Identifying common failures in pavements and sustainable solutions using plastic waste

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ABSTRACT

Flexible pavements play a vital role in transportation infrastructure; however, they are prone to various types of failures due to increasing traffic loads, environmental effects, poor drainage, and inadequate construction practices. Common pavement failures such as rutting, cracking, potholes, raveling, and fatigue cracking reduce service life and increase maintenance costs. At the same time, the rapid growth of plastic waste has become a serious environmental concern, causing land pollution and disposal problems. This project focuses on identifying common failures in pavements and proposes a sustainable solution through the utilization of waste plastic in road construction.

The study involves a detailed review of typical pavement failures, their causes, and conventional repair methods. The project further investigates the use of waste plastic as a partial replacement in bituminous mixes to improve pavement performance. Waste plastic, when blended with bitumen, enhances binding properties, increases strength, improves resistance to moisture damage, and reduces deformation under heavy loads. Laboratory studies and findings from previous research indicate that plastic-modified bitumen exhibits better durability and stability compared to conventional bituminous mixes.

The use of plastic waste in pavements not only improves road performance but also provides an eco-friendly method for plastic waste management. This sustainable approach helps in reducing environmental pollution, conserving natural resources, and lowering construction and maintenance costs. The project concludes that incorporating waste plastic in pavement construction is an effective and economical solution for minimizing pavement failures while promoting sustainable infrastructure development.

1. INTRODUCTION

1.1 Pavements

A pavement is an engineered structure consisting of a series of layers constructed above the natural ground surface, designed to distribute vehicular loads safely to the subgrade and provide a smooth, durable, and safe riding surface for traffic.

1.2 Features of pavements:

A pavement is a layered structural system constructed over natural soil (subgrade) to provide a smooth, durable, and safe riding surface for vehicles.

1. Load Distribution

- Pavements distribute wheel loads from vehicles to the subgrade.
- This prevents excessive stress and failure of soil.
- Load transfer occurs through different pavement layers.

2. Smooth Riding Surface

- Provides comfort to road users.
- Reduces vehicle vibration and operating cost.
- Improves travel speed and safety.

3. Structural Strength

- Pavements are designed to withstand repeated traffic loads.
- They resist:
  - Fatigue cracking
  - Rutting
  - Shear failure

4. Durability

- Pavements are designed for a specified design life (e.g., 15–30 years).
- Should resist:
  - Weather effects
  - Traffic wear
  - Temperature variations

5. Skid Resistance

- Surface texture provides adequate friction.
- Prevents skidding, especially during wet conditions.
- Important for curves, intersections, and braking zones.

6. Drainage Property

- Good pavements allow quick drainage of water.
- Prevents:

- Weakening of subgrade
- Potholes and cracks
- Drainage is provided by surface slope and subsurface layers.

7. Weather Resistance

- Pavements resist damage due to:
- Rainfall
- Temperature changes
- Sunlight (UV radiation in bituminous pavements)

8. Economy

- Designed to be cost-effective considering:
- Initial construction cost
- Maintenance cost
- Life-cycle cost

9. Ease of Maintenance

- Pavements should allow easy repair and maintenance.
- Bituminous pavements are easier to repair than rigid pavements.

10. Safety

- Provides:
- Proper visibility (surface color and reflectivity)
- Skid resistance
- Stable riding surface

1. Flexible Pavement

- Constructed using bituminous materials.
- Load is transferred through grain-to-grain contact.
- Has low flexural strength.
- Deforms slightly under load.

Layers:

- Surface course
- Base courses

- Sub-base courses
- Subgrade

Examples:

- Bituminous roads
- Asphalt concrete roads

Advantages:

- Low initial cost
- Easy to repair
- Short construction time

Disadvantages:

- Higher maintenance
- Shorter life

2. Rigid Pavement

- Constructed using cement concrete.
- Load is distributed by slab action.
- Has high flexural strength.
- Very less deformation.

Types:

- Jointed plain concrete pavement (JPCP)
- Jointed reinforced concrete pavement (JRCP)
- Continuously reinforced concrete pavement (CRCP)

Advantages:

- Long life
- Low maintenance
- High load-carrying capacity

Disadvantages:

- High initial cost
- Requires skilled construction

3. Semi-Rigid Pavement

- Uses cement-treated or lime-treated layers.
- Behaviour lies between flexible and rigid pavements.
- Better load distribution than flexible pavement.

Examples:

- Soil-cement roads
- Cement-treated base roads

4. Composite Pavement

- Combination of flexible and rigid pavements.
- Usually concrete base with bituminous surface.

Purpose:

- Combines strength of rigid pavement
- Smooth riding surface of flexible pavement

Example:

- Bituminous overlay on concrete pavements

Simple Classification (Exam-Friendly)

Type	**Material Used**	**Load Transfer**
Flexible	Bitumen	Layer action
Rigid	Cement concrete	Slab action
Semi-rigid	Treated soil	Partial slab action
Composite	Concrete + Bitumen	Combined action

1.1 Failures in pavements

Cracking

Fatigue cracking sometimes called alligator or crocodile cracking—is a common type of damage in flexible pavements. It shows up as a network of connected cracks, usually in the wheel paths, and happens because of repeated traffic loading over time. When the pavement isn't thick enough to handle the weight and volume of vehicles, tiny cracks start to form and eventually join together, creating this distinctive pattern.

- Longitudinal Cracks: These run along the direction of traffic and are often caused by poor joint construction or weak bonding between layers.

