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PAVEMENT USING RECYCLED PLASTIC WASTE MATERIALS

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ABSTRACT

The amount of plastic waste produced by urbanization and globalization is rapidly increasing. Over the past few decades, plastic consumption has increased, and this trend is certain to continue. Just 9% of the 7 billion tons of plastic produced up to 2022 were recycled in India. With an annual production of 1.5 million tons of plastic waste (PW), India is among the top ten countries in the world for plastic production. A lot of plastic waste might be bad for the environment and general public's health. The present publication provides a comprehensive approach for machine and chemical recycling processes. In order to create plastic products with additional value, this study delves into the technical facets of mechanical recycling that are connected to gathering, sorting, grading, and general management.

These days, using recycled plastics is becoming more and more common, especially in light of the 2017 plastics problem. The use of recycled materials in asphalt pavement has a long history, and the industry has established itself as a leader in this area.

Still, there isn't much enthusiasm for using recovered plastics in road construction.

requires the knowledge of how to regularly include them into asphalt mixtures. A study was conducted to evaluate the effects of five proprietary recycled plastics on bitumen properties, bitumen-aggregate affinity, resistance to moisture and permanent deformation, and skid resistance of five asphalt mixes (AC14 surf). PE (low) makes up the bulk of the recycled plastics used.

The study assessed the future recyclability of plastic-modified asphalt (P-RAP) produced through three different mixing methods: dry, wet, and mixed. Loose plastic-modified asphalt mixes were aged and crushed to produce P-RAP, which was then incorporated into a new hot mix at a 30% percentage. The comprehensive mechanical testing scheme showed that P-RAP is recyclable and provides similar performance to standard RAP mixes.

INTRODUCTION :

The huge amount of garbage generated daily on Earth is one of the biggest environmental problems. The problem of plastic garbage is severe everywhere in the world. For example, the total amount of plastics consumed in Australia was found by the Plastics Recycling Survey.

Recycling plastic waste for use in pavements is a sustainable solution that addresses environmental concerns while enhancing pavement performance. Studies highlight the potential of incorporating waste plastics, particularly polyethylene (PE), into asphalt mixtures to improve properties like stability, tensile strength, and resistance to cracking and temperature variations. By partially replacing asphalt with PE, the resulting PE-substituted asphalt binders exhibit superior performance compared to virgin asphalt binders, showcasing the viability of using recycled plastics in pavement construction [5]. Life cycle assessments emphasize the environmental benefits of utilizing recycled plastics in asphalt pavements, reducing plastic waste release and outperforming conventional landfill disposal methods. Overall, the integration of waste plastics in pavement construction presents a promising avenue for sustainable resource management and improved pavement quality, contributing to both environmental conservation and infrastructure development. 3,513,100 tons were produced between 2016 and 2017, of which 415,200 tons were recycled (Austroads 2019). Over 30 million tons of waste plastics are produced annually in China as a result of the country's widespread use and manufacture of plastics (Chen et al. 2019). According to estimates, 192 coastal nations produced 275 million metric tons of plastic debris in 2010, of which 4.8 to 12.7 million metric tons ended up in the ocean (Jambeck et al. 2015). Despite the fact that plastic waste management.

A limited number of studies have recently concentrated on the conversion of cement and concrete products using waste glass, recycled crushed glass (RCG), steel slag, steel fiber, tires, and plastics in pervious concrete (PC) to develop the mechanical properties of PC and solve disposal issues (Shah and Pitroda, Bazzaz 2018b). On the other hand, material engineering has concentrated on developing the material's mechanical, structural, and physical attributes because ordinary PC pavement lacks these qualities. Furthermore, it is very hard to achieve significant strength using common materials and their combinations due to the voids and porosity of PC pavement (Ramadhansyahet al., 2014; Shakraniet al., 2017). Thus, including substances like admixture and superplasticizer cement or aggregates replacements besides few waste materials and Nano Nano-materials have been applied to increase the properties of PC pavement (Huang et al. 2007). This study analyzed the waste materials utilized in pavement porous concretes, including recycled crushed glass (RCG), steel slag, steel fiber, tires, plastics, and recycled asphalt, and reported on their corresponding mechanical, durability, and permeability functions.

2. Methodology:

Recycled Waste Materials in Construction and Road Projects

This study explores the use of recycled waste materials in construction and road infrastructure, focusing on tires, plastics, glass, and steel slags. These materials demonstrate potential for sustainability and resource efficiency, but their utilization faces technical and economic challenges.

