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Sustainable Road Construction: Utilizing Waste Tyre in Bituminous Pavements for Enhanced Performance and Durability

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ABSTRACT

India is a rapid urbanizing country. Due to overall development new roads are being constructed forever increasing population. Density of vehicular traffic increases day by day. The wear and tear of tires from these vehicles is undoubted. So, a large number of scrap tires are being generated. A large number of waste and worn-out tires are 15-20% each year. These tires are discarded indiscriminately or stockpiled. The used tires pose a great threat to human health and environment, since they are non-biodegradable; the waste tire rubber has become a problem of disposal. This paper is intended to study the feasibility of the waste tire rubber as a blending material in bitumen, which is used for road construction. The Waste tire rubber appears to possess the potential to be partially added in bitumen, providing a recycling opportunity. If Waste or used tire rubber can be added in bitumen for improving the properties, and disposing off the tires, thus the environmental gains can be achieved.

1. INTRODUCTION

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. However, with the use of waste tire rubber in bitumen, it will definitely be environmentally beneficial, it can improve the bitumen binder properties and durability, and it will also have a potential to be cost effective. As disposal of waste tires has become a worldwide problem and has caused worry to administrators, researchers and environmentalists. This intended to study the feasibility of the waste tire rubber as a blending material in bitumen, which is used for road construction. The waste tire rubber appears to possess the potential to be partially added in bitumen, providing a recycling opportunity. If waste or used tire rubber can be added in bitumen for improving the properties, and disposing off the tires, thus the environmental gains can be achieved. Introduction to using waste tyres in

Bitumen Roads. The disposal of waste tyres is a significant environmental challenge due to their non-biodegradable nature. One innovative and sustainable solution is their use in road construction by incorporating them into bitumen, commonly known as rubberized bitumen. This method enhances road performance while addressing the issue of tyre waste. For this research work aggregate, bitumen and crumb of scrap tyre was used. Different properties of bitumen and aggregate have been tested. Then prepare different mixes of bitumen and crumb of waste tire rubber with varying proportions by using wet process. The percentage weight of crumb tyre rubber replaces for percentage weight of bitumen taken for test. The feasibility of different mixes of bitumen and crumb tire rubber with varying proportions with aggregate has been tested.

A. Uses of Waste Tyres in Bitumen Roads

Waste Management: Helps reduce environmental impact of discarded tyres.
Improved Road Durability: Enhances flexibility, reducing cracks and potholes.
Cost-Effectiveness: Increases Road lifespan, reducing maintenance costs.
Better Resistance: Provides improved resistance to temperature variations and traffic loads.
Eco-Friendly: Reduces dependency on virgin materials and minimizes pollution.

B. How It Works

The process involves shredding waste tyres into small rubber particles (crumb rubber) and blending them with hot bitumen to create a modified binder. This binder is then used for road content of 25 percent. Frost penetration in the tire shred embankment is larger than in the natural ground because of the low water content and presence of large voids in tire shreds and the difference in snow cover. It was observed that the surface deflection of the tire shred embankment is 15 to 25 mm, under 21000 kg axle loads. An average rebound of 11 mm and irrecoverable displacement of 7 mm were recorded after two passes of load. The elastic modulus of the tire shreds is proportional to the bulk density of the shreds. Non-linear elastic isotropic analysis gives a conservative estimate of the deflection of the tire shred embankments as compared to the linear elastic analysis. The design of road embankments with large-size tire shred layers surfacing; improving elasticity and longevity. The use of waste tyres in bitumen roads is a practical approach to sustainable infrastructure development, promoting both environmental conservation and enhanced road performance.

Figure 1: Waste tyre

2. Literature Review

Niraj d. Bariaya, there are a large number of ways to manage the waste rubber tyres. It can be in the form of whole tyre or slit tyre, chopped tyre, ground rubber or as a crumb rubber product. The rubber tyre employed in bituminous mix in the form of rubber particles, when subjected to a dual cycle of magnetic separation are then screened and recovered in various sizes, thus giving rise to the product called “rubber aggregate” various processes like de-dusting and washing are used to clean the waste rubber-tyre. All the rubber pieces are sieved through 22.4 mm sieve and retained through 5.6 mm sieve as per the specifications of mix design. These clear pieces are added in bituminous mix, 10-20% by weight of stone aggregate. Then, these well sieved and cleaned rubber aggregate is mixed well with stone aggregate and bitumen at temperature of about 160^0c-170^0c for the proper mixing of bituminous mix. The waste rubber tyres are thermodynamically set; thus, they are not melted in bitumen at the time of mixing altogether in a mix plant. Large quantities of waste rubber tyres are collected from road sides, dumpsites and waste buyers. The collected waste tyres are sorted as per the required sizes for the mixing purposes. The waste tyres are cut in the form of aggregate size usually ranging from 22.4mm.

R. A. Khan and a. Shalaby, Author concluded that the thermal conductivity of the tire shreds is five times lower than the thermal conductivity of clay with a dry density of 1500 kg/m3 and moisture content of 25 percent. Frost penetration in the tire shred embankment is larger than in the natural ground because of the low water content and presence of large voids in tire shreds and the difference in snow cover. It was observed that the surface deflection of the tire shred embankment is 15 to 25 mm, under 21000 kg axle loads. An average rebound of 11 mm and irrecoverable displacement of 7 mm were recorded after two passes of load. The elastic modulus of the tire shreds is proportional to the bulk density of the shreds. Non-linear elastic isotropic analysis gives a conservative estimate of the deflection of the tire shred embankments as compared to the linear elastic analysis. The design of road embankments with large-size tire shred layers can be made using the non-linear elastic analysis model presented in this paper. Large size tire shreds can be an economical alternative compared to the small size tire shreds in the construction of the tire shred embankment.

