

Natural Rubber Latex Modified Concrete: Mechanical Performance, Durability, Sustainability and Pavement Applications

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Abstract—Latex-modified concrete (LMC) is a cement-based composite in which a polymer latex is introduced to improve selected aspects of strength, durability and performance during service. This review brings together the published literature on LMC, with particular attention to natural rubber latex (NRL), material constituents, the mechanisms behind performance changes, fresh and hardened properties, durability, rapid-strength bridge-deck overlays, sustainability, and the use of fibres and secondary materials. The studies considered report that suitable latex mixtures can limit the movement of water and chlorides and can improve adhesion, flexibility, abrasion resistance and flexural behaviour. These characteristics make LMC relevant to pavement works and bridge-deck repairs. NRL is a renewable, bio-based option alongside synthetic latexes and has also been investigated with fibres, fly ash, bottom ash and recycled fine aggregate. Outcomes depend on the latex formulation and quantity, mixture proportions, workability, curing regime and exposure conditions. Too much latex may increase entrained air, interfere with hydration, reduce workability or lower compressive strength. Overall, LMC— including NRL-based mixtures—has potential for transportation and repair works when its mix design and construction are carefully controlled.

Keywords—Bottom ash, Bridge deck overlay, Chloride permeability, Durability, Latex-modified concrete, Natural rubber latex, Pavement, Recycled aggregate, SBR latex, Very-early strength

I. INTRODUCTION

Concrete is widely used in construction because it is versatile, readily available and strong in compression. Nevertheless, conventional concrete may be affected by permeability, limited tensile and flexural capacity, shrinkage, surface wear and exposure to aggressive environments. These weaknesses have encouraged the study of polymer modification as one way to improve the service performance of cement-based materials [3].

Latex-modified concrete is produced by incorporating a polymer latex dispersion into a Portland-cement mixture. In synthetic systems, including styrene-butadiene rubber (SBR) latex [1], [3], latex is commonly blended with part of the mixing water.

During mixing, the polymer remains dispersed; as the material cures and dries, the particles can form a film within the cementitious structure.

More recent approaches explore the use of NRL together with fibres, bottom ash and recycled fine aggregate [2], [4], [5]. The aim is to investigate whether improved concrete performance can be achieved while making greater use of renewable inputs and recovered materials.

II. OBJECTIVES

This paper reviews previously published studies [1]–[7] to provide a general technical discussion of latex-modified concrete, particularly NRL and transportation-related uses. It outlines the principles of latex modification; summarizes reported mechanical and durability outcomes; considers workability, placement and curing; reviews very-early-strength LMC for bridge rehabilitation; discusses the sustainability potential of NRL; and identifies applications, limitations and topics requiring further research.

III. CONCEPT OF LATEX-MODIFIED CONCRETE

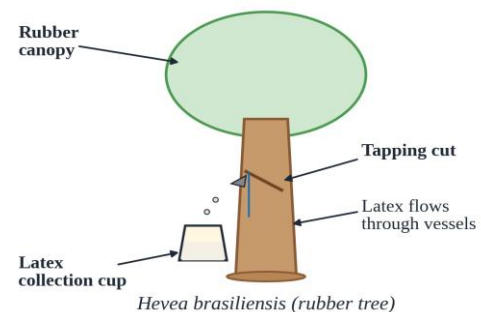


Figure 1. Schematic representation of natural rubber latex extraction from *Hevea brasiliensis*.

LMC is Portland-cement concrete modified with a dispersed polymer. In the conventional system, SBR particles are suspended in water and used to replace part of the mixing water. As the mixture develops and dries, the particles can coalesce into a polymer film within the cement paste [1], [3].

Natural rubber latex is a milky fluid obtained from the tree *Hevea brasiliensis*. Its rubber component is cis-1,4-polyisoprene, and the collected latex is generally stabilized and concentrated for commercial use. When introduced into concrete, latex particles distribute through the cementitious mixture and can form a continuous or partly continuous polymer phase as film formation proceeds. This phase may occupy small voids, bridge microcracks and improve contact between the paste and aggregate [2], [5].

These changes may make it more difficult for water and aggressive ions to travel through the concrete and may improve flexibility and crack bridging. However, the benefit depends on the amount and type of latex used. An excessive dose can entrain more air, impair workability, slow hydration and reduce compressive strength in some mixtures [2], [4].

IV. MATERIALS AND MIXING

The studies included in this review use different polymer systems and mixture proportions. One NRL high-performance-concrete investigation examined dry-rubber contents of 0.5–2% by cement mass and used a binder containing 20% fly ash [2]. The bottom-ash investigation assessed 10% and 20% replacement of river sand, with NRL dosages of 0%, 1.0%, 1.5% and 2.0% by cement mass [5]. A separate study using recycled fine aggregate tested replacement levels of 0–40% and included SBR latex at 5% of cement mass in its modified mixtures [4].