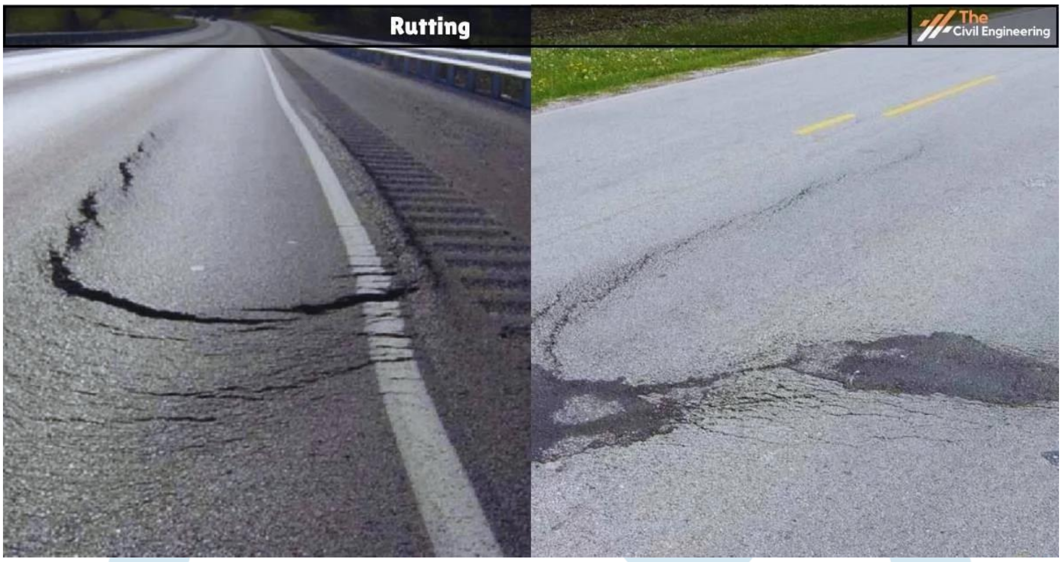
- Transverse Cracks: These run across the road, perpendicular to traffic flow, and are usually linked to

temperature changes causing the pavement to expand and contract.

- Alligator Cracks: These interconnected cracks look like a crocodile's skin and indicate serious structural failure due to repeated stress from traffic.

Rutting

Rutting refers to the permanent deformation or depressions in the wheel paths of a flexible pavement. This type of failure often results from consolidation or lateral movement of the asphalt or subgrade layers. Rutting is dangerous because it can lead to water accumulation, which increases the risk of hydroplaning for vehicles. It typically indicates that the pavement structure lacks adequate stiffness or that there is poor drainage beneath the surface.



Potholes

Rigid pavements, primarily constructed of concrete, often suffer from failures such as pumping and faulting. Pumping occurs when water and fine materials are ejected from beneath the slab through joints or cracks due to heavy wheel loads. Faulting refers to vertical displacement at joints or cracks, where one slab becomes higher than the adjacent one. Both issues are signs of structural failure in the sub-base or subgrade.

Surface Wear

Functional failures do not necessarily indicate a weakness in the load-bearing capacity of the pavement but can still affect the safety, comfort, and performance of the roadway. These types of failures often occur due to environmental factors, poor surface maintenance, or aging.

- Ravelling: Loss of aggregate particles from the surface. Indicates aging or poor mix.
- Polishing: Smooth, slippery surfaces formed due to traffic polishing aggregates, reducing skid resistance.

(i)

(ii)

Figure Q1(c): Pavement Distress

Edge Breaks and Depressions

Thermal cracks develop due to temperature variations, especially in areas with hot days and cold nights. In asphalt pavements, these are usually transverse cracks running across the lane. They are more prevalent in climates with extreme seasonal or daily temperature changes. Usually occur on narrow or poorly drained roads. Heavy loads near road edges can cause them to break away.

2. LITERATURE REVIEW

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Studies on Pavement Failures

- **Journal of Chemical Health Risks**

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On, A Review on Design of Flexible Pavement Using Waste Plastic

The extensive use of plastic wrappers for items like betel nuts, chocolates, chips, handbags, and cold drink bottles presents significant environmental and economic challenges. The production and disposal of these wrappers consume substantial energy and resources, contributing to environmental harm. While industries favor plastic for its lightweight, inexpensive, and sturdy qualities, a potential shift to alternative materials like paper and wood may worsen environmental issues. Polyethylene, Polystyrene, and Polypropylene, the main components of plastic, resist easy decomposition in the environment. This study emphasizes the importance of utilizing plastic in construction processes, particularly through the heating and coating of plastics on aggregates at 160 ℃, minimizing air gaps and enhancing stability. Proper disposal of non-biodegradable plastic remains challenging due to insufficient landfills. Research suggests that incorporating waste plastics into road construction materials results in stronger, more damage-resistant, and cost-effective roads. In India, roads adhere to specific guidelines with bituminous concrete layers over a granular base, utilizing Bitumen Grade VG-30 and specific aggregate sizes. The addition of polymers to road materials offers advantages such as increased longevity, damage resistance, cost-effectiveness, reduce maintenance, effective insulation, and diminished noise pollution, contributing to a sustainable construction approach.

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On,

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Review Paper on Sustainable Pothole Repair Using Plastic Waste in Bituminous Mixes

The road infrastructure in India, vital to its economic development, is severely impacted by the recurring issue of potholes, which disrupt traffic, damage vehicles, and pose safety risks, especially during the monsoon season. At the same time, the country faces a growing environmental challenge with millions of tons of non-biodegradable plastic waste produced annually. This study presents a novel, sustainable solution to pothole repair by integrating shredded plastic waste into VG-30 bitumen. Experimental results show that a 9% plastic waste addition optimally enhances mechanical properties such as Marshall Stability, flow while preserving the workability of the material. This innovative method not only provides a cost-effective and durable solution for pothole repair but also aligns with the principles of a circular economy by repurposing plastic waste. The paper offers practical recommendations for scaling this solution, with particular relevance for developing nations like India. Keywords: Pothole Repair, Plastic Waste, Bitumen Modification, Sustainable Pavement, VG-30 Bitumen, Marshall Stability, Economy, Environmental Sustainability.