2.1 Tires

- *Usage*: Waste tires are repurposed in energy recovery, raw materials, and unauthorized dumping, with 22% used for energy recovery and 9% incinerated in cement kilns over a decade.
- *Challenges*: High processing and transportation costs limit their recycling. For example, transportation costs are approximately £1/ton/km in Europe.
- *Potential*: Tires have a higher energy value than coal, making them suitable for applications like asphalt and pavement construction.

2.2 Plastics

- *Sources*: Recycling primarily originates from commercial and household waste like bottles.
- *Barriers*: Financial obstacles and inconsistent environmental assessments hinder scaling up plastic recycling.
- *Potential*: Recycled plastics have high thermal content (38 MJ/kg) compared to coal (31 MJ/kg), making them suitable for public spaces, insulation, and pipe production, though underutilized in pavement construction.
- *Notable Issue*: PVC has the lowest recycling rate among plastics due to packaging challenges.

2.3 Glass

- *Recycling Rates*: Of 1.1 Mt of waste glass, 33% is recycled, mainly for container goods (66%) and secondary aggregates (13%).
- *Landfilling*: A significant portion, 67% (2.3 Mt), is still landfilled.
- *Opportunities*: Improved recycling systems could reduce waste glass disposal and increase its use in secondary applications.

2.4 Steel Slags

- *Production and Usage*: Steel slag constitutes 7.5–15% of steel production. It is a priority material for recycling, with efficient processing offering advantages over other solid waste products.
- *Application*: Fully recyclable steel slags are ideal for asphalt pavements due to their consistency and quality.

2.5 Methods of Modification

To incorporate recycled materials into construction, two primary methods are used:

1. ***Wet Process***
- *Description*: Heated bitumen is blended with recyclable plastic.
- *Advantages*: Enhances bonding and dispersion of plastic particles.
- *Challenges*: Requires precise temperature control to prevent plastic degradation.

2. ***Dry Method***
- *Description*: Recyclable plastic is added before mixing bitumen with aggregates.
- *Advantages*: Improves adhesion and coating of aggregates.
- *Challenges*: Ensuring uniform distribution of plastic within the mixture.

Figure:4 experimental investigation of the influence of multi-recycling on the fracture behavior of post-consumer high impact polystyrene from disposable cups evaluated by the j-integral approach. January 2022iium engineering journal 23(1):268-281

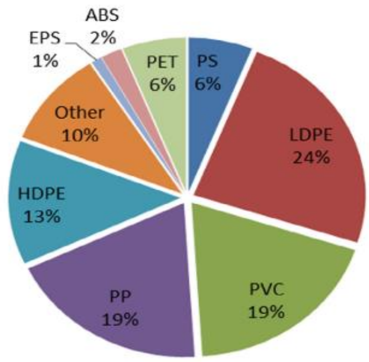
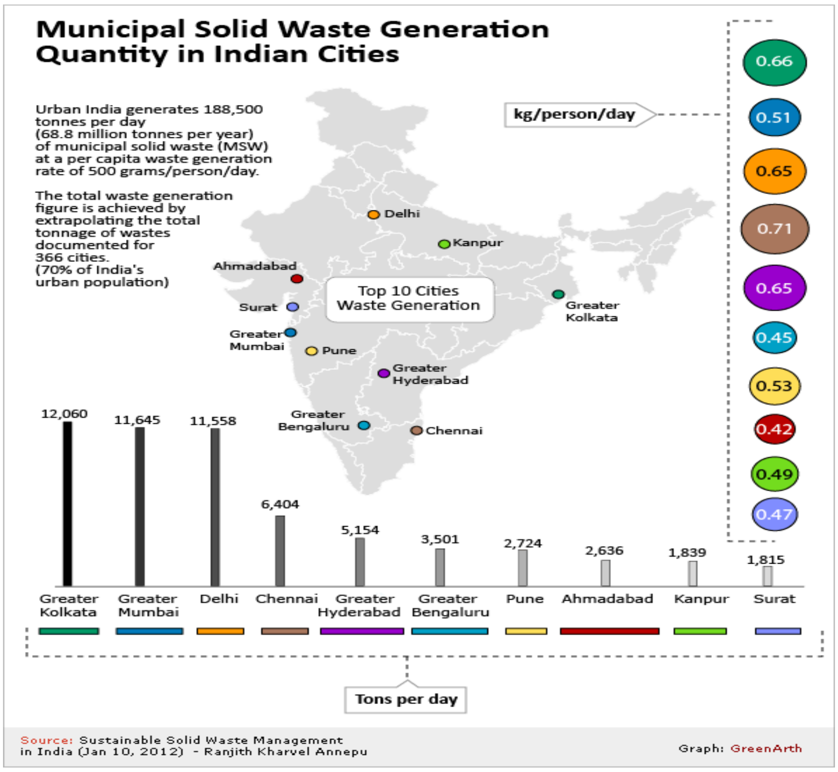
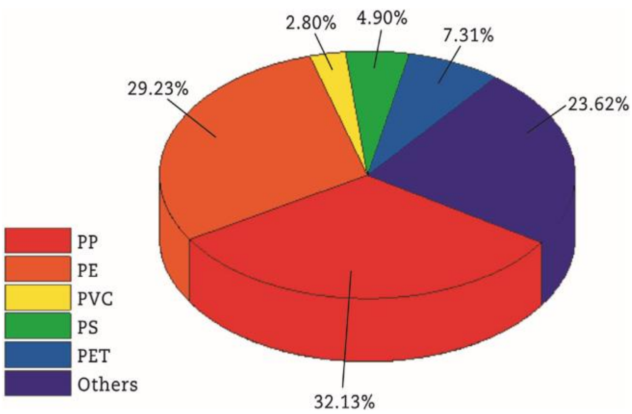


