

Rubberized Bituminuos Concrete for Durable Road Infrastructure

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Abstract: *The disposal of waste tyres has emerged as one of the most serious environmental problems across the globe. Every year, millions of tyres are discarded from vehicles and end up in landfills or are burned, causing severe air and soil pollution. Due to their non-biodegradable nature and high volume, waste tyres occupy valuable landfill space and contribute to environmental degradation. Therefore, it has become necessary to find eco-friendly and economically viable methods for utilizing waste rubber effectively.*

In the field of civil engineering, several researchers have explored the incorporation of waste tyre rubber in road construction as a sustainable alternative material. When crumb rubber, obtained from shredding discarded tyres, is blended with bitumen, it modifies the physical and chemical properties of the binder, improving its performance under varying climatic and traffic conditions. The resulting material, known as Crumb Rubber Modified Bitumen (CRMB), has been widely recognized for enhancing flexibility, elasticity, and resistance to cracking, rutting, and aging...

Keywords: waste tyres

I. INTRODUCTION

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The use of CRMB not only improves the performance of pavements but also provides a dual benefit of environmental conservation and cost reduction. Studies carried out in different countries, including India, have demonstrated that the addition of 8–10% crumb rubber by weight of bitumen yields optimum results in terms of durability and strength. Moreover, several field trials and research projects conducted by organizations such as the Central Road Research Institute (CRRI) and the Rubber Research Institute of India (RRII) have shown that rubberized roads possess better resistance to deformation, longer service life, and lower maintenance requirements compared to conventional bituminous roads.

This literature review compiles and discusses significant national and international research work related to the use of waste rubber in road construction. It focuses on the laboratory investigations, field performance studies, and case applications that have contributed to the advancement of rubber-modified pavement technology. The aim is to highlight the technical achievements, identify gaps in the existing research, and establish the foundation for the present study on the performance of rubberized roads such as the Kottayam–Kumily Road in Kerala and the Chennai–Tiruvallur High Road in Tamil Nadu. 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.



SCOPE AND METHODOLOGY

- The study on utilizing waste rubber in construction in road construction aims to explore the feasibility, benefits, and implementation of this technology in sustainable infrastructure development the scope includes.
- Types of Rubber Waste Used The study covers various forms of rubber waste, mainly from used vehicle tires such as shredded rubber, crumb rubber, and rubber granules. These types are chosen for their availability, durability, and compatibility with bituminous binders in road construction.
- Application in Road Construction The research focuses on incorporating rubber waste into flexible pavement construction. Rubber is used as a modifier in bituminous mixes to improve pavement performance and reduce the use of natural resources like bitumen and aggregates.
- Performance Evaluation Performance is measured by testing the mechanical and physical properties of rubber modified bitumen. Laboratory tests such as Marshall Stability, penetration test, ductility test, and softening point are conducted to analyze strength, flexibility, and resistance to cracks.
- Environmental and Economic Aspects The study assesses how rubber waste recycling in roads helps reduce pollution and manage non-biodegradable waste. It also examines cost savings over time through reduced maintenance and the decreased need for new materials, supporting green and cost-efficient infrastructure.
- Challenges and Future Prospects This part identifies challenges such as mixing issues, standardization gaps, and public awareness. The study also explores future improvements in rubber processing, advanced mix designs, and policy support for large-scale implementation in road infrastructure.

				
63%	13%	23%		1%
Waste disposal (leaching of toxic organic compounds through contact with water)	Combustion and pyrolysis (release of large amounts of toxic substances and carbon dioxide into the atmosphere; enhancement of the greenhouse effect)	Shredding (crumb rubber is widely used in the fields of industry and construction)		Tire retreading (retreading of expensive truck and specialty tires)

II. MATERIALS AND METHODOLOGY

Types of Waste Rubber Used

1. Crumb Rubber

Made by grinding tyres into fine particles (0.5–2 mm) and mixed with bitumen. Improves road flexibility, reduces cracks, and increases durability.

Eco-friendly as it helps recycle waste tyres.

2. Shredded Rubber

Consists of large tyre pieces (10–50 mm) used in base layers. Provides good drainage, elasticity, and shock absorption. Reduces road noise and extends pavement life.

