Use of Crumb Rubber in Flexible Pavement and Comparison in Strength & Quality

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ABSTRACT

Today disposal of different wastes produced from different Industries is a great problem. These materials pose environmental pollution in the nearby locality because many of them are non-biodegradable, Crumb rubber is one of them. Soil, stone aggregate, sand, bitumen, cement etc. are used for road construction. Natural material are limited in nature, its quantity is decreasing and cost is increasing. Concerned about this, engineers are looking for alternative materials for highway construction, by which the quality of road is increase with low cost. Keeping in mind the need for bulk use of these solid wastes in India, it was thought expedient to test these materials and to develop specifications to enhance the use of waste tyres in road making in which higher economic returns may be possible. The waste tyres can be used in the form of aggregate which on mixing with various bitumen in suitable size.

Key Words: *crumb rubber, chip seal coat.*

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1. INTRODUCTION

The American Society of Testing and Materials (ASTM D8) defines rubberised bitumen as “a blend of asphalt cement [bitumen], reclaimed tyre rubber and certain additives, in which the rubber component is at least 15% by weight of the total blend and has reacted in the hot asphalt cement [bitumen] sufficiently to cause swelling of the rubber particles,” [AST05] This definition was developed in the late 1990’s. Centre for Transportation Engineering of Bangalore University compare the properties of the modified bitumen with ordinary bitumen.

It was observed that the penetration and ductility values of the modified bitumen decreased with the increase in proportion of the plastic additive, up to 12 percent by weight. Therefore the life of the pavement surfacing using the modified bitumen is also expected to increase substantially in comparison to the use of ordinary bitumen.

These materials in highway road construction, the pollution and disposal problems can be successfully be reduced. Minding the bulk ruse of these wastes in India, it was thought necessary to examine these materials and to develop specifications to increase the use of rubber wastes in road making, in which higher economic returns may be possible. These materials should be used in road construction in each and every part of our country. The waste tyres can be used in the form of aggregate which on mixing with various bitumen in suitable size. This reduces the pollution occurred due to waste tyres as well as minimizes the use of natural aggregate, which help in reducing global warming as well as health problems.

2. METHODOLOGY

Waste rubber tyres were collected from roads sides, dumpsites and waste-buyers. The collected waste tyres were sorted as per the required sizes for the aggregate. The waste tyres were cut in the form of aggregate of sizes ranging from 22.4 mm to 6.00 mm (as per IRC-SP20) in the tyre cutting machine. The waste rubber tyres can be managed as a whole tyre, as slit tyre, as shredded or chopped tyre, as ground rubber or as a crumb rubber product. The rubber of tyre usually employed in bituminous mix, in the form of rubber particles are subjected to a dual cycle of magnetic separation, then screened and recovered in various sizes and can be called as Rubber aggregate. It was cleaned by de-dusting or washing if required. The rubber pieces (rubber aggregate) were sieved through 22.4 mm sieve and retained at 5.6 mm sieve as per the specification of mix design and these were added in bituminous mix, 10 to 20 percent by weight of the stone aggregate. These rubber aggregates were mixed with stone aggregate and bitumen at temperature between 1600c to 1700c for proper mixing of bituminous mix. As the waste rubber tyres are thermodynamically set, they are not supposed to melt in the bitumen, at the time of mixing of rubber aggregate, stone aggregate and bitumen in hot mix plant.

3. EXPERIMENTAL SETUPS

Experimental setup is an approach of considering the essential set of experiments suitable and useful for the testing of the materials. There are some certain tests for aggregate, bitumen, rubber waste, etc. By the test, strength, durability and lots of factors will be justified. Before the testing of material, there should be proper selection of appropriate material for the research so that proper experiment should be carried out. In this research methodology, deals with the explanation of all the experiments required for our research. The testing methodology will consist of the following step:

- Selection of material
- Material Processing
- Material Testing
- Observations & Calculations
- Result & Discussion

4.1 EXPERIMENTS & RESULTS

4.1.1 Sieve Analysis of Aggregates

This test is use to determine the particle size distribution of the coarse and fine aggregates as shown in Table 1. This test is works as per IS: 2386 (Part I) – 1963.