Justo et al (2002) [3], Author have done the research work in the centre lab for transportation engineering of Bangalore university on the possible use of the processed plastic bags as an additive material in bituminous concrete mixes. These properties of the modified bitumen were compared with ordinary bitumen. In the research 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 % by weight. Due to this the life of the pavement surfacing course using the modified bitumen is also expected to increase substantially with comparison to the use.

A. Literature Summary

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. The use of waste plastic and waste rubber tyre in construction of roads brings out a better performance. Since there is better binding of bitumen with plastic and tyre the frequency of voids is also reduced due to increased bonding and area of contact between polymers and bitumen. Addition of waste tyre in rubber aggregate modifies the flexibility of surface layer.

3. METHODOLOGY

For this research work aggregate, bitumen and crumb of scrap tyre was used. Different properties of bitumen and aggregate have been tested. Then prepare different mixes of bitumen and crumb of waste tire rubber with varying proportions by crumb tyre rubber replaces for percentage weight of bitumen taken for test. The feasibility of different mixes of bitumen and crumb tire rubber with varying proportions with aggregate has been tested.

A. Mixing Process

Collection of material: Bitumen, Waste tyre, Aggregate.

Heating/Melting of bitumen: Bitumen and waste tyre rubber are melting at 1200C to 2400C

Mixing: After melting mix waste tyre rubber bitumen and aggregate

Crumb Rubber: The major component of crumb rubber modifier (CRM) is scrap tyre rubber which is primarily natural and synthetic rubber and carbon black. Automobile tyres have more synthetic rubber than truck tyre. Truck tyres contain a higher percentage of nature rubber than automobile tyre. Advances in tyre manufacturing technology have decreased the difference in chemical composition between the types of tyre rubber. The typical bulk CRM produced in today's market is uniform in composition. The average car tyre 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, pigment, etc.

Figure 2: Crumb Rubber

Figure 3: Bitumen mix

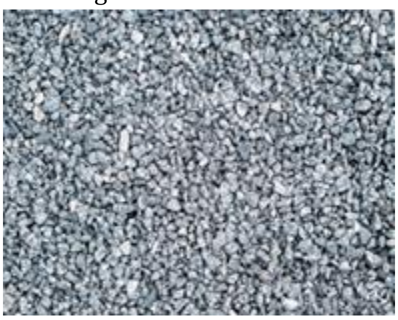

Figure 4: Fine Aggregates

Aggregates: Fine aggregates play a crucial role in bituminous road construction. They are typically sand or crushed stone passing through a 4.75 mm sieve. Their primary functions include:

Filling Voids: Fine aggregates fill the voids in coarse aggregates, ensuring better compaction and reducing air gaps in the mix.

Improving Workability: They enhance the workability of the bituminous mix, making it easier to spread and compact.

Providing Strength & Stability: Properly graded fine aggregates contribute to the overall strength and stability of the pavement.

Enhancing Cohesion: They help in binding bitumen with coarse aggregates, improving the adhesion and durability of the road.

Preventing Bleeding: A well-balanced fine aggregate content prevents excessive bitumen from rising to the surface, which could cause slipperiness.

Affecting Texture & Skid Resistance: They influence the surface texture, affecting skid resistance and ride quality. Proper selection and grading of fine aggregates are essential for the durability and performance of bituminous roads.

4. EXPERIMENTAL STUDIES

In preparing the modified binders, about 500gm 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^{0}C and then crumb rubber was added. For each mixture sample 0%, 5% 9% 13% 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^{0}C and the whole mass was stirred using a mechanical stirrer for about 50 minutes. Care is taken to maintain the temperature between 160^{0}C to 170^{0}C. The contents are gradually stirred for about 55 minutes. The modified bitumen is cooled to room temperature and suitably stored for testing.

Record of Observation: -Actual test temperature =250C

A. Penetration test

Table 1: Penetration Test Result

% of CRMB	Reading	Trial			Average Value in mm
		1	2	3	
5% of CRMB	Initial	0	0	0	69
	final	64	69	75	
Penetration value		64	69	75	
9% of CRMB	Initial	0	0	0	49.33
	final	44	48	56	
Penetration value		44	48	56	
13% 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	

B. Softing Point Test

Table 2: Softing 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
	5% of CRMB	49.1	51.5	50.3
	9% of CRMB	51.4	51.9	51.65
	13% of CRMB	54.1	51.9	54.5
	14% of CRMB	54.2	55.8	55

C. Ductility Test

Table 3: Ductility Test Result

Sr. No	Aggregate Test	Test results obtained
1	Crushing value (%)	24.8
2	Impact value (%)	20.8
3	Los Angeles abrasion value (%)	28

Table 4: Physical properties of Aggregate

	Sample Reading in cm			
% of CRMB	Reading 1	Reading 2	Reading 3	Average
0% of CRMB	71	73	75	73
5% of CRMB	39	40	41	40
9% of CRMB	34	36	36	35
13% of CRMB	27.2	28.1	30.2	28.5
14% of CRMB	23.3	24.6	25.9	24.6

CONCLUSION

1. Penetration value test result shows that Penetration value decrease 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.
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 increases on the road.

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

Conflict Of Interest

The authors declare that they have no conflict of interest.

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