➢ **TechBrief**

This Tech Brief summarizes guidance to the pavement community on sustainability considerations for asphalt pavement systems, as presented in greater detail in the recently published Towards Sustainable Pavement Systems: A Reference Document (FHWA 2015b). Sustainability considerations throughout the entire pavement life cycle are examined (from material extraction and processing through the design, construction, use, maintenance/rehabilitation, and end-of-life phases) and the importance of recognizing context sensitivity and assessing trade-offs in developing sustainable solutions is emphasized.

This Tech Brief focuses exclusively on sustainability considerations associated with asphalt-surfaced pavement structures and the materials used in their construction. For the purposes of this document, all permanent surfaces constructed with asphalt concrete are generically referred to as “asphalt” pavements.

The primary audience for this document is practitioners doing work within and for government transportation agencies, and it is intended for designers, maintenance, material and construction engineers, inspectors, and planners who are responsible for the design, construction and preservation of the nation’s highway network.

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On,

Recycling Waste Plastics In Pavement Engineering: Advances, Performance Enhancement, And Circular Economy Perspectives

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Global accumulation of plastic waste has surpassed 400 million tons within a single year and only 9% of it is recycled which causes huge challenges to the environment and resources. One of the sustainable and scalable solutions to efficiently manage plastic waste is Avenue to Pavement. The most recent advancements and their recycling techniques are summarized in this review with special focus to aggregate, fiber, and filler usage in concrete, as well as dry and wet asphalt processes. The asphalt industry benefits from the addition of recycled plastic as it decreases the use of virgin plastics and improves the rutting resistance, fatigue life, moisture sustainability, and ageing durability. The addition of plastics to concrete lowers the density, enhances ductility, improves impact resistance and counteracts strength reduction through surface modification and hybrid composites. Recycled plastics geosynthetics, modular systems, and insulation framework offer long-lasting low-maintenance solutions. Issues pertaining to contamination, incompatible polymers, waste streams, microplastes the absence of diverse regulations can be addressed through stringent feedstock requirements advanced compatibilization, and performance-based regulations. Plastic-modified pavements can outperform the conventional systems economically and environmentally if processing is optimized and under supportive policy frameworks, according to lifecycle and economic assessments. The results generally confirm that recycled plastic integrated into pavement infrastructure is a high-performing financially feasible solution consistent with the objectives of the circular economy and global climate.

3. METHODOLOGY AND MATERIALS

Materials Used

- **Bitumen**

Bitumen is used as the binding material in flexible pavements. In this study, conventional paving grade bitumen is considered for analysis. Bitumen possesses good adhesive and waterproofing properties, which help in binding aggregates together. The properties of bitumen such as penetration value, softening point, and ductility play an important role in pavement performance.

- **Aggregates**

Aggregates form the majr portion of bituminous mixes and contribute to strength and load- bearing capacity. Coarse aggregates and fine aggregates are considered in this study. Aggregates should be clean, hard, durable, and free from dust and organic matter. roperties such as crushing value, impact value, abrasion value, and water absorption influence pavement behaviour.

- **Plastic Waste**

Waste plastic is used as a modifier in bituminous pavement construction. Commonly available plastic wastes such as carry bags, packaging materials, and bottles are considered. These plastics are non-biodegradable in nature and create environmental problems if not properly disposed. The plastic waste is cleaned, dried, and shredded into small pieces before use in pavement construction.

- **Filler Material**

Mineral filler such as stone dust or cement is used to fill the voids in the bituminous mix. The filler improves the density and stability of the mix and enhances bonding between aggregates and bitumen.

Methodology Adopted

Identification of Common Pavement Failures

A review of literature and field observations are used to identify common pavement failures in flexible pavements. Pavement distresses such as cracking, rutting, potholes, ravelling, and bleeding are studied along with their causes and effects on pavement performance.

Collection and Processing of Plastic Waste

Plastic waste is collected from local sources such as households and commercial areas. The collected plastic is sorted to remove impurities and then washed to remove dirt and dust. After drying, the plastic is shredded into small pieces of size ranging from 2 mm to 4 mm for effective mixing with aggregates.

Preparation of Plastic-Modified Aggregates

The dry process method is adopted for incorporating plastic waste. In this method, aggregates are heated to a temperature of about 160–170°C. The shredded plastic is then added to the hot aggregates, allowing the plastic to melt and coat the aggregate surface uniformly. This improves the binding property and moisture resistance of the aggregates.

Preparation of Bituminous Mix

After coating aggregates with plastic waste, hot bitumen is added to the plastic-coated aggregates and mixed thoroughly to obtain a uniform bituminous mix. The mix is prepared at a controlled temperature to ensure proper coating and workability.

Laboratory Testing of Bituminous Mix

Standard laboratory tests are conducted to evaluate the performance of the plastic-modified bituminous mix. Tests such as Marshall stability test are used to determine strength and stability characteristics. The results of plastic-modified mixes are compared with conventional bituminous mixes to study improvements in pavement performance.

Analysis and Comparison

The test results obtained from laboratory investigations are analysed and compared. The effect of plastic waste on stability, flow value, and overall performance of the pavement is evaluated. Based on the comparison, the effectiveness of plastic waste as a sustainable solution to pavement failures is assessed.