Test Result

Table 1 Sieve Analysis Report

Sieve Size	Mass Retained (g)	Percentage Retained	Cumulative Percentage Retained	Cumulative Percentage Passing
13.20 mm	0	0	0	100
9.50 mm	371.8	18.6	18.6	81.4
6.70 mm	392.5	19.6	38.2	61.8
4.75 mm	222.1	11.1	49.3	50.7

2.36 mm	387.5	19.4	68.7	31.3
1.70 mm	97.9	4.9	73.6	26.4
1.18 mm	109.1	5.5	79.1	20.9
425 µm	170.8	8.6	87.7	12.3
150 µm	76.7	3.8	93.8	6.2
<150 µm	123.0	-	-	-
Total	1997.2	100	-	-

4.1.2 Specific Gravity & Water Absorption Test

To determine the specific gravity and water absorption of aggregates by using aggregate.

Test Result

Material	Specific gravity	Apparent S.G.	Water Absorption
Aggregate	2.64	2.70	0.92
Rubber Aggregate	1.96	2.01	1.22

4.1.3 Aggregate Impact Value Test

This test is help to determine the aggregate impact value of aggregate as per IS: 2386 (Part IV) – 1963.

Test Result

4.1.3.1 Impact test on Aggregate-

Weight of empty cylinder = 1401 gm
Weight of aggregate sample (W1) = 577 gm.
Weight of aggregate after impact (W2) = 511 gm.

(W3) = W1 – W2 = 66 gm.
Impact value = 66 / 577 * 100=11.43 %

4.1.3.2 Impact test on (Aggregate + Rubber)

Weight of empty cylinder = 1401 gm

Weight of (aggregate + rubber) sample (W1) = 563 gm
Weight of (aggregate + rubber) after impact (W2) = 522 gm
(W3) = W1 – W2 = 41 gm Impact value = 41 / 563 * 100 = 7.282 %

4.1.4 Aggregate Crushing Value Test

This test is use to determine the aggregate crushing value of aggregates in Table 2 as per IS: 2386 (Part IV) – 1963.

Test Result

Table 2 Aggregate Crushing Value result

Sl.No.	Net Weight (g) (A)	The fraction passing through 2.36mm Sieve (g) (B)	The fraction Retaining on 2.36mm sieve (g) (C)	Aggregate Crushing Value (%) =(B*100)/A
1	3230 (Aggregate)	302	2928	9.34 %
2	3500 (Aggregate + Rubber)	0	3500	0 %

4.1.5 Abrasion in the Los Angeles Machine

The Los Angeles test is use to determine abrasion or attrition.

Test Result

4.1.5.1Abrasion test on Aggregate

Size of aggregate = 40mm to 50mm
Weight of sample (W1) = 5000gm
Weight of sample of abrasion after sieving by 1.7mm sieve (W2) = 384gm
Abrasion value of aggregate = 384 / 5000*100 = 7.68%

4.1.5.2 Abrasion test on Crumb rubber

Weight of sample (W1) = 5000gm
Weight of sample of abrasion after sieving by 1.7mm sieve (W2) = 15g
Abrasion value of crumb rubber = 15 / 5000*100 = 0.3%

4.1.5 **Abrasion test on (Aggregate + Crumb rubber)**

Weight of sample (W1) = 5000gm

Weight of sample of abrasion after sieving by 1.7mm sieve (W2) = 46gm

Abrasion value of (Aggregate + Crumb rubber) = 46 / 5000*100 = 0.92%

SUMMARIZED RESULT

Table 3 Tests on Aggregates

Sr.No.	Aggregate Test	Test Result Obtained
1	Crushing value %	9.34
2	Impact value %	11.43
3	Los Angeles abrasion value %	7.68
4	Combined index %	29
5	Water absorption %	0.92
6	Specific gravity of coarse aggregate	2.64
7	Specific gravity of fine aggregate	2.37