3. Ground Rubber

Finely processed rubber (0.5–1 mm) added to bitumen. Improves strength, skid resistance, and smoothness of roads. Reduces maintenance costs and surface wear.

4. Devulcanized Rubber



Chemically treated rubber that blends easily with bitumen. Enhances flexibility, temperature resistance, and bonding. Environment-friendly and improves road performance.

Collection and Processing of Waste Rubber

1. Collection of Waste Rubber

The process begins with the collection of used and discarded tyres from various sources such as vehicle service centre, garages, tyre shops, and municipal waste dumps. These waste tyres are gathered because they are difficult to decompose naturally and can cause environmental pollution if left unattended. Before sending them for processing, the tyres are inspected and sorted to remove any non-rubber materials like mud, stones, or metal rims. This ensures that only reusable rubber is sent for further stages of processing.



2. Sorting and Cleaning

After collection, the tyres are cleaned thoroughly to remove dirt, grease, and other contaminants. The tyres are then sorted according to their type, size, and condition. Removing unnecessary materials like steel belts, fabrics, and nylon is important as these can affect the quality of rubber used in road construction. The cleaning process helps in producing high-quality crumb or ground rubber that can mix well with bitumen.

3. Shredding of Tyres

In this step, the cleaned tyres are cut into smaller pieces using a shredding machine. These machines can reduce large tyres into manageable rubber chips of about 10–50 mm in diameter. Shredded rubber is easier to handle and transport, and it forms the base material for further grinding. This stage also helps in separating steel and textile materials using magnets and air separators.



4. Grinding or Crumbing Process

The shredded rubber is then passed through grinding machines where it is converted into fine particles known as crumb rubber or ground rubber. The particle size usually ranges from 0.5 mm to 2 mm depending on the application. Crumb rubber is commonly used for modifying bitumen in flexible pavements, while slightly larger pieces may be used in the base layers of the road. This process increases the surface area of the rubber, allowing it to mix uniformly with bitumen and improve the road's strength and elasticity.

5. Devulcanization (Chemical Treatment)

In some cases, the rubber is chemically treated through a process called devulcanization. This process breaks down the sulphur bonds formed during tyre manufacturing, making the rubber soft and flexible again. Devulcanized rubber can blend more easily with bitumen and improves the bonding between the rubber and asphalt. It also enhances the temperature resistance and flexibility of the final road mixture.



6. Quality Testing and Grading

The processed rubber is tested for quality parameters such as particle size, cleanliness, and moisture content. High-quality rubber ensures better road performance and longer pavement life. Once the material meets the required standards, it is graded and packed for storage.

7. Storage and Transportation

Finally, the processed rubber is stored in clean, dry areas to prevent contamination and moisture absorption. It is then transported to asphalt mixing plants or construction sites where it is mixed with bitumen or used in different road layers. Proper storage and handling are essential to maintain the quality of the rubber until it is used.

Methods of Rubber Incorporation in Roads

Wet Process

Definition In the wet process, crumb rubber is blended with hot bitumen before mixing it with aggregates.

This process modifies the bitumen itself — producing what is called Crumb Rubber Modified Bitumen (CRMB) or Asphalt Rubber (AR).

Procedure

Step 1. Heating of Bitumen

Bitumen is heated to 170°C – 180°C in a blending tank to reduce viscosity. Ensure temperature control (avoid overheating >190°C, as it may degrade rubber).



Step 2. Addition of Crumb Rubber

Add 5%–15% crumb rubber by weight of bitumen. Crumb rubber size 0.425 to 2.36 mm.

Step 3. Blending / Mixing

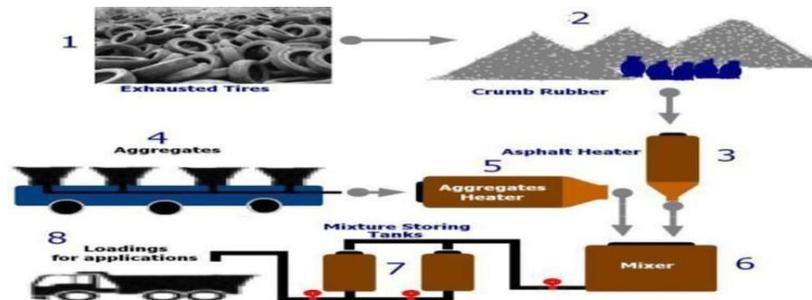
Use a high-shear mechanical mixer or paddle-type agitator. Maintain temperature $175^{\circ}\text{C} \pm 5^{\circ}\text{C}$ and stir for 45–60 minutes continuously. During this time, rubber particles swell by absorbing light oils from bitumen, forming a gel-like structure.