4. Methods of Identifying the failures

Visual Inspection Method

Visual inspection is the simplest and most widely used method to identify pavement failures. In this method, the pavement surface is carefully observed to detect visible defects such as cracks, potholes, rutting, raveling, bleeding, and surface deformation. The location, type, and severity of distress are recorded. This method helps in quick assessment of pavement condition and is often used during routine maintenance surveys.

Pavement Condition Survey

A pavement condition survey involves systematic data collection on pavement surface distress. The pavement is divided into sections, and each section is evaluated based on distress type, extent, and severity. Ratings or condition indices are assigned to assess overall pavement performance. This method provides quantitative information and helps in prioritizing maintenance and rehabilitation works.

Deflection Measurement Method

Deflection measurement is used to evaluate the structural condition of pavements. In this method, pavement surface deflection under wheel load is measured using devices such as Benkelman Beam. Excessive deflection indicates weak pavement layers or poor subgrade support. This method is useful for identifying structural failures like fatigue cracking and rutting.

Roughness Measurement

Surface roughness indicates ride quality and comfort. Roughness is measured using instruments such as bump integrators or roughness meters. High roughness values indicate surface irregularities caused by failures such as potholes, settlements, and uneven deformation. This method helps in assessing serviceability of the pavement.

PSR.	Road Quality	IRI m/km or Mm/m
Less than1	V. poor	More than6
1 - 2	Poor	6- 3,5
2 - 3	Fair	3,5 - 2
3 - 4	Good	2 - 0.9
4 - 5	V. good	0,9 to 0

Skid Resistance Test

Skid resistance tests are conducted to assess pavement surface friction, especially under wet conditions. Poor skid resistance indicates surface polishing, bleeding, or presence of loose materials. This method helps in identifying safety-related pavement failures and the need for surface treatment.

Core Cutting and Sampling

In this method, pavement cores are extracted from the road surface for laboratory examination. The thickness of pavement layers, material condition, and presence of voids or moisture damage are studied. Core cutting helps in identifying construction defects, layer failure, and stripping of bitumen.

Subgrade Evaluation

Subgrade condition plays a major role in pavement performance. Field tests such as California Bearing Ratio (CBR) test are conducted to evaluate subgrade strength. Weak subgrade leads to rutting, cracking, and overall pavement failure. This method helps in identifying the root cause of structural distress.

Drainage Condition Assessment

Drainage assessment is carried out to check surface and subsurface drainage conditions. Blocked side drains, water stagnation, and seepage indicate poor drainage. Improper drainage accelerates pavement deterioration and leads to failures such as potholes and stripping.

Traffic Volume and Load Study

Traffic studies are conducted to analyze traffic volume, axle loads, and vehicle composition. Overloading and increased traffic repetitions contribute to premature pavement failure. This method helps in correlating pavement distress with traffic loading conditions.

Laboratory Testing of Material

Laboratory tests are conducted on pavement materials to assess their quality and suitability. Tests on bitumen and aggregates help identify material-related failures such as poor bonding, excessive deformation, and moisture damage.

5. SOLUTIONS OF THE PAVEMENT FAILURES

Cracking (Alligator, Longitudinal and Transverse Cracks)

Cracks in pavements are mainly caused by traffic loads, temperature variations, aging of bitumen, and poor construction practices.

Repair Solution:

- The damaged surface is cleaned and cracks are sealed using hot bitumen.
- Waste plastic is shredded into small pieces (2–4 mm size).
- The shredded plastic is coated over hot aggregates before mixing with bitumen (dry process).
- Plastic-modified bitumen improves flexibility and reduces crack propagation.

Benefits:

- Increased binding strength
- Reduced water penetration
- Enhanced fatigue resistance

Potholes

Potholes occur due to water infiltration, weak subgrade, and repeated traffic loads.

Repair Solution:

- Loose and damaged materials are removed from the pothole.
- The surface is dried and cleaned.
- A plastic-modified bituminous mix is prepared and placed in the pothole.
- Proper compaction is carried out to restore the pavement surface.

Benefits:

- Improved resistance to moisture damage
- Longer-lasting repair
- Reduced recurrence of potholes

Rutting

Rutting is the permanent deformation of pavement layers caused by heavy axle loads and weak pavement materials.

Repair Solution:

- The rut-affected layer is milled and removed.
- Plastic-coated aggregates are used in the resurfacing layer.
- Plastic increases stiffness and load-bearing capacity of the pavement.

Benefits:

- Better resistance to deformation
- Improved load distribution
- Increased pavement life

Ravelling

Ravelling occurs due to loss of aggregate particles caused by poor bonding between bitumen and aggregates.

Repair Solution:

- The affected surface is cleaned thoroughly.
- Plastic-modified bitumen is applied as a wearing course.
- The improved adhesion between plastic, bitumen, and aggregates reduces aggregate loss.

Benefits:

- Stronger aggregate binding
- Reduced surface wear
- Improved riding quality

Bleeding

Bleeding is caused by excess bitumen on the pavement surface, especially in hot weather.

Repair Solution:

- Excess bitumen is removed from the surface.
- Plastic-modified bitumen is used in the resurfacing layer to control bitumen flow.
- Proper mix design is ensured to avoid excess binder content.

Benefits:

- Better temperature resistance
- Reduced surface slipperiness
- Improved skid resistance

Use of Plastic Waste in Pavement Repair (Dry Process)

The dry process is the most commonly adopted method for incorporating plastic waste in road construction as per IRC SP:98–2013.