Table 4 Tests on Crumbed Rubber

Sr. No.	Rubber Test	Test Result Obtained
1	Crushing value %	0
2	Los Angeles abrasion value %	0.3
3	Water absorption %	1.22
4	Specific gravity	1.96

Rubber has an elastic property, so we can say that addition of waste tyres as rubber aggregate modifies the flexibility of surface layer. The test result on crumbed rubber is shown in Table 4. According to test result optimum content of waste rubber tyres to be used is between the ranges of 10% to 13% with different-2 size in different-2 layers. Rubber is a flexible material, so it decries the vertical strain on top of subgrade. And because of this deformation in subgrade is also decries. Rubber has property of absorbing sound, which also help in reducing the sound pollution of heavy traffic roads. According to our test results, test values of crumb rubber (Impact value, abrasion value, crushing value, etc.) are less than test values of aggregate. We can be save a certain quantity of natural stone aggregate. Table 3 shows the summarized results of various tests conducted on aggregates.

5. HISTORY

Rubberized Bitumen is being used in USA from 1960 Currently Arizona, Florida, Texas and California using 2 million tons of Rubberized Bitumen. Rubberized Bitumen is very popular in Australia for chip sealing wearing course sand structural layers. Use of Rubberized Bitumen being increase in developing countries of Latin America. In 1960s scrap tyres were processed and used as a secondary material in the pavement industry. One application was introduced by two Swedish companies which produced a surface asphalt mixture with the addition of a small quantity of ground rubber from discarded tyres as a substitute for a part of the mineral aggregate in the mixture, in order to obtain asphalt mixture with improved resistance to studded tyres as well as to snow chains, via a process known as ‘‘dry process’’. In the same period Charles McDonalds, a materials engineer of the city of Phoenix in Arizona (USA), was the first to find that after thoroughly mixing crumbs of RTR with bitumen (CRM) and allowing it to react for a period of 45 min to an hour, this material captured beneficial engineering characteristics of both base ingredients. He called it Asphalt Rubber and the technology is well known as the ‘‘wet process’’.By 1975, Crumb Rubber was successfully incorporated into asphalt mixtures and in 1988 a definition for rubberised bitumen was included in the American Society for Testing and Materials (ASTM) D8 and later specified in ASTM D6114- 97. In 1992 the patent of the McDonald’s process expired and the material is now considered a part of the public domain. Furthermore, in 1991, the United States federal law named ‘‘Intermodal Surface Transportation Efficiency Act’’ (then rescinded), mandated its widespread use, the Asphalt-Rubber technology concept started to make a ‘‘quiet come back’’. Since then, considerable research has been done worldwide to validate and improve technologies related to rubberised asphalt pavements. Nowadays, these rubberised bitumen materials, obtained through the wet process, have spread worldwide as solutions for different quality problems (asphalt binders, pavements, stress absorbing lays and inlayers, roofing materials, etc.) with much different evidence of success demonstrated by roads built in the last 30 years.

6. PROCESS OF MAKING RUBBERISED BITUMEN

This terminology is related to the system of producing RTR-MB with the original wet process proposed by Charles McDonald in the1960s. The McDonald blend is a Bitumen Rubber blend produced in a blending tank by blending Crumb Rubber and bitumen. This modified binder is then passed to a holding tank, provided with augers to ensure circulation, to allow the reaction of the blend for a sufficient period (generally 45–60 min). The reacted binder is then used for mix production. Continuous Blending-reaction Systems: This system is similar to the McDonald process of blending, the difference is that CRM and bitumen are continuously blended during the mix production or prepared by hand and then stored in storage tanks for later use. Therefore, it consists of a unique unit with agitators, in which the reaction occurs during the blending.

