

Abstract

In recent decades, the transition towards decarbonisation and circular economy principles has driven the research in road pavement engineering. In this context, a key challenge lies in optimising asphalt mixtures that incorporate high proportions of recycled products while ensuring adequate mechanical performance and durability.

Although the Reclaimed Asphalt (RA) represents a well-established circular practice in this sector, the application of high RA contents is often limited by the stiffness and brittleness of the aged binder. To overcome these limitations, rejuvenating agents are commonly employed, with growing interest in bio-based additives as more sustainable alternatives.

In parallel, the inclusion of recycled waste plastics in asphalt mixtures has emerged as a promising solution to enhance both environmental and mechanical performance of road pavements. However, the properties of mixtures integrating all these components cannot be extrapolated from the individual benefits provided by each material. Therefore, their combined influence needs to be further explored, in particular in terms of fatigue resistance.

The present study aims to assess the mechanical properties of sustainable asphalt mixtures incorporating 50% RA, a bio-based rejuvenating agent, and a recycled plastic compound (RPC) introduced through the hybrid modification method. Different RPC dosages (0.3%, 0.5%, and 0.7%) were investigated and compared against a reference wet-modified asphalt mixture produced with a virgin styrene-butadiene-styrene polymer-modified binder (SBS PmB).

The experimental programme was structured in three phases: (i) mix design optimisation, (ii) mechanical and performance-based laboratory investigation, and (iii) verification through in-plant production.

Findings from the laboratory investigation showed that hybrid-modified mixtures exhibited higher stiffness and strength than the wet-modified reference. While all mixtures manifested excellent resistance to permanent deformation due to the high RA content, fatigue testing demonstrated that the synergistic combination of RA and RPC yields resistance comparable to, and occasionally exceeding, the mixture manufactured with the SBS PmB.

Moreover, an additional experimental activity conducted on different base materials highlighted the temperature-dependent effectiveness of the hybrid modification approach and underscored the beneficial role of the bio-based rejuvenator in improving blending, moisture resistance, and low-temperature performance.

Although plant-scale production was impacted by issues regarding rejuvenator dosage, the findings confirmed the great potential of recycled waste plastics to be incorporated in high-RA mixtures, provided that the polymeric compound dosage is adequately balanced.