Steps Involved:

1. Collection and segregation of waste plastic.
2. Shredding plastic into small pieces.
3. Heating aggregates to 160–170°C.
4. Coating shredded plastic over hot aggregates.
5. Mixing plastic-coated aggregates with hot bitumen.
6. Laying and compacting the mix on the pavement surface.

Advantages of Using Plastic Waste in Pavement Repair

- Improves strength and durability of pavements
- Reduces common pavement failures
- Provides effective utilization of waste plastic
- Cost-effective and eco-friendly solution
- Enhances resistance to water and temperature variations

Limitations

- Proper segregation of plastic is required
- Skilled supervision during mixing is necessary
- Not suitable for plastics with toxic emissions (e.g., PVC)

6. SOURCE OF PLASTIC WASTE

- Presently global production of plastic is about 360 million tonnes.
- Average worldwide utilization of plastic is 45 kg/person.
- Many plastics are discarded after a very short lifecycle (e.g., single use), which causes colossal waste accumulation and critical environmental concerns. Approximately 3% of each year's plastic waste ends up in the sea, harming the environment and wildlife
- Safe disposal of waste plastic is a serious environmental problem.
- Plastic is a non-biodegradable material which can last as long as 4,000 years.
- If dumped in landfills, it can find its way back to the environment through air and water erosion, can choke the drains and drainage channels, can be eaten by grazing animals causing them illness and death and can contaminate the construction fill.
- Further, dumping on open land will result in wasteful use of scares land resource.
- Land pollution and disposal of waste plastic challenge can reduce significantly if this materials are utilized in road construction.

Thermoplastic as a Waste Plastic	Origin	Yes/No
Low-Density Polyethylene (LDPE)	Carry bags, Sacks, Milk pouches, bin lining, cosmetic and detergent bottles	Shall be used
High Density Polyethylene (HDPE)	Carry bags, bottle caps, house hold articles etc.,	Shall be used
Polyethylene Terephthalate (PET)	Drinking Water Bottles etc.,	Shall be not used
Polypropylene (PP)	Bottle Caps and Closures, Wrappers of detergent, biscuit wrappers, microwave trays for readymade meal etc.,	Shall be not used

Polystyrene (PS)	Yoghurt pots, clear egg packs, bottle caps, foamed polystyrene, food trays, egg boxes, disposable cups, protective packaging etc.,	Shall be not used
Polyvinyl Chloride (PVC)	Mineral Water bottles, credit cards, toys, pipes and gutters; electrical fittings, furniture, folders and pens, medical disposables etc.	Shall be not used

Waste Plastic Applications in Road *Construction*

- First plastic was constructed in Chennai in 2002 from shredded waste plastic.
- In Tamil Nadu, the length of roads around 1,000 km on various stretches were constructed using waste plastic under the scheme "1000 km plastic road". The performance of all these roads stretches is satisfactory.
- The performance of more than 2,000 km roads constructed with waste plastic in Bangalore found to be satisfactory.
- In Delhi, a number of test sections about 50 km were constructed using waste plastic which are performing well.
- MoRTH sponsored research scheme on the use of waste plastics in SDBC mix made on test track on NH 207 reported excellent performance of waste plastic in bituminous mixes.

Waste Plastic Applications in Road Construction

- Rural road programme (PMGSY) has completed more than 13,000 km of plastic roads. The performance of these roads has been rated as excellent.
- In order to encourage the use of plastic waste, Ministry of Road Transport & Highways decided that bituminous mix with plastic waste shall be the default mode for periodic renewal of highways falling within the 50 km periphery of

an urban area, having population of more than 500 thousand.

- MoRTH, NHAI and NHIDCL have set targets for completing about 300 km length of National Highways using waste plastics in the current financial year 2020-21.

Mechanism of Plastic Waste in Pavements

When waste plastic is introduced into bituminous mixes, it melts and forms a thin coating over the surface of aggregates. This plastic coating fills micro-voids and enhances the bonding between aggregates and bitumen. The presence of plastic reduces air voids and permeability of the pavement layer, thereby minimizing moisture damage and stripping. Plastic also improves the stiffness and elasticity of the bituminous mix, resulting in enhanced resistance to deformation and cracking.

Method of Using Plastic Waste in Pavements

The **dry process** is the most widely adopted method for using plastic waste in pavements and is recommended by IRC SP:98–2013.

In this process, waste plastic is shredded into small pieces of size 2–4 mm. Aggregates are heated to a temperature of about 160–170°C. The shredded plastic is then added to the hot aggregates, where it melts and coats the aggregate surface uniformly. Hot bitumen is then added to the plastic-coated aggregates and mixed thoroughly. The prepared plastic-modified bituminous mix is laid and compacted on the pavement surface.

Role of Plastic Waste as a Pavement Repair Solution

Plastic waste improves pavement performance in the following ways:

- Acts as an additional binding material
- Improves adhesion between bitumen and aggregates
- Reduces moisture penetration into pavement layers
- Enhances resistance to temperature variations

As a result, pavements constructed or repaired using plastic waste show reduced cracking, improved resistance to pothole formation, and better load-carrying capacity.

1. Cracking Repair

Cracks develop due to fatigue, thermal stresses, and bitumen aging.

Role of Plastic Waste:

Plastic-modified mixes exhibit improved flexibility and elasticity. Plastic reduces brittleness of bitumen, allowing the pavement to accommodate repeated traffic loads and thermal movements without cracking. In repair works, plastic-modified overlays delay crack propagation and improve fatigue life.

Result:

- Reduced crack width and frequency
- Improved resistance to temperature-induced stresses

2. Pothole Repair

Potholes form due to water infiltration, loss of binding, and weak pavement layers.