Good dispersion is necessary for consistent results. In the methods reported in the literature [1], [5], latex is first blended with the mixing water before the liquid is introduced into the mixer. Workability can be affected by the latex formulation, temperature, emulsifiers, super plasticizers and the time spent transporting the fresh concrete [6]. For this reason, construction control should include material temperature, mixing order, slump retention, air content and curing.

V. MECHANISM OF PROPERTY IMPROVEMENT

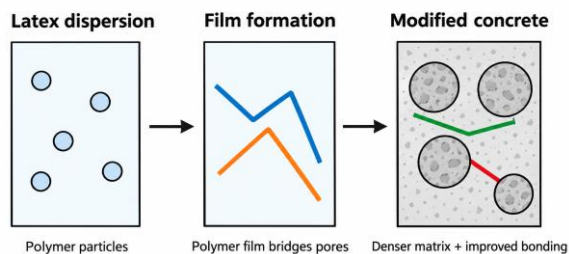


Figure 2. Schematic mechanism of latex modification in the concrete matrix.

The effect of latex develops through a sequence of related processes. Polymer particles first spread through the cementitious mixture. As curing and drying progress, the particles can join to form a continuous or partly continuous film. This film may bridge fine cracks, fill some pores and improve the bond between cement paste and aggregate. Together, these effects can reduce transport paths for water and aggressive ions and contribute to a more flexible composite.

According to Mathew and Joseph [2], scanning electron microscopy (SEM) showed a denser-looking matrix and latex layers around hydrated cement paste. The study associated these observations with lower water absorption and chloride penetration. The bottom-ash study [5] also reported improved interfacial bonding and crack-bridging behaviour when NRL was used. Conversely, a high latex dosage may create thicker polymer films that disrupt the cementitious network and delay hydration.

VI. MECHANICAL PERFORMANCE

Compressive-strength results vary with the latex system and dosage. In the NRL high-performance-concrete study [2], increasing NRL from 0.5% to 2% led to a small reduction in compressive strength relative to the control concrete. The same study indicated that combining latex with fibres could improve compressive performance. In the bottom-ash mixtures [5], 1.0% NRL improved compressive strength and helped offset losses associated with bottom-ash replacement, while higher NRL contents were less effective.

Flexural behaviour is a key performance measure for pavement and bridge-deck materials. Mathew and Joseph [2] reported a 35–45% increase in flexural strength for mixtures containing both NRL and fibres. Latex may also improve toughness and tensile behaviour by allowing better crack bridging and deformation. These features are useful in elements exposed to bending and repeated traffic loads.

A further benefit is offered by specially formulated very-early-strength LMC used in bridge rehabilitation. The field study of Sprinkel [1] targeted a compressive strength of about 20.7 MPa after three hours, although the target was not reached in every batch. Variations in cement and curing temperature influenced the rate of early strength development.

VII. WORKABILITY AND CONSTRUCTION

Maintaining workable concrete can be difficult when latex-modified mixtures lose slump quickly. The field study of Sprinkel [1] documented rapid slump loss, making prompt placement important.

Research on summer construction [6] examined workability loss in hot conditions and evaluated nonionic emulsifiers and superplasticizers as possible ways to improve slump retention. The use of recycled fine aggregate can create an additional workability challenge and increase slump loss [4].

Before an overlay is placed, the existing concrete surface must be prepared properly. Sprinkel [1] describes mechanical scarification or shot-blasting, removal of contaminants and appropriate moisture conditioning. Latex is blended with the mixing water before the dry constituents are added, helping it disperse throughout the mix. Depending on site requirements, placement can use pumping, mechanical screeding or another suitable method.

Curing conditions and weather management affect the final result. Fast evaporation in hot or windy conditions can shorten the finishing period and increase the risk of plastic-shrinkage cracks. Field guidance [1] recommends moist curing followed by suitable air curing to support polymer-film formation and strength development.

VIII. DURABILITY PERFORMANCE

Improved durability is a major reason for considering LMC. The polymer phase and changes in the pore structure may restrict the movement of water and chloride ions. Sprinkel [1] describes improved resistance to chloride ingress in LMC overlays, which can help reduce corrosion risk for reinforcement in bridge decks. Mathew and Joseph [2] also reported lower water absorption and chloride permeability.

Published studies also report potential gains in resistance to surface wear and impact. In the NRL study of Mathew and Joseph [2], concrete wear was reduced by up to 12% with latex and by up to 19.84% when latex was combined with fibres. The hybrid fibre-latex mixture showed an increase in impact energy absorption of up to 231%. These figures apply to the specific mixtures tested and should not be treated as universal values for all latex-modified concrete.

Resistance to freeze-thaw cycling varies with the polymer system and its dosage. Moodi et al. [3] found different responses among the polymer-modified mixtures. Chemical resistance also depends on the exposure: Muhammad and Ismail [7] reported improved sulfate resistance under the tested conditions, but sulfuric-acid exposure caused volume changes associated with latex. NRL should therefore not be assumed to perform equally well in every chemical environment.

