

Microwave-Activated Rejuvenator Intercalated Graphene Nanoplatelets for Self-Healing Asphalt Binders

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Abstract

Asphalt binder aging and fatigue cracking remain critical challenges for pavement durability, limiting service life and increasing maintenance costs. Here, we introduce rejuvenator filled graphene nanoplatelets (GnP-Rej), an advanced multifunctional additive designed to address these issues by combining graphene's structural reinforcement with bio-based rejuvenation and microwave-triggered self-healing. GnP-Rej is prepared by intercalating a vegetable-oil-derived rejuvenator into graphene nanoplatelets, creating a high-surface-area hybrid with the ability to store and release healing agents under microwave activation. Structural and chemical characterization using FTIR, Raman spectroscopy, XRD, XPS, TGA, and high-resolution TEM confirmed strong physical adsorption of the rejuvenator onto graphene surfaces, as well as defect formation that facilitates molecular interactions with asphalt. Rheological tests revealed that low-to-moderate GnP-Rej contents (0.1–0.24 wt%) improved rutting resistance ($G^*/\sin \delta$), while maintaining workability within acceptable limits. Microwave activation further enhanced rejuvenator diffusion, leading to significant improvements in fatigue life and flexibility. Linear Amplitude Sweep (LAS) results showed that GnP-Rej formulations achieved up to a two-fold increase in fatigue life compared to controls, with strain sensitivity reduced at higher additive loadings. Multiple Stress Creep Recovery (MSCR) tests confirmed improved deformation resistance and elastic recovery, while healing analysis demonstrated a Healing Index above 1.4 for microwave-treated binders. Collectively, these results demonstrate that GnP-Rej provides a scalable, cost-effective, and sustainable pathway for extending pavement service life by enabling extrinsic self-healing through synergistic graphene reinforcement, bio-based rejuvenation, and microwave activation [1].

References

[1] Akkouri, N.; Al-Shraideh, N.; Ben Salem, Y. A.; Alkhateb, H.; Nouranian, S.; Ucak-Astarlioglu, M. G.; Ben Youcef, H.; Al-Ostaz, A.; Majdoub, M. *Langmuir* 2025, 41 (30), 20280–20296

Figures

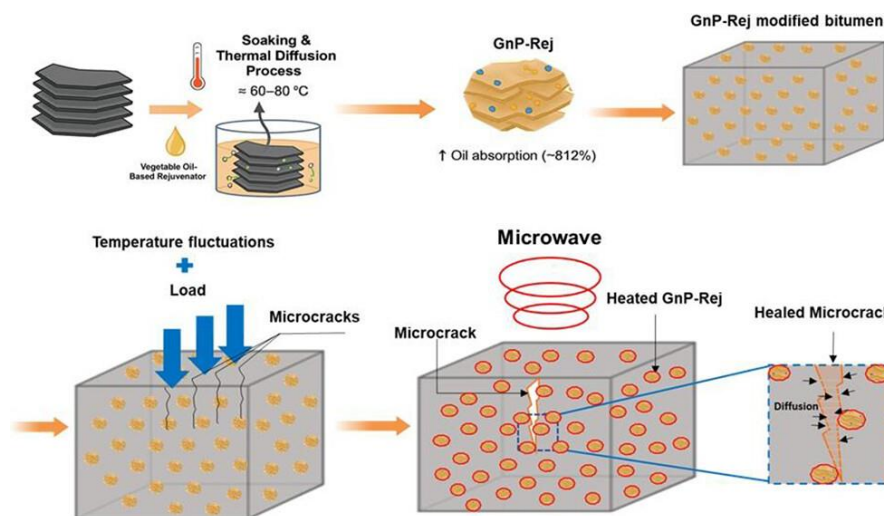


Figure 1: Schematic illustration of rejuvenator intercalated graphene nanoplatelets (GnP-Rej) preparation and microwave induced self-healing mechanism.