Figure5: Average plastic consumption by polymer type in a European context (Brems et al., 2012).





Plastic content breakdown in municipal solid waste (MSW): polypropylene (PP), polyethylene (PE), polyvinyl chloride (PVC), polystyrene (PS), polyethylene terephthalate (PET), and others (Dubois et al., 2020).

3.Discussion:

Impact of Recycled Plastic Waste on Mechanical Properties and Performance

The integration of recycled plastics into bituminous materials for road construction offers innovative solutions for waste management and infrastructure enhancement. However, these practices must balance the mechanical, environmental, and health impacts to ensure sustainability and safety.

3. Impact on Mechanical Properties and Performance

- *Adhesion*: Recycled plastics enhance binder-aggregate adhesion, improving pavement durability and performance.
- *Enhanced Performance*: Properly incorporated plastics improve stiffness, resistance to deformation, and fatigue life, leading to better load distribution and reduced rutting or cracking.
- *Compatibility*: Plastics such as polyethylene (PE), polypropylene (PP), and polystyrene (PS) are compatible with bituminous materials under appropriate design and processing.
- *Water Resistance*: Plastics improve moisture resistance, reducing aggregate stripping caused by water intrusion.
- *Environmental Benefits*: Incorporating recycled plastics reduces landfill waste and the reliance on non-renewable bitumen.
- *Mechanical Properties*: Recycled plastics improve tensile strength, elastic modulus, and creep resistance, contributing to longer-lasting pavements with reduced maintenance needs.

3.1 Environmental and Health Concerns

Recycled plastics in pavements offer resource savings and waste reduction but pose potential environmental and health risks that require careful management.

3.1.1 Environmental Issues

- *Micro plastic Release*: Pavement deterioration over time may release micro plastics, affecting soil, water, and air ecosystems.
- *Hazardous Emissions*: During processing, plastics can emit harmful chemicals like PAHs and VOCs, contributing to pollution.
- *Chemical Leaching*: Stabilizers and other additives may leach into soil and water, potentially harming ecosystems and human health.

3.2 Environmental Lifecycle Impact

- A comprehensive lifecycle assessment is essential to evaluate whether the benefits of using recycled plastics outweigh the environmental costs across collection, processing, and pavement life.

3.3 Health Concerns

- *Exposure to Toxic Substances*: Workers may face risks from handling and processing recycled plastics, including skin irritation and respiratory issues.
- *Hazardous Gas Emissions*: Heating and mixing operations may release harmful gases (e.g., CO, dioxins, furans), causing respiratory and long-term health issues like cancer.
- *Micro plastic Inhalation*: Dust and micro plastics from pavement wear may pose risks, especially near busy roads, with potential respiratory and health effects.

3.4 Managing Safety Risks

- Proper safety protocols, monitoring, and protective measures are crucial to mitigate health risks for workers and communities during processing and application.