7. USES OF RUBBERISED BITUMEN

7.1 Rubberised Bitumen as a Slurry Material:

Recognizing that fatigue cracking generally occurred in larger areas that small patches couldn’t handle, the concept was extended to full pavement sections by spreading the rubberised bitumen with slurry seal equipment, Figure 2, followed by aggregate application with standard chip spreaders [MCD81]. This process had two distinct construction problems. First, in order to achieve the desired reaction of the bitumen and crumb rubber in the limited time available in the slurry equipment, it was necessary to employ bitumen temperatures of 4500 F (2320 C) and higher. Second, the thickness of the membrane varied directly with the irregularity of the pavement surface. This resulted in excessive materials in areas such as wheel ruts and insufficient membrane thickness.

7.2 Rubberised Bitumen as a Chip Seal Application:

In 1971, technology had developed to the point that standard bitumen distributor Lorries were employed to apply a uniform thickness of binder to the pavement, Figure 3. Although problems with distribution and segregation of materials were encountered on the early projects, these were recognized as primarily equipment limitations.

Within the next few years equipment was developed with pumping, metering and agitation capabilities needed to handle the highly viscous rubberised bitumen materials. As noted earlier, the Arizona Department of Transportation (ADOT) monitored the development of AR and placed a Band-Aid type maintenance application of AR in 1964. In 1968, experience from trial and error and the burning of a couple of distributor boot lorries led to improvements in mixing to a satisfactory degree that AR could be safely and consistently placed with a distributor lorry by using a diluent (kerosene). From 1968 - 1972, ADOT placed AR on six projects that were slated for reconstruction. The cracking on these projects was generally typical of a failed pavement needing at least a six inch overlay or complete reconstruction. For these seal coat type application projects a boot truck distributor was used to apply the AR. In these early applications the ground tyre rubber was introduced into the top of the boot lorry and mixed by rocking the lorry forward and backward. Even with this rather primitive early technology it was possible to construct the first full scale ADOT field experiment in 1972 using AR as a seal coat or Stress Absorbing Membrane (SAM), as well as an interlayer under a not mix asphalt (HMA) surfacing. The interlayer application is typically referred to as a Stress Absorbing Membrane Interlayer (SAMI).

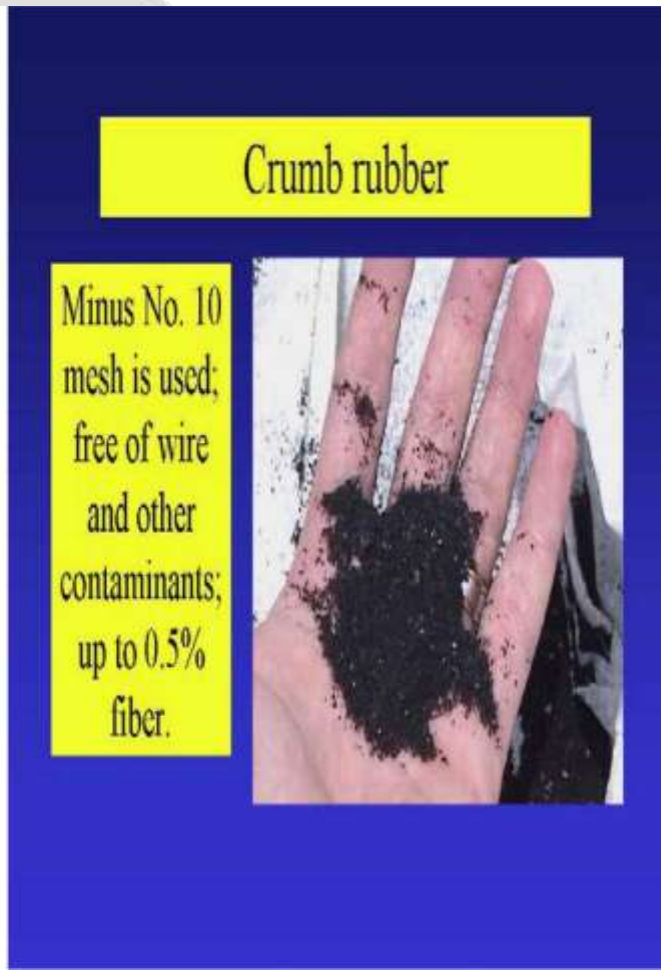

Fig -4: Rubberised bitumen chip seal applied to badlycracked pavement

Fig -5: Crumb rubber

Table -5: Ground Tyre Rubber Gradation

Sieve	Percent Passing
2 mm, #10	100
1.18 mm, #16	65-100
600 µm, #30	20-100
300 µm, #50	0-45
75 µm, #200	0-5

