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Analysis and Design of using Waste Rubber Tyres in Construction of Bituminous Road

Ankit Kumar[1], Vaibhav Dubey[2]

[1]M.tech, Department of Civil Engineering Rama University Kanpur UP
[2]Assistant Professor, Department of Civil Engineering Rama University Kanpur UP

Abstract -The usage of four-wheeled, two-wheeled, and other vehicles is growing daily. As a result, there are also more used tyres in the garbage. In India, used tyres are considered hazardous or solid trash. In both urban and rural locations, it is thought that 60% of discarded tyres are disposed of through unidentified routes. This causes a number of environmental issues, such as air pollution from tyre burning in the open (which may produce dangerous pollutants including dioxin, polycyclic aromatic hydrocarbons, and oxides of nitrogen), as well as aesthetic pollution. Because of this, it is essential to properly utilise wastes as each field's technology advances.If the old tyres are chopped into aggregate and given the name rubber aggregate, they can be utilised as well-sized aggregate in a variety of bituminous mixtures.This reduces the amount of traditional aggregate that is used, which is a finite resource, as well as the pollution caused by discarded tyres.The building industry is significantly impacted by changes to building materials. Therefore, there have been several attempts made in the construction material sector to turn waste materials, such as worn-out tyres, into functional and affordable commodities. The waste of rubber from tyres is a major environmental issue everywhere.

***Key Words*:** Tyre, Dioxin, Rubber

1. INTRODUCTION

The issue of heat cracking and persistent deformation is resolved by the rubber aggregate. It is a substance that may be used as a chip seal coat, used to fill joints and seal cracks, and combined with hot mineral aggregate to create a special asphalt paving material that solves issues with thermal cracking and permanent deformation in hot climates. Rubber's ability to absorb sound contributes to its role in mitigating noise pollution. Thus, used rubber tyres may be used to enhance the functionality and condition of the roadways. When used to the construction of roads, it can tolerate more extreme temperatures.Disposal of various wastes generated by various industries is a major challenge nowadays. Many of these materials are non-biodegradable, which causes environmental contamination in the neighbourhood. For the construction of roads, traditional materials include dirt, stone aggregate, sand, bitumen, cement, etc. Natural resources are finite and their availability is dwindling with time. Additionally, the cost of obtaining high-quality natural resources is rising. Scientists are searching for substitute materials for building highways out of concern about this, in an effort to partially alleviate the pollution and disposal issues. Given the requirement for large-scale use of these solid wastes in India, it was deemed necessary to test these materials and set requirements to improve the usage of waste tyres in road construction, where larger financial returns may be achievable. For the development of low traffic roads in various regions of our nation, it is important to explore the potential uses of these materials. In order to employ solid wastes as efficiently as possible in the various layers of the road surface, the relevant requirements should be developed. Studies on the performance of the pavement created after the building of low-traffic roads will be conducted, and they will have two key advantages. (i) It will assist in removing massive trash dumps from precious land (ii) It will also assist to conserve the environment by preserving aggregates' natural reserves. Rubber tyres are user-friendly but not environmentally friendly because they are often not biodegradable. Due to the fast reduction in accessible landfill sites and degradation of the environment, the practise of open burning and dumping of old tyres in landfills is becoming intolerable. By weight of the aggregate, the traditional bituminous mix contains stone aggregate and 3% to 5 % bitumen. The rubber from recycled tyres may be added to bitumen, which is sometimes referred to as modified bitumen, and rubber granules, ground rubber, or crumb rubber can be utilised as a fraction of the fine stone aggregate. When garbage is added to hot bituminous mixes, the performance of the pavement is improved, the environment is protected, and more affordable, quieter roads are provided.

Using certain temperatures, crumb rubber modified bitumen (CRMB 55) was mixed, according to Shankar et al. Marshall's mix design was implemented by varying the modified bitumen content while maintaining the ideal rubber content. Subsequent tests were carried out to identify the various mix design features as well as for regular bitumen (60/70). As a consequence, the properties of the bitumen have significantly enhanced when compared to straight flow bitumen, and this is at a lower than ideal modified binder level (5.67%).

