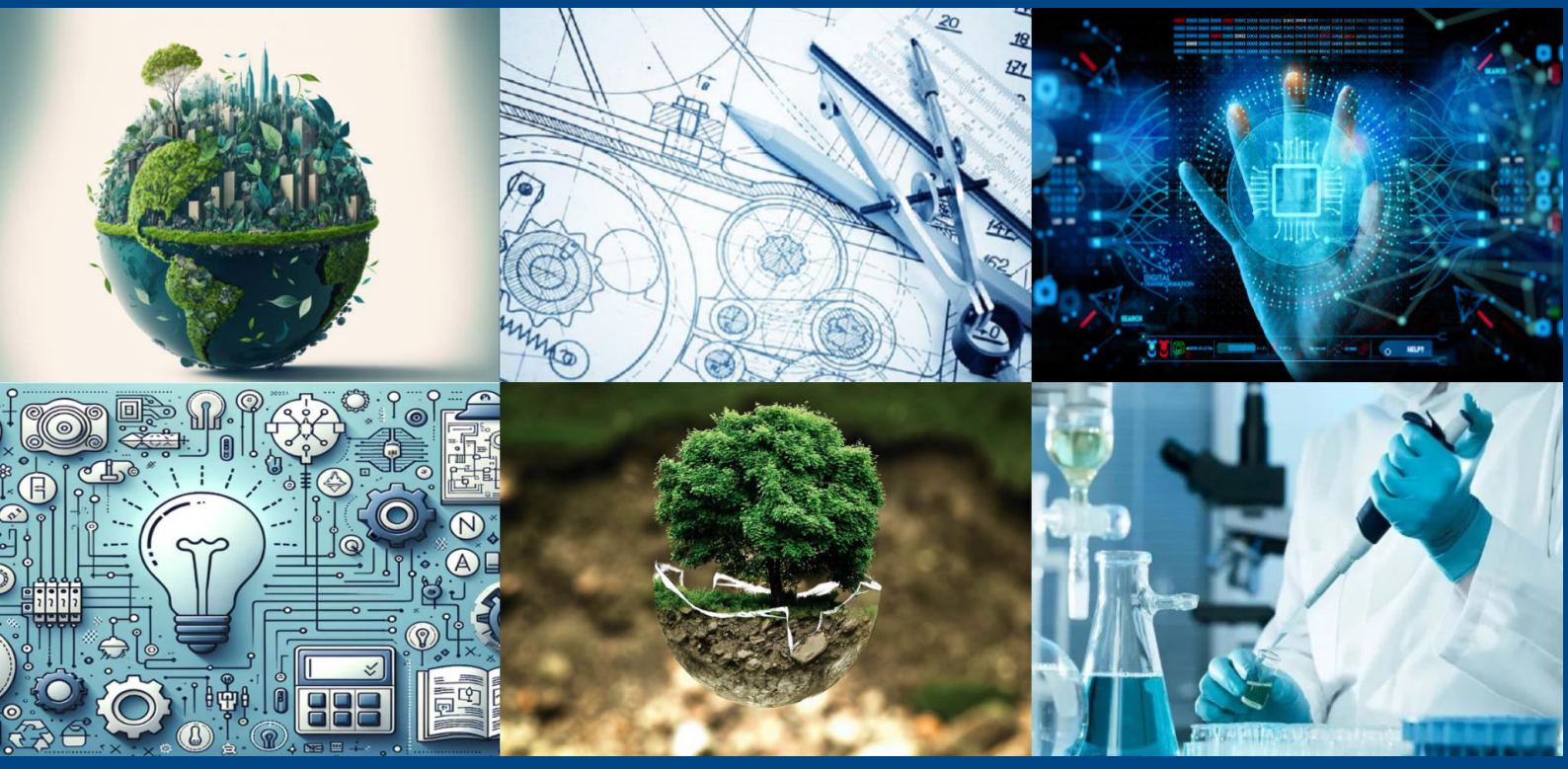
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Sustainable Permeable Bituminous Pavement Using Waste Plastic: An Experimental Investigation

