Quieter Roads Ahead: A Review on How Innovative Pavement Materials Can Tackle Tire-pavement Noise at the Source

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Abstract

One of the loudest—and most ignored—types of urban pollution that demands attention is tire-pavement noise. The most promising materials for quieter roads are examined in this review: porous asphalt, rubberized asphalt and recycled plastic composites. By absorbing or lessening the sound produced when tires strike pavement, these materials can reduce road noise by 3 to 10 decibels. Although porous asphalt is the most popular, rubberized asphalt is a reliable and long-lasting alternative, and if plastic composites are improved, they can also provide sustainability benefits. We explain how these materials function, and their potential futures based on current research and real-world case studies.

Keywords: *Road noise, porous asphalt, rubberized pavement, recycled plastic composites, tire-pavement interaction*

1. Introduction

With rapid urbanization comes a sharp increase in road noise, primarily caused above 40 km/h by tire-pavement contact (Li et al., 2024). This noise negatively impacts mental health, sleep, focus, and even property values in exposed areas. In response, road engineering is evolving to incorporate materials designed to limit noise at the source:

- Porous asphalt (PA): Engineered with interconnected voids that absorb sound waves.
- Rubberized asphalt (RA): Uses crumb rubber from recycled tires to enhance damping.
- Recycled plastic composites (RPC): Emerging materials combining plastic waste and aggregates.

1.1. Sources and Mechanisms of Tire-Pavement Noise

Rolling noise stems from three key phenomena:

- Air pumping between surface voids,
- Tread block vibration under loading,
- Surface texture effects that amplify or reduce vibrations.

Reducing these effects requires: Controlled macrotexture, Adequate porosity (>15%), Effective sound absorption (Chen et al., 2024).

This review examines their effectiveness, technical feasibility, and potential for widespread implementation.

2. Material and methods

This study is structured as a targeted literature review focused on evaluating innovative pavement materials that reduce tire-pavement interaction noise. The goal is to synthesize recent, high-quality research on three specific material categories: porous asphalt (PA), rubberized asphalt (RA), and recycled plastic composites (RPC).

2.1. Selection Criteria

Peer-reviewed articles, technical reports, and recent field studies (from 2020 to 2024) were selected based on the following criteria:

- Relevance to road noise reduction through pavement design or material innovation,
- Inclusion of measured or modeled sound performance data (e.g., dB(A) reduction, sound absorption coefficients),
- Evaluation of durability, sustainability, or implementation feasibility.

Databases searched included ScienceDirect**,** Springer**,** MDPI. Key search terms included: *porous asphalt noise reduction*, *rubberized pavement acoustic performance*, *plastic road surface sound absorption*, and *tire-pavement interaction noise*.

2.2 Analysis Framework

Each selected material was analyzed across five main dimensions:

- Noise reduction performance (in decibels or absorption coefficients),
- Physical mechanisms behind acoustic behavior (e.g., porosity, elasticity),
- Durability and maintenance requirements,
- Environmental impact (e.g., use of recycled content),
- Cost and practicality for public works applications.

2.3 Limitations

As a literature review, this study does not involve direct experimentation or fieldwork. The conclusions are based on published data and may vary depending on regional climate, construction practices, and traffic types. Efforts were made to include only reliable, replicable sources and to highlight when data is preliminary or under development (especially for RPC).

3. Results and discussions

3.1 Noise Reduction Performance

Across all reviewed studies, porous asphalt (PA) consistently shows the highest potential for road noise reduction. Depending on void content, mix design, and layer thickness, it achieves reductions of 4 to 6 dB(A) in most cases—and up to 10 dB(A) in advanced double-layer systems (Castro-Fresno et al., 2024; Liao et al., 2024). These reductions are substantial: every 3 dB(A) drop halves the perceived noise level to the human ear.

Rubberized asphalt (RA), while not as acoustically aggressive as PA, delivers 2.5 to 4 dB(A) reduction on average (Chen et al., 2024). Its strength lies in its damping properties and durability under traffic loading.

Recycled plastic composites (RPC) demonstrate 1.5 to 2.5 dB(A) reduction depending on composition and application method (Liao et al., 2024). Though promising, the acoustic performance of RPC remains inconsistent and requires further refinement before large-scale adoption.

3.2 Durability and Maintenance

Durability is a key differentiator. RA outperforms other materials in resistance to rutting, fatigue cracking, and thermal deformation. It also shows self-healing potential under heat treatments, thanks to its elastic rubber content (Chen et al., 2024).

PA, while acoustically excellent, is vulnerable to clogging and weather degradation, especially in freeze–thaw regions. Long-term performance depends on maintenance strategies like vacuum sweeping or sealing.

RPC's durability varies by formulation. Some studies report early cracking under load or degradation under UV exposure. However, its chemical resistance and hydrophobic behavior make it a candidate for certain climates or modular road systems.

3.3. Environmental Impact

RA and RPC both offer clear circular economy benefits by incorporating end-of-life materials—tires and plastics, respectively. RA diverts tires from landfills and lowers embodied carbon, while RPC potentially addresses plastic waste challenges.

PA has modest sustainability benefits (e.g., reduced water spray, lower nighttime temperature due to reflectivity with light aggregates), but its environmental value improves significantly when paired with recycled aggregates or low-carbon binders.

3.4 Practical Implications for Road Design

- Porous asphalt is ideal for urban highways and high-speed zones where maximum noise reduction is critical.
- Rubberized asphalt suits urban and suburban roads, especially in warmer climates with heavy traffic loads.
- RPCs may be suited for pilot projects, low-speed areas, or as surface treatments—but require additional validation for long-term use.

3.5 Synthesis of Trade-Offs

Each material presents a trade-off between acoustic performance, cost, durability, and sustainability. Figure-based comparisons (see summary table 1) help decision-makers prioritize based on project goals. For example:

- PA is acoustically best, but higher maintenance.

- RA balances performance, durability, and sustainability.
- RPC is the most sustainable but least proven acoustically.

Table 1: *Comparative summary of the explored materials*

Material	Noise Reduction	Durability	Environmental Impact	Initial Cost
Porous Asphalt	★★★★★ (4–6 dB)	★★★	★★★★	★★★
Rubberized Asphalt	★★★★ (2.5–4 dB)	★★★★★	★★★★★	★★
Rec-Plastic Composites	★★ (1.5–2.5 dB)	★★	★★★★★	★★

CONCLUSIONS

Transitioning to quieter roads is both possible and urgent. Integrating porous asphalt, rubberized asphalt, or recycled plastic composites into infrastructure projects can reduce up to 85% of the sound energy generated by tire-pavement interaction. These technologies offer strong technical, environmental, and societal value. Public agencies and engineers should lead the way in implementing these solutions fully aligned with the goals of NCBMGSE-Béjaïa 2025.

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