40
10 % of CRMB	34	36	36	35
12 % of CRMB	27.2	28.1	30.2	28.5
14 % of CRMB	23.3	24.6	25.9	24.6

Result:

Ductility test was done for normal bitumen and modified bitumen with 0%, 8%, 10%, 12%, and 14% of rubber waste content. The result was shown in Table 4. The result shows 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.

5. CONCLUSION

1. Penetration value test result shows that Penetration value decreased with the increased amount of the rubber waste added. Lower penetration value making a harder grade of asphalt, giving additional strength to the road and reduces water damage. Lower Penetration thereby making a harder grade of asphalt, giving additional strength to the road and reduces water damage.
2. Softening point test shows that Softening Point increased with the increased amount of the rubber waste added. This showed that the bitumen becomes less susceptible to temperature changes as the content of rubber waste increased. Increase of Softening Point, thereby giving it protection against hot climatic conditions.

3. Ductility test result shows 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.

4. The biggest advantage of using rubberized bitumen is that the road life increases in comparison to the normal bitumen whereas the cost increase on the road.

5. Improved adhesion aggregates and binder thereby giving better strength, stability and longer life.

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