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ABSTRACT: The present study evaluates an eco-friendly method of reducing urban stormwater using permeable pavement, which also uses solid waste. A 150mm thick bituminous layer is used with 10% by mass waste plastics in the form of shreddates. This is placed on top of a 150mm thick impervious concrete base made up of M40 concrete with 30% recycled coarse aggregates (RCA). Three bitumens were studied, a conventional dense graded mix (Mix A), an open graded permeable mix (Mix B) and a plastic modified permeable mix (Mix C). The lab results showed that the plastic modified mix had higher Marshall stability than the other mixes. Mix C had a Marshall stability value of 7.2KN (Improved by 10.77% from Mix B). The air voids were also within the correct range at 18.0%. The mix also managed to produce 75% of the water applied through the side collection system without any ponding. The M40 RCA concrete produced a 28 day compressive strength of 41.33MPa. The addition of waste plastics into permeable bitumens can be seen to improve the strength of the mixture whilst maintaining efficient drainage.

I. INTRODUCTION

With the rapid increase in urban development there has been an increase in impermeable surfaces. This leads to increased stormwater runoff, ponding at the surface and accelerated pavement stripping and degradation. Permeable bituminous pavements have been found to be an effective solution to reduce stormwater runoff by allowing water to percolate through the interconnected voids within the surface. However, they can typically suffer from poor load bearing capabilities and increased susceptibility to aggregate raveling. There are also significant environmental issues within the civil engineering industry as there is a lot of non-biodegradable plastic waste and a reduction in natural aggregates. Therefore, this paper looks at experimental results of a combined stormwater management and solid waste recovery system. A 150mm thick permeable bituminous surface with 10% waste plastic content by mass of bitumen was utilised and a 150mm thick impermeable M40, concrete base incorporating 30% recycled coarse aggregate (RCA) were used. Drainage channels were incorporated within the system above the concrete slab to safely remove any infiltration. This paper provides an evaluation of the volumetric, mechanical, hydraulic and structural properties of the system in comparison to conventional and unmodified permeable pavement mixtures.

II. LITERATURE REVIEW

2.1. Zhou et al. (2025): Reviewed porous asphalt performance, highlighting that pore structure, binder modification, and aggregate gradation are crucial to preventing pore clogging, moisture damage, and aggregate raveling.

2.2. Yadav et al. (2024): Evaluated flexible pavements incorporating PET waste plastic and recycled concrete aggregate (RCA), reporting marked improvements in Marshall stability, moisture resistance, and overall durability, though hydraulic permeability was not addressed.

2.3. Akhtar et al. (2021): Explored the critical relationship between stability and water permeability in porous asphalt, emphasizing that mix designs must carefully balance structural load-carrying capacity with void connectivity.

2.4. Movilla-Quesada et al. (2019): Investigated the dry-process addition of waste plastic scrap as a partial bitumen substitute, demonstrating that controlled replacement percentages can successfully reduce neat binder consumption without compromising mechanical behavior.

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2.5. Putman and Neptune (2011): Assessed porous asphalt pavements under rainfall conditions, proving that open-graded surfaces effectively reduce peak runoff and enhance infiltration while maintaining structural performance under suitable traffic.

Research Gap

Previous work has investigated the incorporation of waste plastics into bituminous mixtures and the inclusion of recycled coarse aggregate in concrete. However, little research has focused on the combined effects of both material types within a multi-layered composite pavement system. In particular, there is no experimental evidence to study the effects of using 10% waste plastics within open graded bituminous mixtures, on the balance between strength and permeability of the pavement, when combined with a 30% RCA M40 impermeable concrete layer and drainage channels. and aggregate grading are vital to avoid clogging, moisture damage and aggregate loss. concrete containing 30% recycled coarse aggregate. Drainage channels have been incorporated into the pavement system above the concrete layer to safely remove infiltration. This paper looks at the properties of the proposed system compared to traditional systems, considering volume, mechanical, hydraulic and structural properties.