Fig-1: Rubber Specimen of tyre

PROPERTIES OF RUBBER TYRES

The following qualities of old tyres make them ideal for use in roadway construction:

1. Lightweight
2. Free Drainage

3. Low earth pressure
4. Good thermal insulator
5. Durability
6. Compressible
7. Vibration Damping
8. Low-Cast

NEED FOR RUBBERIZED BITUMEN

1 A more hostile traffic situation.
2 Extreme weather with daily and seasonal temperature volatility.
3 Roads need to be kept in better serviceable condition.
4 Greater flexibility and increased fatigue resistance of bituminous mixtures under repeated loading.
5 Increased cohesiveness, which helps with weather resistance and adherence to lower the possibility of the binder being washed away by water.
6 Achieve a greater rigidity modulus to reduce the thickness of resurfacing in urban areas and to prevent milling.

Protection against creep failure, ravelling, cracking, and deformation.

SCOPE OF THE PRESENT STUDY

1. Construction of flexible pavement using used rubber tyres.
2. To minimise the use of natural resources in the production of the pavement.
3. To investigate the variance in strength characteristics through various testing.
4. To understand the standard of pavement rubber replacement.
5. To keep building costs as low as possible.
6. The burning of these discarded tyres produces carbon.
7. Due to the land issues in our nation, this quantity of tyres is so great that it is hazardous and unpleasant to place.
8. It was discovered that dangerous compounds had been in contact with very acidic solutions.

2. METHODOLOGY

Waste rubber tyres were gathered from landfills, waste-buyers, and the sides of the road. Waste tyres were gathered and sorted according to aggregate size requirements. In the tyre cutting device depicted in Fig. 3.1, the discarded tyres were chopped into aggregate with diameters ranging from 22.4 mm to 6.00 mm (according to IRC-SP20)..

Waste rubber tyres can be processed into whole, split, grind, chopped, or shredded tyres as well as into crumb rubber products. Tyre rubber, which is typically used in bituminous mixtures, is separated magnetically twice, screened, and recovered in a range of sizes to create what is known as rubber aggregate. If necessary, it was cleaned by washing or de-dusting. According to the requirements of the mix design, the rubber bits (rubber aggregate) were sieved through a 22.4 mm sieve and kept at a 5.6 mm sieve, and they were added to bituminous mix at a rate of 10 to 20 percent by weight of the stone aggregate. These rubber aggregates were mixed with stone aggregate and bitumen attemperaturebetween160^{0}c to 170^{0}c 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.

. **Fig:2** Rubbertyres cutting machine

Ambient grinding-This form of processing involves grinding or processing used tyres at temperatures equal to or higher than ambient. In order to increase contact with the paving bitumen, ambient processing is often needed to generate irregularly shaped, torn particles with relatively wide surface areas. The crucial stage in this mechanical grinding, which is carried out by revolving knives and blades, is the separation of the fibres, which often includes steel fibres. Once the metallic component has been removed, ambient grinding can provide rubber crumbs with a grain size ranging from 5 to 0.5 mm. The most popular and possibly most economical way of treating end-of-life tyres is ambient grinding. Figure 3 provides a schematic illustration of ambient grinding.

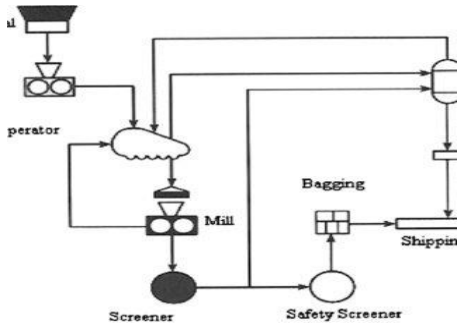


Fig.3. Schematic representation of ambient grinding

Cryogenic grinding-The RTR is frozen using liquid nitrogen, typically between 87 and 198 °C, until it becomes brittle, as shown in Fig4. The frozen rubber is then broken into smooth particles with a relatively lower surface area than those produced by ambient grinding. Oliver demonstrated how the specific gravity and particle size of the rubber granulate, as well as the granules' surface porosity, affect the elastic properties of the Crumb Rubber and those that are dependent on the final mix. In contrast to the results obtained utilising granules with larger porous surfaces and lower specific weight, rubber particles with a smooth surface in the wet process actually demonstrated less reactivity with the bitumen and worse the elastic characteristics of the combination. As a result, it is not recommended to utilise CRM from the cryogenic process in bituminous mixes . Table summarises a comparison of the characteristics of cryogenic and ambient ground rubber.