Role of Plastic Waste:

Plastic is hydrophobic in nature and resists water penetration. When used in pothole repair, plastic-modified mixes reduce moisture damage and stripping of aggregates. The improved binding strength prevents loosening of aggregates under traffic loads.

Result:

- Longer-lasting pothole repairs
- Reduced recurrence of potholes

3. Rutting Resistance

Rutting occurs due to permanent deformation under heavy axle loads.

Role of Plastic Waste:

Plastic increases stiffness and load-bearing capacity of the bituminous mix. During repair, plastic-modified layers distribute wheel loads more effectively and resist shear deformation.

Result:

- Improved resistance to permanent deformation
- Stable pavement surface under heavy traffic

4. Ravelling Control

Ravelling is caused by loss of aggregate particles due to weak bonding and oxidation of bitumen.

Role of Plastic Waste:

Plastic improves adhesion and cohesion within the mix. The plastic coating prevents oxidation of bitumen and minimizes aggregate dislodgement.

Result:

- Reduced surface wear
- Improved riding quality

5. Control of Bleeding

Bleeding results from excess bitumen flow, especially at high temperatures.

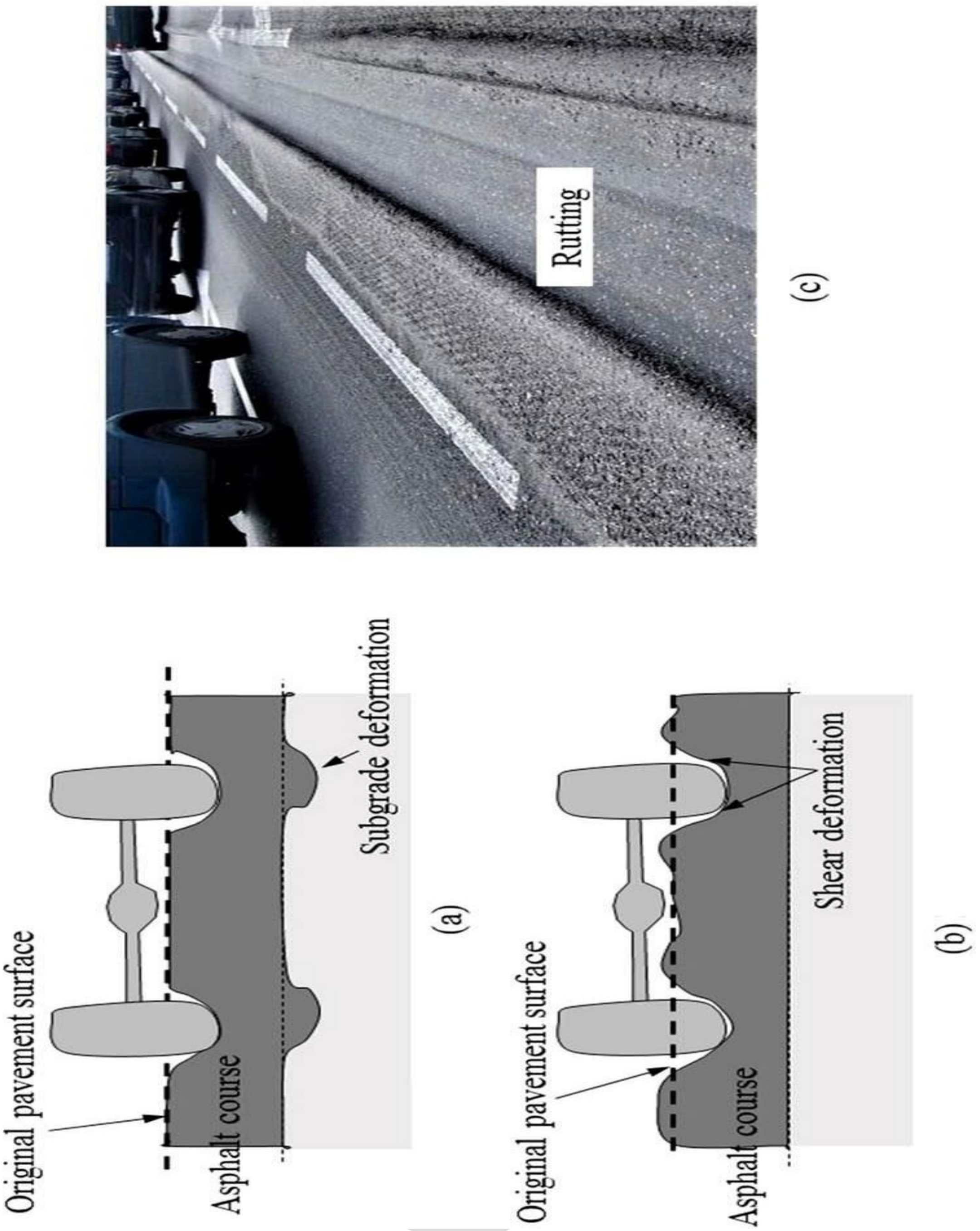
Role of Plastic Waste:

Plastic increases softening point and reduces temperature susceptibility of bitumen. During pavement repair, plastic-modified mixes maintain stability even in hot climatic conditions.

Structural Improvement in Repaired Pavements

Plastic waste contributes to overall structural enhancement of repaired pavements by:

- Increasing Marshall Stability
- Reducing penetration value of bitumen
- Improving tensile strength and fatigue life
- Enhancing resistance to aging and oxidation



These improvements result in stronger and more durable repaired pavement layers.