III. PROBLEM STATEMENT

Traditional impermeable pavements are causing major problems with surface water build up and quick degradation. Accumulation of plastic waste and the depletion of natural aggregates are also causing major environmental issues. However, the addition of waste plastics into permeable bitumen and recycled aggregates into the base concrete is seen to be a sustainable solution. It is unknown however whether this combination can provide an acceptable amount of strength and drainage due to lack of experimental data. This study aims to investigate if a 10% waste plastic modified permeable bitumen pavement, with an M40 concrete layer incorporating 30% recycled coarse aggregate and a pipe drainage system will provide an acceptable level of strength and drainage compared to traditional pavement mixes.

IV. OBJECTIVES

4.1To design an M40 concrete sub-base incorporating Recycled Concrete Aggregate (RCA)
4.2To produce a permeable wearing course using waste shredded plastic.
4.3 To Incorporate vertical drainage pipes for recharging the ground water below the slab.
4.4To Test the composite pavements, infiltration and recharging ability.

V. METHODOLOGY

The experimental framework was structured to evaluate the mechanical stability, volumetric characteristics, and hydraulic drainage performance of a sustainable composite pavement system. The proposed configuration couples a porous bituminous upper course with an impermeable structural concrete base designed to channel runoff without saturating the road subgrade.

5.1 Material Characterization and Preparation

- **Bituminous Binder & Plastic Modifier:** A standard 60/70 paving-grade bitumen was utilized as the baseline binder across all asphalt specimens. Post-consumer waste plastic was gathered, systematically sorted, cleaned of contaminants, dried, and mechanically shredded into fine flakes. For the modified mix, the plastic was introduced at a dosage of 10% calculated relative to the mass of the reference bitumen.
- **Aggregates:** Clean, crushed natural coarse and fine aggregates were oven-dried and sieved according to standard grading requirements. Sieve analyses were performed to isolate the targeted nominal aggregate sizes (10 mm, 20 mm, and 50 mm) for the open-graded layered structure.
- **M40 Concrete Constituents:** The concrete support slab was developed using OPC 53-grade cement, Zone II natural sand, natural coarse aggregate (NCA, specific gravity 2.74), and crushed recycled coarse aggregate (RCA, specific gravity 2.50, water absorption 4.0%) derived from demolition debris. A polycarboxylate ether-based superplasticizer (1.0% by mass of cement) was used to achieve the desired workability.

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5.2 Mix Proportioning and Specimen Fabrication

To assess the relative influence of aggregate porosity and plastic modification, three comparative bituminous mixtures were fabricated:

- **Mix A (Control):** A conventional dense-graded bituminous mixture with 0% waste plastic, designed with an illustrative 5% binder content.
- **Mix B (Permeable Baseline):** An open-graded bituminous mixture formulated with coarse aggregate and minimal fines to create interconnected voids, utilizing 0% waste plastic.
- **Mix C (Modified Permeable):** An open-graded permeable mixture identical in gradation to Mix B, but incorporating 10% shredded waste plastic by reference bitumen mass.

Specimens were mixed at elevated temperatures, placed in standard cylindrical moulds (101.6 mm diameter × 63.5 mm height), and compacted under uniform laboratory conditions. In parallel, concrete batches were proportioned for an M40 grade with a design water–cement ratio of 0.40, replacing 30% of natural coarse aggregate by mass with RCA. Standard 150 × 150 × 150 mm cubes were cast, demoulded after 24 hours, and water-cured for testing.

5.3 Composite Pavement Model Assembly

A laboratory model representing the full composite pavement profile was constructed to examine overall hydraulic routing:

- **Permeable Bituminous Course (150 mm total):** Layered sequentially with a 60 mm top wearing course (nominal 10 mm aggregate), a 40 mm middle transition layer (nominal 20 mm aggregate), and a 50 mm open drainage layer (nominal 50 mm aggregate).
- **Impermeable Concrete Base (150 mm):** The cured M40 concrete base provided an impermeable barrier below the porous layers to block vertical infiltration into underlying soil strata.
- **Drainage Collection Interface:** Lateral collection was integrated at the interface using 90 mm diameter PVC pipes to intercept percolating water and direct it to an external discharge point. Joint seals were applied to boundary interfaces to prevent lateral edge leakage during trials.