Physical property	Ambient	Cryogenic
Specific gravity	Same	Same
Particle shape	Irregular	Regular
Fibre content	0.5%	Nil
Steel content	0.1%	Nil
Cost	Comparable	Comparable

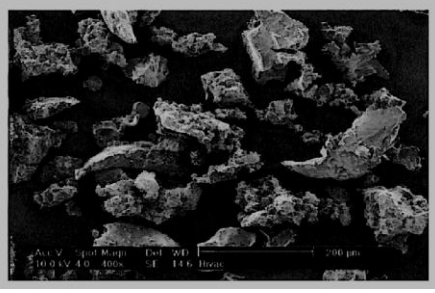


Fig.4 and Table: Cryogenic rubber crumbs. SEM analysis at 200um and 400x magnification

Wet-grinding-A proprietary grinding technique called wet-grinding uses a liquid media, generally water, to further reduce the size of microscopic rubber particles. Between two closely spaced grinding wheels, grinding takes place. As a bitumen modifier, the produced fine mesh RTR is mostly employed. Reduced size of hydro jets. This method uses pressured water to break down RTR into smaller particles. Clean, wire-free rubber crumbs are produced by water jets rotating at high speeds in arrays at very high working pressure (about 55.000 psi). The methodology for the process is, however, still largely unknown in the sector because it is so recent. However, the resultant rubber crumbs' high level of roughness makes this product extremely desirable for bitumen modification.

3. EXPERIMENTAL STUDIES

Mixing Of Crumb Rubber with Plain Bitumen- A metal container with a 1.5-liter capacity was filled with 500 g of bitumen and heated to a fluid state in order to prepare the modified binders. Crumb rubber was added after bitumen had been heated to a temperature of 160 °C in preparation for mixing. Each mixed sample contains 0%, 8%, 10%, 12%, and 14% by weight of crumb rubber. About 3–4 minutes are spent hand blending the mixture. The mixture is then heated to 160 °C and stirred thoroughly for around 50 minutes using a mechanical stirrer. The temperature is carefully kept between 160 °C and 170 °C. The mixture is stirred gradually for roughly 55 minutes. The modified bitumen is properly kept for testing after being cooled to room temperature.

Physical Properties of rubber tyres-

Sr No.	Properties of Crumb rubber	Result
1	Specific gravity	1.016
2	Moisture content	0.70%

Penetration test-

By measuring the depth in tenths of a millimetre to which a standard loaded needle would penetrate vertically in 5 seconds, it is possible to determine how hard or soft a bitumen is. The test methodology and equipment had been standardised by BIS. The penetrometer is made up of a 100g needle assembly and a locking and unlocking mechanism that may be used in any position. The bitumen is well agitated until it has a pouring consistency, then it is poured into containers at a depth that is at least 15 mm deeper than the penetration that is anticipated.A specific temperature of 25o C should be used for the test. It should be noted that any mistake in the temperature of the pour, the size of the needle, the weight on the needle, and the test temperature has a significant impact on the penetration value. When bitumen is graded as 40/50, it signifies that under typical test circumstances, the penetration value falls between 40 and 50. It is preferable to use a lower penetration grade in warmer areas.

Record of Observation for penetration test:

Actual temperature = 25˚ c

% Of CRMB	Reading	Trial 1	Trial 2	Trial 3	Average. Value In mm
0% of CRMB	Initial	0	0	0	69.00
	Final	65	68	75	
Penetration Value		65	68	75	
8% of CRMB	Initial	0	0	0	49.33
	Final	45	46	53	
Penetration Value		45	46	53	
10% of CRMB	Initial	0	0	0	38.67
	Final	34	35	45	
Penetration Value		34	35	45	
12% of CRMB	Initial	0	0	0	19.67
	Final	19	21	19	
Penetration Value		19	21	19	
14% of CRMB	Initial	0	0	0	14.33
	Final	14	15	14	
Penetration Value		14	15	14	

The used rubber tyres can be handled in a variety of ways. It comes in a variety of forms, including entire or sliced tyres, chopped tyres, ground rubber, and products made of crumb rubber. When rubber particles used in bituminous mix are exposed to a dual cycle of magnetic separation, they are subsequently screened and recovered in varied sizes, leading to the creation of the substance known as "Rubber Aggregate" . The used rubber tyre is cleaned using a variety of procedures, including washing and de-dusting. According to the mix