6. Moisture Damage Resistance

One of the primary causes of pavement failure is moisture infiltration.

Role of Plastic Waste:

Plastic acts as a moisture barrier by reducing permeability of pavement layers. This prevents stripping of bitumen from aggregates and maintains structural integrity during wet conditions.

Material along with plastic

1. Bitumen

Bitumen is the primary binding material in flexible pavements and is most commonly mixed with plastic waste.

Role with Plastic:

- Plastic modifies the rheological properties of bitumen
- Increases softening point
- Reduces temperature susceptibility
- Improves binding and cohesion

Application:
Plastic is added either by coating aggregates (dry process) or by blending with hot bitumen (wet process).

Result:

- Improved resistance to cracking, rutting, and bleeding

2. Aggregates (Coarse and Fine)

Aggregates form the main structural component of pavements.

Role with Plastic:

- Plastic melts and coats aggregate surfaces
- Fills surface voids and micro-cracks
- Improves adhesion between aggregates and bitumen

Result:

- Reduced stripping of aggregates
- Improved load distribution
- Increased pavement durability

3. Mineral Filler (Cement / Lime / Stone Dust)

Mineral fillers are used to fill voids and improve the density of the bituminous mix.

Role with Plastic:

- Enhances stability of the mix

- Improves moisture resistance
- Works synergistically with plastic to reduce voids

Result:

- Better compaction
- Improved strength of pavement layers

4. Crumb Rubber (Optional Additive)

Crumb rubber is obtained from waste tyres and can be used along with plastic.

Role with Plastic:

- Improves elasticity and flexibility
- Enhances fatigue resistance
- Reduces noise and vibration

Result:

- Suitable for high-traffic roads
- Improved long-term performance

5. Fly Ash

Fly ash is an industrial by-product used as a filler or stabilizing material.

Role with Plastic:

- Improves workability of mix
- Enhances resistance to moisture damage
- Reduces cost and environmental impact

Result:

- Sustainable pavement construction
- Improved durability

6. Reclaimed Asphalt Pavement (RAP)

RAP consists of recycled pavement materials.

Role with Plastic:

- Plastic improves binding of aged bitumen in RAP
- Enhances strength of recycled mix

Result:

- Cost-effective pavement rehabilitation
- Reduced consumption of new materials

7. Anti-Stripping Agents (Lime / Liquid Additives)

These are used to improve moisture resistance.

Role with Plastic:

- Works together with plastic to prevent stripping
- Enhances adhesion in wet conditions

Result:

- Improved durability in rainy regions

8. Sand and Stone Dust (Fine Aggregates)

Used for improving gradation and surface finish.

Role with Plastic:

- Plastic improves cohesion between fine particles
- Reduces loss of fines

Result:

- Better surface texture
- Improved riding quality

PLASTIC ROADS

Plastic use in road construction is not new. It is already in use as PVC or HDPE pipe mat crossings built by cabling together PVC (polyvinyl chloride) or HDPE (high-density poly-ethylene) pipes to form plastic mats. The plastic roads include transition mats to ease the passage of tires up to and down from the crossing. Both options help protect wetland haul roads from rutting by distributing the load across the surface. But the use of plastic-waste has been a concern for scientists and engineers for a quite long time. Recent studies in this direction have shown some hope in terms of using plastic-waste in road construction i.e., Plastic roads. A

Bangalore-based firm and a team of engineers from R. V. College of Engineering, Bangalore, have developed a way of using plastic waste for road construction. An initial study was conducted in 1997 by the team to test for strength and durability. Plastic roads mainly use plastic carry-bags, disposable cups and PET bottles that are collected from garbage dumps as an important ingredient of the construction material. When mixed with hot bitumen, plastics melt to form an oily coat over the aggregate and the mixture is laid on the road surface like a normal tar road.

7. PREPARATION OF PLASTIC MATERIAL FOR CONSTRUCTION

The aggregate is heated to around 1700C; the plastic waste shredded to the size varying between 2.36mm and 4.75mm. This shredded plastic waste is added over hot aggregate with constant mixing to give a uniform distribution. The plastic get softened and coated over the aggregate. The hot plastic waste coated aggregates are mixed with hot bitumen 60/70 or 80/100 grade (1600C).

BASIC PROCESSES

1. Segregation
2. Cleaning Process
3. Shredding Process
4. Collection Process

Two Processes used in construction of plastic road

1. Wet Process

In this process, the waste plastic is directly mixed with hot Bitumen at 1600C and this mixture is then mixed using a mechanical stirrer. This mixture also contains additional stabilizers and requires proper cooling. It is not popular because it requires huge investments, larger plants and more equipment than the Dry Process.

2. Dry Process

First the plastic waste is collected, segregated and stored. The segregation is done because certain kinds of plastic like polyvinyl chloride (PVC) and flux sheets cannot be used due to safety concerns. The next step involves the cleaning of the plastic. This is necessary because most of the plastic waste collected has been used for packaging (55% in India) and hence is likely to contain residual substances such as little bits of food which must be removed. After this the plastic goes through the process of shredding which reduces it to the correct thickness, 2-4mm. The aggregate is heated to around 1600C-1700C and then the plastic is added and after 30-40s a uniform coating is observed. This coating gives it an oily look. The Bitumen is then added and the mixture is thoroughly mixed before laying. The Bitumen is added at a temperature of around 1550C - 1630C. This temperature is carefully regulated to make sure that the binding is strong. The process is described by the diagram below.