5.4 Laboratory Testing and Analytical Procedures

- **Volumetric & Density Analysis:** Compacted bulk densities (ρ) and theoretical maximum specific gravities were determined to compute the interconnected air-void percentages for each mix.
- **Marshall Stability & Flow:** Conditioned specimens were loaded to failure in a standard Marshall testing frame to quantify peak load resistance (stability in kN) and vertical plastic deformation (flow in mm).
- **Water Infiltration & Drainage Efficiency:** A hydraulic test was executed by uniformly applying 1,000 mL of water onto the surface of the compacted specimens and composite model. Parameters recorded included infiltration time, presence of surface ponding, and the total volume of effluent collected at the drainage outlet.
- **Compressive Strength of Concrete:** Concrete cubes were tested under axial compression at curing intervals of 7 and 28 days to verify that the 30% RCA mix satisfied the M40 target mean strength

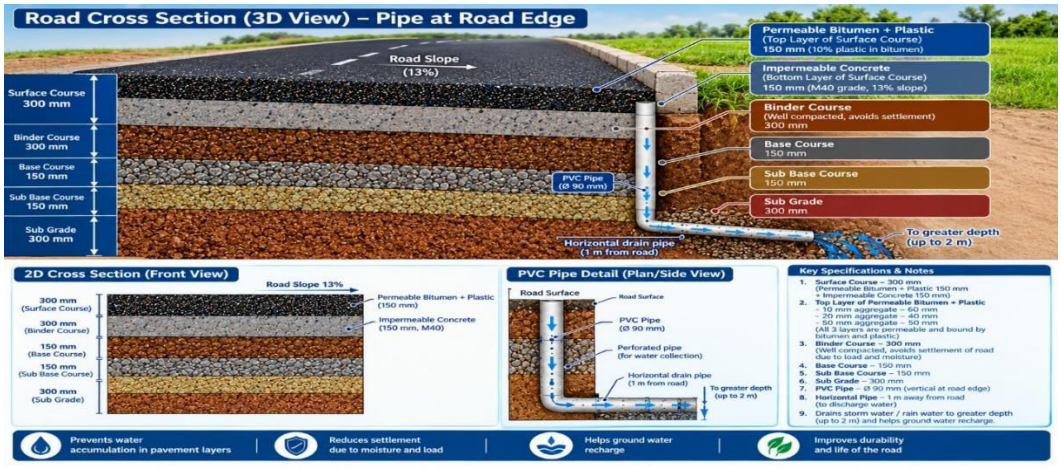


Figure 1:Road Cross Section

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VI. RESULTS AND DISCUSSION

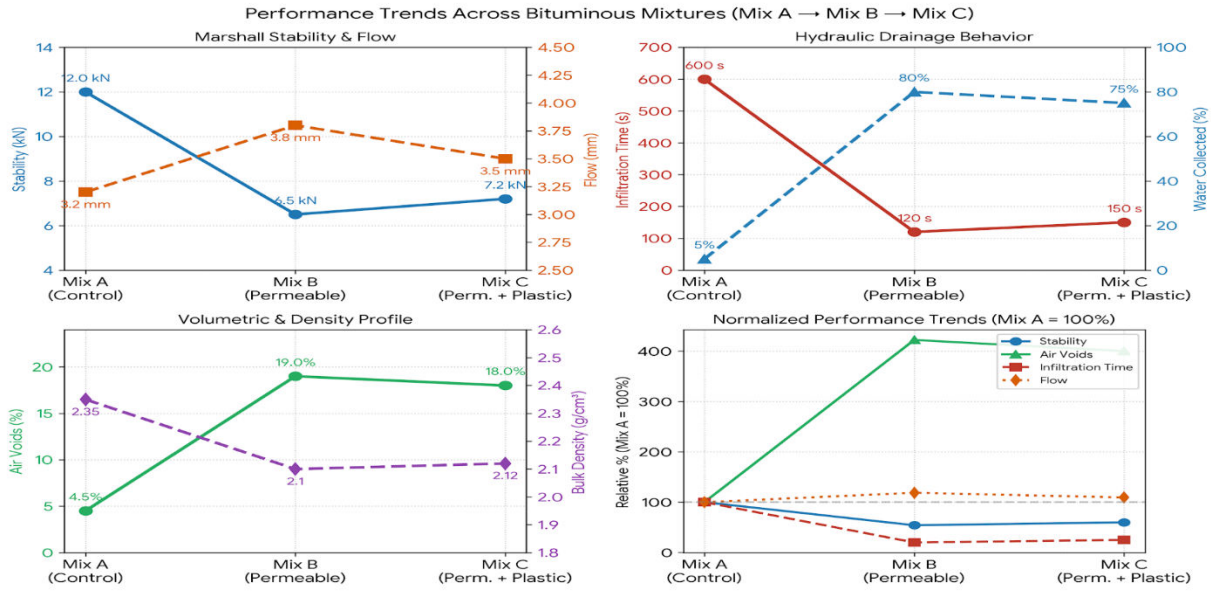


Figure 2:Multi-Parametric Performance Evaluation of Bituminous Mixtures

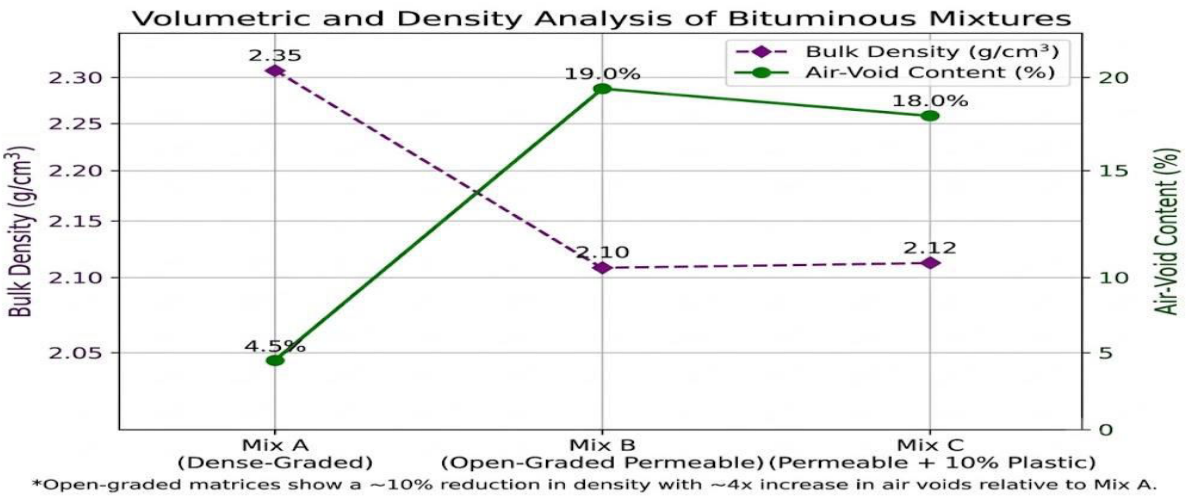


Figure 3:Volumetric and Density Analysis of Bituminous Mixtures

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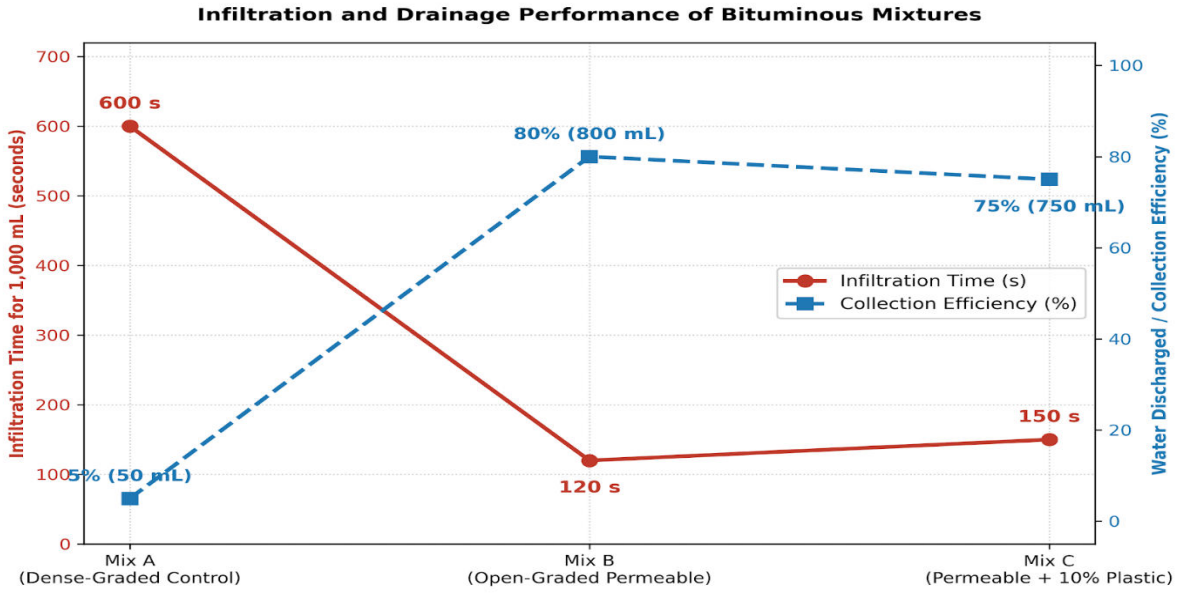


Figure 4:Infiltration and Drainage Performance of Bituminous Mix

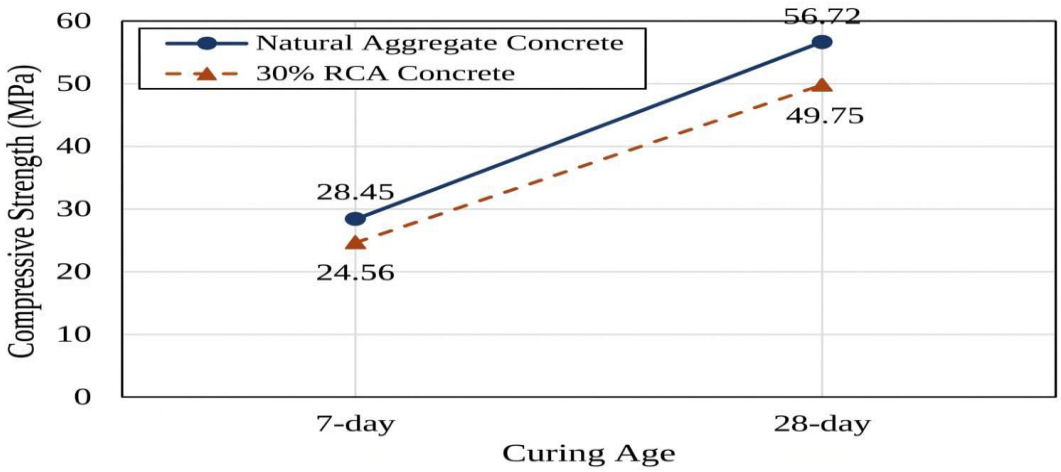


Figure 5:Compressive Strength Comparison

VII. CONCLUSION

The engineering feasibility of an environmentally friendly composite pavement system was successfully demonstrated through the use of a 10% modified permeable bitumen top layer composed of waste plastics and an impermeable M40 concrete sub-base with 30% recycled coarse aggregates. It was shown that by incorporating shredded waste plastics into the open graded mixture the mechanical properties improved leading to a significantly increased Marshall Stability of 7.2kN (10.77% increase from permeable bitumen top layer) and reduced deformation flow (7.89% decrease in deformation flow to 3.5mm). An air void content of 18.0% was achieved which allowed rapid drainage into the permeable mixture (150s), with 75% of the surface water directed into the side collection pipes without any build up. The concrete slab showed an average compressive strength of 41.33MPa (28 days) which was well within the design requirements. This composite system provides a robust, environment friendly way of controlling stormwater and using solid waste in low to medium traffic areas.

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