8. Rubberised Bitumen Mix Construction:

Construction of an AR pavement involves first mixing and fully reacting the crumb rubber with the hot bitumen as required by specification. Typically 20 percent ground tyre rubber that meets the gradation shown in Table 1 and is added to the hot base bitumen. The bitumen needs to have a temperature of about 177^{O}C (about 350^{O}F) before being put into the blending unit, that heats the bitumen to 191^{0}C to 218^{O}C (375^{O}F to 425^{O}F) just prior to adding the rubber particles. The rubber and bitumen are mixed for at least one hour. After reaction, the rubberised bitumen mixture is kept at a temperature of between 163^{O}C and 191^{O}C (325°F and 375^{O}F) until it is introduced into the mixing plant Samples of the rubber, base bitumen, and AR mixture are taken and tested accordingly. The ARFC, which typically has one percent lime added to the mix, is placed with a conventional laydown machine and immediately rolled with a steel wheel roller.

8.1. Why is Rubberised Bitumen a Best Practice?

1. It is a less expensive application when used as a thin top course over failed pavement that would otherwise need replacement (California & Arizona studies);

2. It is less expensive to maintain per lane-kilometer (lane-mile) in years 6 through 15 of pavement life over conventional pavements, and the same in years 1 through 5 (Arizona & California studies);

3. It significantly reduces noise as opposed to concrete pavements, and also is quieter than bituminous pavements; rubber bitumen makes urban environments more habitable (Arizona DOT studies);

4. It significantly improves wet surface traffic safety (Texas DOT studies);

5. It provides better surface road drainage when used in an Open Grade Friction Course (Texas & Arizona studies);

6. It is a hugely beneficial use for post-consumer waste tyre materials, using about 1,000 waste passenger tyres per lane-mile (about 621 waste passenger tyres per lane-kilometer).

9. CRUMB RUBBER MODIFIED BITUMEN (FLEXTAL)

Crumb Rubber Modified Bitumen (CRMB) is hydrocarbon binder obtained through physical and chemical interaction of crumb rubber (produced by recycling of used tyres) with bitumen and some specific additives. The Flextal range of CRMB offers binders which are stable and easy to handle with enhanced performances.

CRMB is suitable for pavements submitted to all sorts of weather conditions, highways, traffic denser roads, junctions, heavy duty and high traffic sea port roads etc. It is a durable and economical solution for new construction and maintenance of wearing courses

10. Crumb Rubber Overview

Crumb rubber is the name given to any material derived by reducing scrap tires or other rubber into uniform granules with the inherent reinforcing materials such as steel and fiber removed along with any other type of inert contaminants such as dust, glass, or rock.

Crumb rubber is manufactured from two primary feed stocks: tire buffings, a byproduct of tire retreading and scrap tire rubber. Scrap tire rubber comes from three types of tires: passenger car tires, which represent about 84 percent of units or approximately 65 percent of the total weight of U.S. scrap tires; truck tires, which constitute 15 percent of units, or 20 percent of the total weight of U.S. scrap tires; and off-the-road tires, which account for 1 percent of units, or 15 percent of the total weight of U.S. scrap tires. End product yields for each of these tire types are affected by the tire' s construction, strength and weight. On average, 10 to 12 pounds of crumb rubber can be derived from one passenger tire.