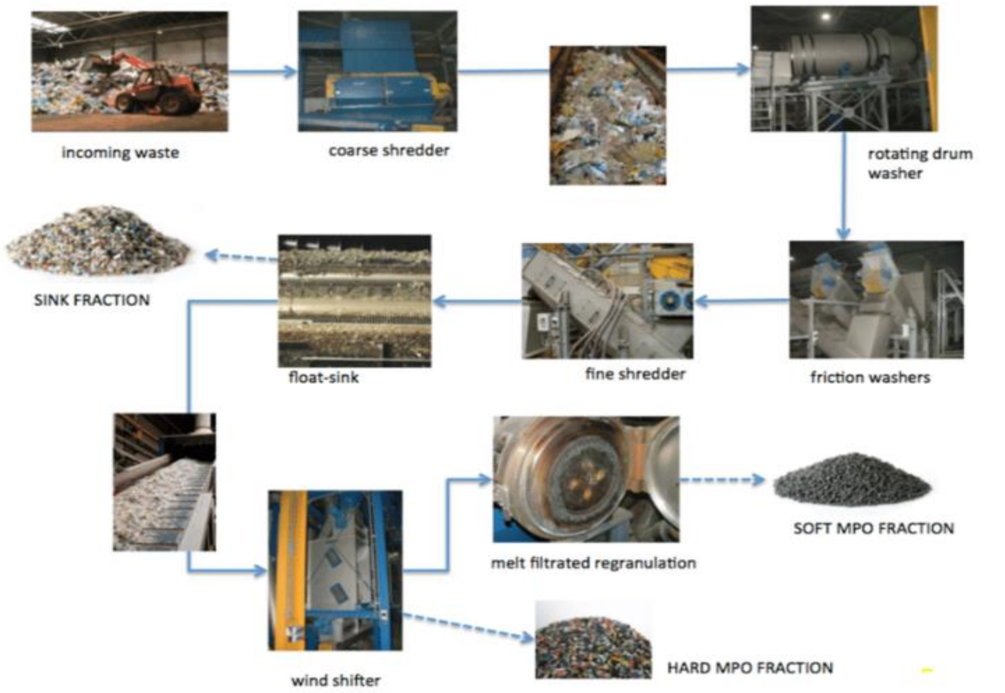


Figure.1: Flow of the PC waste within Eco-oh! (courtesy of Eco-oh!, BE).

Figure.2: Schematic of the principles of the Circular Economy (EU-Parliament, 2015).

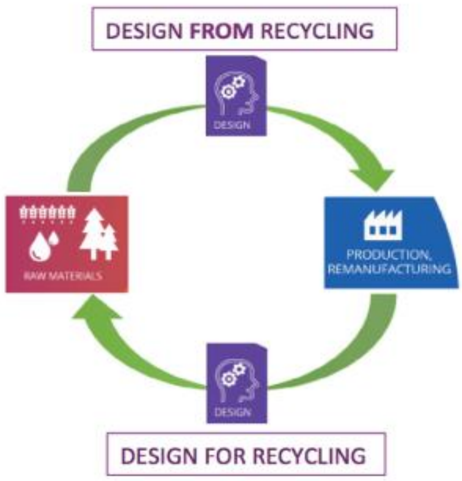


Figure.3: The complementarity of Design for and from Recycling in the Circular Economy (icons). adapted from EU-Parliament (2015)

4.Conclusion

The study explores the integration of recycled plastic waste into pavement construction, presenting it as a promising solution for sustainable infrastructure development and effective waste management. Key findings emphasize the following:

Key Benefits

1. *Improved Mechanical Properties*:
   - Enhanced stiffness, flexibility, and durability of pavements.
   - Improved resistance to rutting, cracking, and moisture damage, leading to better performance under load.
2. *Environmental Advantages*:
   - Supports circular economy principles by reducing plastic waste in landfills and oceans.
   - Decreases reliance on non-renewable resources like virgin bitumen.
3. *Economic Benefits*:
   - While initial processing and modification incur costs, long-term benefits include extended pavement life and reduced maintenance, resulting in cost savings.

Challenges and Recommendations

1. *Material Compatibility and Quality Control*:
   - Ensuring recycled plastics are compatible with bituminous materials.
   - Strict quality control is necessary to address variability in waste plastic properties.
2. *Environmental and Health Concerns*:
   - Risks include microplastic release, toxic emissions, and chemical leaching.
   - Implementation of robust health and safety regulations, improved processing techniques, and continuous environmental monitoring is critical.
3. *Processing Methods*:
   - Optimized techniques and strict control over processing conditions are essential to ensure uniform dispersion and bonding of recycled plastics with bituminous mixes.

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