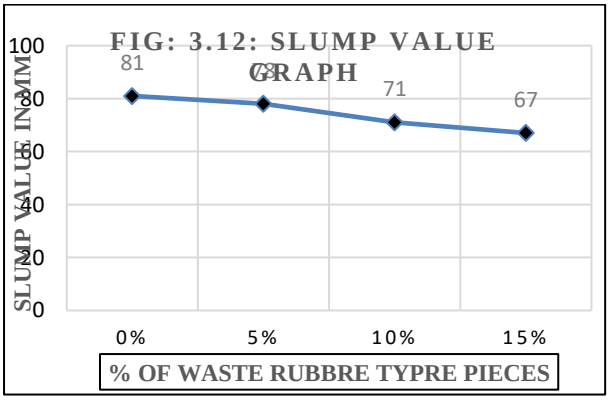
design parameters, all of the rubber bits are sieved through a 22.4 mm sieve and kept via a 5.6 mm sieve. The bituminous mix contains 10–20% by weight of these transparent bits of stone aggregate. Once properly combined with stone aggregate and bitumen at a temperature of between 1600°C and 1700°C, the well-sieved and well cleaned rubber aggregate is added. Because the waste rubber tyres are thermodynamically fixed, they do not melt when mixed with bitumen in a mix plant. garbage rubber tyres are collected in large quantities from roadside ditches, landfills, and garbage purchasers. For the aim of mixing, the gathered waste tyres are sized according to the requirements. The tyre cutting machine depicted in the image below cuts the discarded tyres into aggregate size, which typically ranges from 22.4mm to 6.00mm (according to IRC:SP20).

Testing of Specimen-

The specimens were taken out of the mould after 24 hours and placed in water for 7 and 28 days to cure. The specimens' compressive and flexural strengths were evaluated after curing. The strength of the specimens was evaluated at 7 days and 28 days using a compression testing machine with a 2000 KN capacity in line with the requirements of the Indian Standard standard IS:516- 1959. The commonly used empirical test, known as the slump test with a w/c ratio of 0.40 for addition of varying percentages of waste tyre rubber, is used to determine the workability of concrete of the M30 grade. Values obtained for various percentage mixes are displayed in the following table-

Table -1: Slump values for different percentage of mix

% of Waste Tyre Rubber	Slump value (mm)
0%	81mm
5%	78mm
10%	71mm
15%	67mm



Compressive Strength Test-Compression strength's outcome 28 days after the first day is noted. The results show that the compressive strength improves as the proportion of waste tyre rubber grows, from 0% to 15%. However, after that point, there is a loss of compressive strength. In other words, we may use used tyre rubber to replace up to 15% of natural coarse aggregate.

According to a recent research, used tyre rubber may substitute coarse gravel by up to 10%.

When 5% of the coarse aggregate is replaced with waste tyre rubber, the compressive strength increases by 3.12%, and when 15% of the coarse aggregate is replaced with waste tyre rubber, the strength reduces by 19.32% when the water-to-cement ratio (W/C) is 0.40.

4. MATERIAL MIX DESIGN & RESULTS DISCUSSIONS

Mix Design-

This chapter gives background information on the components of crumb rubber modified bitumen as well as their requirements. The manufacturing and qualities of CRM, its shipment and management, and the characteristics of asphalt cement as they relate to asphalt rubber are just a few of the specific issues that will be covered-