11. CRUMB RUBBER MANUFACTURING TECHNOLOGIES

Generally, crumb rubber is produced by reducing scrap tires down to sizes ranging from 3/8" to 40 mesh particles and removing 99 percent or more of the steel and fabric from the scrap tires. There are several processes for manufacturing crumb rubber. Two of the most common are ambient grinding and cryogenic processing. A third technology-the wet grind process-is also in use in the U.S. to produce finer mesh crumb rubber ranging from 40mesh to 200 mesh.

11.1. Ambient Process

Ambient grinding can be accomplished in two ways: granulation or cracker mills. In an ambient system, the rubber, tires or other feedstock remain at room temperature as they enter the cracker mill or granulator.

Ambient grinding is conducive to any size particle, including whole tires. It can be accomplished in two ways: granulation or cracker mills. In an ambient system, the rubber, tires or other feedstock remain at room temperature as they enter the cracker mill or granulator.

Ambient grinding is a multi-step processing technology that uses a series of machines (usually three) to separate the rubber, metal, and fabric components of the tire. Whether using granulation equipment or cracker mills, the first processing step typically reduces the original feedstock to small chips. The second machine in the series will grind the chips to separate the rubber from the metal and fabric. Then a finishing mill will grind the material to the required product specification. After each processing step, the material is classified by sifting screens that return oversize pieces to the granulator or mill for further processing. Magnets are used throughout the processing stages to remove wire and other metal contaminants. In the final stage, fabric is removed by air separators.

Rubber particles produced in the granulation process generally have a cut surface shape and rough texture, with similar dimensions on the cut edges. Uses for the crumb rubber or granulate produced in this process include safety and cushioning surfaces for playgrounds, horse arenas and walking/jogging paths.

Cracker mills - primary, secondary or finishing mills - are all very similar and operate on basically the same principle: they use two large rotating rollers with serrations cut in one or both of them. The roll configurations are what make them different. These rollers operate face-to-face in close tolerance at different speeds. Product size is controlled by the clearance between the rollers. Cracker mills are low speed machines operating at about 30-50 RPM. The rubber usually passes through two to three mills to achieve various particle size reductions and further liberate the steel and fiber components.

11.2. Cryogenic Process

Cryogenic processing refers to the use of liquid nitrogen or other materials/methods to freeze tire chips or rubber particles prior to size reduction. Most rubber becomes embrittled or "glass-like" at temperatures below -80°C. The use of cryogenic temperatures can be applied at any stage of size reduction of scrap tires. Typically, the size of the feed material is a nominal 2 inch chip or smaller. The material can be cooled in a tunnel style chamber, immersed in a "bath" of liquid nitrogen, or sprayed with liquid nitrogen to reduce the temperature of the rubber or tire chip. The cooled rubber is ground in an impact type reduction unit, usually a hammer mill. This process reduces the rubber to particles ranging from 1/4 inch minus to 30 mesh, with the majority of the particle distribution between 1/4 inch minus and 20 mesh. A typical throughput is 4,000 to 6,000 pounds per hour. Cryogenic grinding avoids heat degradation of the rubber and produces a high yield of product that is free of almost all fiber or steel, which is liberated during the process.

11.3. Fine Grind - Ambient Method

Micro milling, also called wet grinding, is a processing technology used to manufacture crumb rubber that is 40 mesh and finer.

The wet grind process mixes partially refined crumb rubber particles with water creating a slurry. This slurry is then conveyed through size reduction and classification equipment. When the desired size is achieved, the slurry is conveyed to equipment for removing the majority of the water and then drying. Aside from the use of water, the same basic principles that are used in an ambient process are utilized in a wet grinding process.

The major advantage for a wet grind process is the ability to create fine mesh crumb rubber. While products as coarse as 40 mesh are produced, the majority of the particles are 60 mesh and finer. A percentage of the overall throughput is finer than 200 mesh. Another advantage for a wet grind process is the cleanliness and consistency of the crumb rubber produced. The process literally “washes” the crumb rubber particles. The wet process removes the fine particles of fiber from the crumb rubber making a very clean product.