Types of Plastics used in Plastic coated road

The most commonly used plastics in this process are polyethylene, polystyrene, polyester, and polypropylene. Polyethylene can be made in 3 different ways. Each of these 3 different ways results in polyethylene with different properties. Hence each one is given a slightly different name. Low density polyethylene is normally used to make plastic bags. High density polyethylene is used to make plastic chairs, dustbins, bowls etc. Linear low-density polyethylene is used to make plastic sheets and wraps. Polystyrene is typically used in fast food cartons and as insulation. Polyester (Polyethylene terephthalate) is mainly used as a fabric for clothes. Polypropylene is used for clothing and is applied in radio-controlled toy planes. All of these plastics, upon incineration liberate large amounts of carbon dioxide and water if sufficient oxygen is used, otherwise, carbon monoxide is produced along with water. Polyvinylchloride (PVC) cannot be used because upon heating it can release dioxin which is toxic gas.

8. ADVANTAGES AND DISADVANTAGES

Advantages of Plastic Roads

1. **Utilization of waste plastic**
   - Helps in effective disposal of plastic waste
   - Reduces environmental pollution and landfill burden

2. **Improved strength of pavement**
   - Plastic-coated aggregates show better bonding with bitumen
   - Increases Marshall Stability value
3. **Higher resistance to water damage**
   - Plastic reduces moisture absorption
   - Less stripping of bitumen during rains
4. **Better durability**
   - Roads have longer life compared to conventional bituminous roads
   - Reduced potholes and cracks
5. **Cost effective (long term)**
   - Lower maintenance cost
   - Reduced bitumen requirement (about 8–10%)
6. **Higher resistance to temperature variations**
   - Performs better in hot climates
   - Less rutting and deformation
7. **Eco-friendly approach**
   - Promotes sustainable construction
   - Supports Swachh Bharat and waste management goals

Disadvantages of Plastic Roads

8. **Toxic emissions (if not properly controlled)**
   - Improper heating of plastic may release harmful gases
9. **Limited recycling options later**
   - Reprocessing plastic-bitumen mix is difficult after road life
10. **Quality control issues**
    - Performance depends on type and quality of plastic used
    - Improper mixing affects road strength
11. **Not suitable for all road types**
    - Limited application for heavy traffic roads if not designed properly
12. **Collection and segregation challenges**
    - Requires clean, sorted plastic waste
    - Increases initial handling effort
13. **Lack of long-term performance data**
    - Still under observation for very long design life

9. SCOPE AND CONCLUSION

FUTURE SCOPE

The future scope of utilizing plastic-coated bituminous roads presents significant potential in both environmental and infrastructural contexts. As concerns over plastic waste management and sustainable construction practices continue to grow, this innovative solution can help address multiple challenges:

1. Waste Plastic Management

Plastic-coated bituminous roads can help in recycling and managing plastic waste. By incorporating waste plastics (such as PET bottles, plastic bags, and other forms of non-biodegradable plastics) into road construction, the amount of plastic waste that would otherwise end up in landfills or oceans can be reduced significantly.

2. Improved Road Durability and Performance

Plastic-coated bituminous roads have been shown to enhance the durability of the road surface. The addition of plastic to bitumen improves its resistance to weathering, water damage, and rutting, which results in longer-lasting roads with reduced maintenance costs. This can be especially valuable in areas prone to high temperatures, heavy rainfall, and extreme weather conditions.

3. Cost-Effectiveness

Incorporating waste plastic into road construction can reduce material costs, as plastic is often less expensive than conventional raw materials. Moreover, the longevity and reduced maintenance needs of plastic-coated roads can lead to long-term savings for municipalities and governments.

4. Environmental Sustainability

By using waste plastic in road construction, the carbon footprint of both plastic production and road maintenance can be reduced. Moreover, plastic-coated roads contribute to reducing plastic pollution, which is a growing environmental issue.

5. Global Adoption and Innovation

Countries like India, which have already begun implementing plastic in road construction, are likely to seen wider adoption. This could also encourage innovations in material science, leading to the development of new types of sustainable and cost-effective construction materials.

6. Infrastructure Resilience in Developing Countries

For many developing countries, plastic-coated bituminous roads offer a way to improve infrastructure without heavily relying on imported materials. This can be a boon for economic development, as road networks will be more resilient, longer-lasting, and require less frequent repairs.

7. Research and Technological Advancements

As research into the effects of plastic on bituminous materials progresses, the use of plastic in road construction may become more refined, leading to new types of plastics or additives that further improve road quality, sustainability, and environmental impact.

10. CONCLUSION

This project focused on identifying common failures in flexible pavements and evaluating sustainable repair solutions using waste plastic. From field observations and literature studies, it was found that pavement failures such as cracking, potholes, rutting, ravelling, and bleeding are mainly caused by heavy traffic loads, poor drainage conditions, temperature variations, aging of bitumen, and inadequate construction practices.

The study demonstrated that the use of waste plastic in pavement construction and repair significantly improves the performance of bituminous pavements. Plastic waste, when incorporated into the bituminous mix, enhances the binding properties, reduces moisture penetration, and improves resistance to temperature variations. The plastic-modified pavement layers showed better strength, durability, and resistance to common pavement failures when compared to conventional pavements.

The dry process of using plastic waste was found to be simple, economical, and suitable for field application. The addition of plastic increased the stability and load-carrying capacity of pavements, reduced maintenance requirements, and extended the service life of roads. Moreover, the utilization of plastic waste provides an effective solution for managing non-biodegradable waste and reducing environmental pollution.

Overall, the project concludes that the use of plastic waste in pavement repair and construction is a technically feasible, economically viable, and environmentally sustainable solution. This method can be effectively adopted for low to medium traffic roads and urban road maintenance, contributing to sustainable infrastructure development and improved pavement performance.