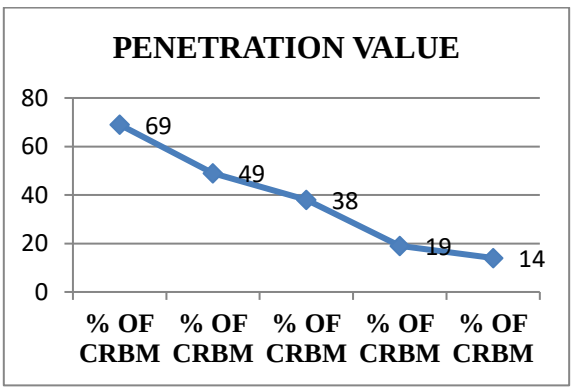
Material Required-

1. Bitumen
2. Crumb Rubber
3. Cracker Mill
4. Granulator
5. Wet grinding
6. Cryogenic Process

EXPERIMENTAL RESULTS-

Penetration-

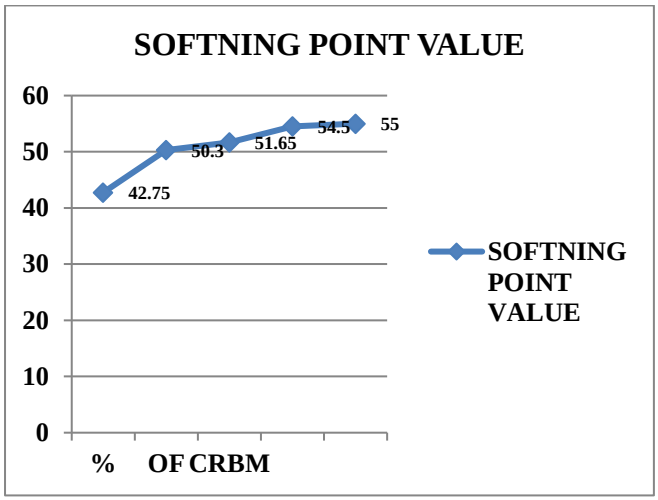
Tests were conducted on both standard bitumen and modified bitumen that contained 0%, 8%, 10%, 12%, and 14% rubber waste. The outcome was displayed in Table 2. According to the test's findings, typical bitumen had a penetration value of 69 mm. The amount of rubber waste added grew as the penetration value dropped. Less penetration results in a stronger grade of asphalt, strengthening the road and minimizing water damage.



Softening Point Test-

The term "softening point" refers to the temperature at which the bitumen softens to a given degree in accordance with test requirements. Use of the Ring and Ball contraption is required

to administer the test. At a specific temperature, a brass ring carrying a bitumen test sample is suspended in a liquid, such as water or glycerin. The liquid medium is heated at a rate of 5oC per minute while a steel ball is put on top of the bitumen sample. When the softened bitumen reaches the metal plate that is located below at a specific distance, the temperature is recorded. Higher softening points are often favoured in hot settings since they imply reduced temperature vulnerability.



	% 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%ofCRMB	42.4	43.1	42.75
	8%OfCRMB	49.1	51.5	50.3
	10%OfCRMB	51.4	51.9	51.65
	12%OfCRMB	54.1	54.9	54.5
	14%OfCRMB	54.2	55.8	55

Table 2-Softening point test result

Result & Discussions-

Normal bitumen and modified bitumen with rubber waste contents of 0%, 8%, 10%, 12%, and 14% underwent softening point tests. The outcome was displayed in Table 4.1. According to the test results, typical bitumen has a softening point of 42.75 degrees Celsius.

The amount of rubber waste injected grew along with the softening point. This shown that as the amount of rubber waste grew; the bitumen became less sensitive to temperature variations.

5. CONCLUSION

In the building of roads, the utilisation of discarded plastic and rubber tyres produces superior results. Since bitumen and plastic and tyres better adhere to one another. Due to enhanced bonding and area of contact between polymers and bitumen, the frequency of voids is also decreased. This finally aids in reducing bitumen degradation and moisture absorption by trapped air. As a result, the roads are more durable since they can resist tremendous traffic. The amount of stone aggregate by volume is reduced, it becomes more flexible, and the flexural strength in the top layer of roadways is increased when rubber aggregate is included into the bituminous mix. If the old tyres are chopped into aggregate and given the name rubber aggregate, they can be utilised as well-sized aggregate in a variety of bituminous mixtures. This reduces the amount of traditional aggregate used, which is a finite resource, as well as the pollution caused by discarded tyres.

The author thinks it is appropriate for the road paving business to employ the RTR-MBs technology widely. In fact, the numerous advantages offered to the performance of asphalt pavements and the general sustainability of the infrastructure are so clear that it is highly encouraged to investigate RTR-MBs technologies as a first alternative to the binders currently used in road paving.

- Waste tyres added as rubber aggregate change how flexible the top layer is.
- The ideal composition of old waste rubber tyres is in the range of 5% to 20%.
- In warmer temperature regions, issues like thermal cracking and persistent deformation are less common.
- Rubber has the ability to absorb sound, which helps to lessen the noise pollution caused by busy highways.
- Waste rubber tyres may therefore be used, which eventually enhances the road performance and quality.
- A limited amount of conventional stone aggregate can be salvaged.
- The results of the penetration value test indicate that the penetration value fell as more rubber waste was added.A tougher grade of asphalt with a lower penetration value increases the strength of the road and lessens water damage. Lower Penetration results in a tougher grade of asphalt, increasing the road's strength and minimising water damage.
- The softening point test reveals that the softening point rose when more rubber waste was added. This demonstrated that as the amount of rubber waste in the bitumen grew, it became less sensitive to temperature variations. Increased Softening Point provides protection from hot weather situations.
- According to the results of the ductility test, adding rubber waste will cause the bitumen to harden.

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