The wet process also produces a unique morphology in the particles. This has proven effective in the manufacturing of several goods used in automotive applications and in certain molded goods

12. THE USE OF CRUMB RUBBER CAN INCLUDE

12.1 ROAD ASPHALT

A tire crumb is easily used for road paving, making these roads stay for much longer without potholes, cracks, or deformations, if we compare them to regular asphalt roads, they also provide to drivers with a more comfortable route and improvements in the impacts caused to the vehicle in general.

12.2 VIBRATION ABSORPTION SYSTEMS FOR RAILWAY STRUCTURES

The use of crumb rubber is also to attenuate the vibrations and annoying noises caused by the transit of trains and trams in areas near buildings. It is made with quick assemblies and are low cost in maintenance.

12.3 ROAD SPEED REDUCERS

The speed reducers manufactured from the crumb rubber are effective and super necessary to increase safety in school zones, residential areas, urban areas, areas where speed is reduced by crossing roads, parking lots, cyclists' areas, etc. Its manufacture, must comply with the regulations of transit of the place, being a modular system that is formed by body, external area and central area that increase safety, since the friction of the reducer with the wheel of the car is greater since they are both of natural rubber and the delineation in yellow must be of high reflective capacity and anti-slip. Likewise, because it is a product made from recycled rubber,

13. Crumb Rubber Constitutions and Concentration

Crumb rubber or waste tyre rubber, is a blend of synthetic rubber natural rubber, carbon black, antioxidants, fillers, and extender type of oils which are soluble in hot paving grade. Asphalt rubber is obtained by the incorporation of crumb rubber from ground tyres in asphalt binder at certain conditions of time and temperature using either dry process (method that adds granulated or crumb rubber modifier (CRM) from scrap tires as a substitute for a percentage of the aggregate in the asphalt concrete mixture, not as part of the asphalt binder) or wet processes (method of modifying the asphalt binder with CRM from scrap tires before the binder is added to form the asphalt concrete mixture). There are two different methods in the use of tyre rubber in asphalt binders; first one is by dissolving crumb rubber in the asphalt as binder modifier. Second one is by substituting a portion of fine aggregates with ground rubber that does not completely react with bitumen**.**

14. Failure of Road Pavement

14.1 Cracking and Permanent Deformation

Two kinds of loading are of specific importance in tandem with the performance of bituminous surfacing. One is due to vehicles loads passing over the road surfacing, while the second is due to thermal contraction in relation to temperature changes. Vehicle loading can lead to distress at either end of the range of pavement surface temperatures. At increased pavement temperatures, the binder can be extremely fluid and probably will not resist the plucking and shearing action of vehicle tyres. At low pavement temperatures, the binder can be so hard (particularly after a long period of service) that vehicle loading causes brittle fracture of the binder films. The explanation to this phenomenon is thought to be due to the theory of "Normal Stresses" (Wiesenberger effect) which applies to viscoelastic material such as a bitumen/scrap rubber mixture. This theory covers normal stress differences, which are forces that develop normally (that is perpendicular) to the direction of shear.

15. CONCLUSION

In the present study, the importance was to add the shredded waste crumb rubber to aggregate and to evaluate the various mix properties like Impact value, abrasion value, crushing value, etc. And also, to check the property of Crumb rubber aggregate. To check the coating property of rubber aggregate with adhesive materials. To check crumb rubber material properties through both laboratory and field evaluation. Develop test data for specification for non-structural / low loading usage. To evaluate the properties of rubber resistance against cracking, fatigue and rutting. Making environment less harm from rubber waste.

So in the end of this we get outcomes which are satisfying all the objectives, like: It modifies the flexibility of surface layer. Waste rubber tyres to be used is between the ranges of 5% to 20%. Problem like thermal cracking (Fatigue) and permanent deformation (Rutting) are reduce in hot temperature region. Rubber has property of sound absorption, which also help in reducing the sound pollution of heavy traffic roads. The use of rubber can improve the quality and performance of road. We can be save a certain quantity of natural stone aggregate.

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