Step 4. Storage / Settling

After mixing, CRMB is kept in an agitated storage tank at $160\text{--}170^{\circ}\text{C}$ for up to 8 hours to maintain uniformity.

Step 5. Usage in Mix

The prepared CRMB is then mixed with hot aggregates in a Hot Mix Plant (HMP). The mixture is laid and compacted like conventional bituminous mix.



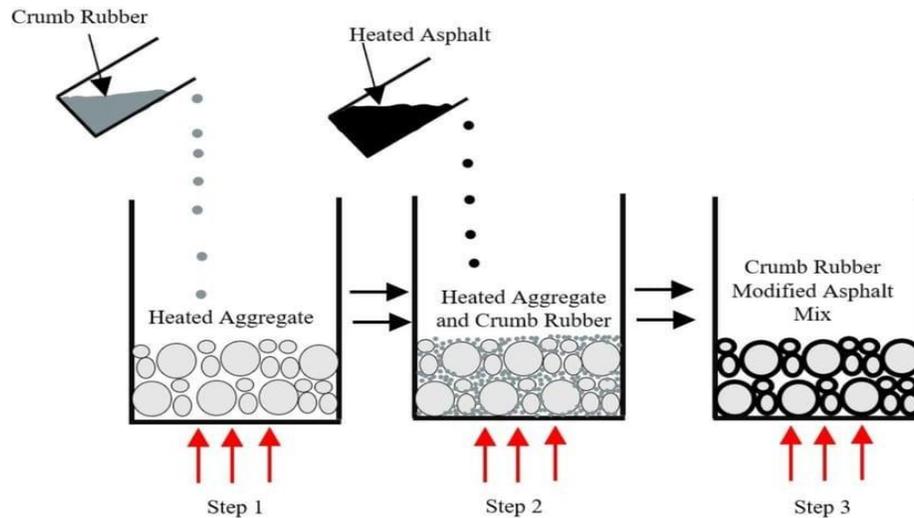
2. Dry Process

Definition In the dry process, crumb rubber is added directly into the hot aggregates before bitumen is introduced. Here, rubber acts as a partial substitute for mineral filler or fine aggregate, rather than modifying the bitumen.

Procedure

1. Heating of Aggregates Coarse and fine aggregates are heated to $160^{\circ}\text{C} - 170^{\circ}\text{C}$ in the dryer drum.
2. Addition of Crumb Rubber Crumb rubber (1–3% by weight of total mix) is added to the hot aggregates in the mixing chamber. Mix thoroughly for 30–45 seconds for uniform distribution.
3. Addition of Bitumen Hot bitumen ($160^{\circ}\text{C} - 170^{\circ}\text{C}$) is then added and mixed for 30–40 seconds to coat the aggregate–rubber mix.
4. Laying and Compaction The mix is transported, laid with a paver, and compacted at $130 - 140^{\circ}\text{C}$.





3. Hybrid Process

Definition The Hybrid Process combines the advantages of both wet and dry methods.

In this method, a portion of crumb rubber is mixed with bitumen (like wet process), and the remaining portion is added with aggregates (like dry process).

Procedure

1. Bitumen Modification (Wet Part) About 50–60% of total crumb rubber is blended with hot bitumen at 175°C using a high-shear mixer. Blending time 30–45 minutes. This creates partially modified bitumen with good elasticity.
2. Addition with Aggregates (Dry Part) The remaining 40–50% of crumb rubber is added directly to hot aggregates (160°C–170°C). Mix thoroughly before adding the modified bitumen.
3. Final Mixing Combine both in the mixing chamber. Mix for about 60 seconds for full coating.
4. Laying Lay and compact the mix at normal temperatures (130–140°C).

III. CASE STUDY

CASE STUDY 1

Kottayam Kumily – Road

The Kottayam–Kumily Road, better known as K K Road is the state highway connecting Kottayam and Idukki districts of Kerala state, India.[1] It is designated as State Highway 13 (SH 13) by the Kerala Public Works Department.[2] It shares its route with National Highway 183 (NH 183), and it is 107.9 kilometres (67.0 mi) long.[3] It is the first rubberised road in Kerala. Its Oldest and first name is Cardamom hill road.

Route Description Kottayam–Kumily Road (SH-13, “KK Road”) is an important state highway linking Kottayam and Kumily across plains and high ranges. This capstone investigates the performance, cost-effectiveness and environmental benefits of using crumb-rubber modified bitumen (CRMB) on selected stretches of KK Road.

Importance KK Road is a strategic state highway with hilly terrain, high rainfall and tourist/heavy-vehicle traffic — areas where improved surfacing pays off. Rubberized bitumen has historic and recent evidence of improving flexibility, rutting resistance and service life; it also uses waste tyres (sustainability benefit).

Kerala has policy/interest in rubber use for roads — local supply of natural rubber and crumb rubber helps create circular economy benefits.



- Details Type of pavement Flexible pavement (bituminous).
- Length About 110 km.
- Route Connects Kottayam (plains) to Kumily (high ranges, near Thekkady).
- Terrain Plain to hilly, with several hair-pin bends.
- Agency Maintained by Kerala PWD.

Use Of Rubber in construction Pilot stretches on this highway were laid using rubber-modified bitumen under Kerala PWD's eco-friendly initiative.

The aim was to improve flexibility, resistance to rutting/cracking, and durability under heavy rainfall and hill-traffic conditions.

The project also promoted sustainable disposal of waste tyres by blending crumb rubber into bitumen.

Observations During the study of the Kottayam–Kumily Road (SH-13), it was observed that the sections constructed using rubber-modified bitumen showed better surface performance compared to conventional bituminous stretches. The road exhibited improved flexibility, reduced cracking, and greater resistance to rutting and pothole formation, even under the region's heavy rainfall and steep gradients. The skid resistance on sharp curves and slopes was also noticeably higher. Although the initial construction cost was slightly more than ordinary bitumen roads, the maintenance frequency and cost were significantly lower. These observations indicate that the use of waste tyre rubber in road construction enhances durability and sustainability, making it a practical solution for flexible pavements in hilly and high-rainfall regions like KK Road.

Problems Identified

1. Frequent Surface Damage Due to the hilly terrain and high rainfall, the road experiences pothole formation, rutting, and stripping of bituminous layers, especially during monsoon seasons.
2. Drainage Issues Inadequate side drains and blocked culverts cause water stagnation on the pavement surface, leading to moisture damage and reduced service life.
3. Landslides and Slope Failures Several road stretches pass through unstable hill slopes, making them vulnerable to minor landslides and soil erosion during heavy rains.
4. High Maintenance Requirement Continuous repair and overlay works are required due to heavy traffic from lorries and tourist buses, increasing the maintenance cost.
5. Environmental Concerns Disposal of waste tyres and other non-degradable materials from nearby areas remains an issue; however, their potential use in rubberized bitumen could mitigate this problem.
6. Temperature Variations The road experiences thermal cracking in some upper stretches due to temperature differences between plains and high ranges.

Recommendations

1. Use of Rubber-Modified Bitumen It is recommended to adopt crumb rubber–modified bitumen (CRMB) for flexible pavement layers. This will improve the elasticity, durability, and resistance to cracking and rutting, especially under heavy traffic and high rainfall.
2. Proper Drainage Design Adequate side drains, cross-drainage structures, and shoulder drains should be provided to prevent water stagnation and moisture damage to the pavement layers.
3. Regular Maintenance Schedule A preventive maintenance plan should be implemented, including periodic inspections, pothole patching, and seal-coating before monsoon seasons.
4. Slope Protection Measures Construction of retaining walls, breast walls, and proper slope vegetation is essential to minimize landslides and erosion along the hilly stretches.
5. Quality Control During Construction Strict supervision of material quality, compaction, and temperature control during laying and rolling of bituminous layers should be ensured to achieve uniform strength.



6. Use of Waste Tyres for Sustainability Encourage the utilization of locally available waste tyres in road construction to reduce environmental pollution and promote sustainable infrastructure practices.
7. Performance Monitoring Regular performance evaluation of rubberized sections (through deflection tests, visual surveys, and rut depth measurements) should be carried out to assess long- term effectiveness