IX. VERY-EARLY-STRENGTH LMC FOR BRIDGE DECKS

Bridge-deck repair projects often aim to minimize disruption by returning traffic to the repaired lane quickly. Very-early-strength latex-modified concrete (LMC-VE) was developed to meet this need. Sprinkel [1] described overlays on two Virginia bridges that, under the reported conditions, could be opened to traffic after approximately three hours.

The field procedure included surface scarification and shot-blasting, wetting, concrete placement and consolidation, control of site conditions, and rapid moist curing with wet burlap and polyethylene. The minimum overlay thickness was 32 mm; the overlay on Route 620 averaged 64 mm. Bond tests often showed failure within the old concrete rather than at the overlay interface. Plastic-shrinkage cracks were also observed, underlining the importance of weather management and curing [1].

The special blended cement used for LMC-VE cost more than conventional cement. However, the field study [1] indicated that reduced traffic-control costs could compensate for the higher material cost. For rehabilitation projects, the total economic assessment should therefore consider not only material price but also the duration of construction and the disruption experienced by road users.

X. NATURAL RUBBER LATEX AS A SUSTAINABLE MODIFIER

Important engineering roles of natural rubber latex

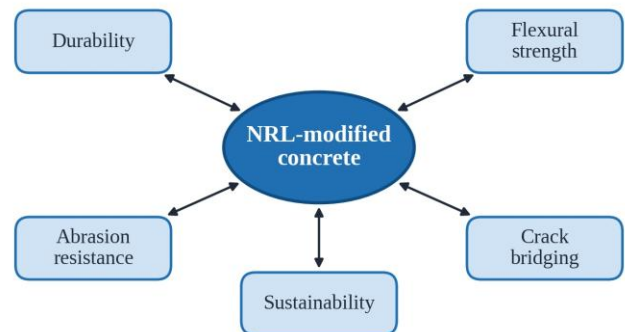


Figure 3. Important engineering roles of natural rubber latex modified concrete.

NRL may offer a bio-based alternative to synthetic rubber latex. It is reported that natural rubber is collected from rubber trees without felling them, while synthetic latex production relies on petroleum-derived resources [2]. Mathew and Joseph [2] give embodied-energy estimates of approximately 15–16 MJ/kg for natural rubber latex and 100–150 MJ/kg for synthetic latex.

Reported engineering functions of NRL include increasing flexibility, damping vibration, improving wear behaviour and strengthening the interface between cement paste and aggregate. India is a major producer and consumer of natural rubber [2], which makes NRL relevant to the Indian construction sector. Its environmental benefit should nevertheless be assessed across the full system, including dosage, processing additives, transportation, curing, service life and end-of-life considerations.

XI. LATEX WITH WASTE MATERIALS AND FIBRES

Research combining latex with industrial by-products and recovered materials seeks to reduce reliance on virgin resources. Bottom ash, a by-product of coal combustion, can be used to replace part of the natural sand. Kantatham et al. [5] described NRL as helping densify the material and improve bonding. Of the combinations examined in that study, a 1.0% NRL dosage gave the best overall balance for the tested bottom-ash mixtures.

Using fine recycled aggregate can reduce the need for newly quarried aggregate. However, residual mortar attached to recycled particles may raise absorption and porosity and make fresh concrete less workable. The study of Al-Luhybi et al. [4] found that SBR latex compensated for some of the strength loss and improved absorption resistance and porosity-related performance. Under the conditions investigated, the authors considered replacement levels up to 30% capable of producing acceptable compressive strength.

Fibre-latex combinations may provide additional control of cracking and improve energy absorption. Polypropylene or basalt fibres can help limit crack propagation, while NRL may improve bonding at the fibre-cement-paste interface. Such hybrid systems are potential options for high-performance pavement and bridge-deck concrete [2].

XII. ENGINEERING APPLICATIONS

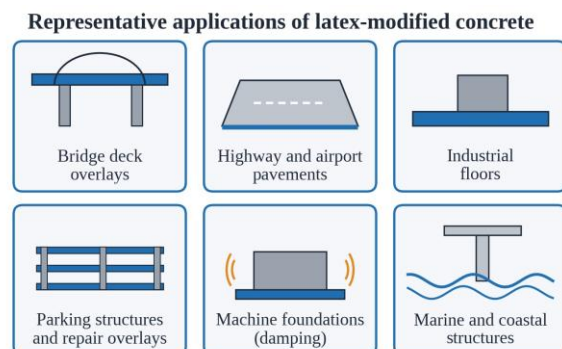


Figure 4. Representative engineering applications of latex-modified concrete.

- Bridge deck overlays and rapid rehabilitation where reduced lane-closure time is important.
- Rigid highway and airport pavements requiring flexural performance, abrasion resistance and durability.
- Industrial floors subjected to wear, impact and selected chemical exposure.
- Parking structures and repair overlays where low permeability and strong bonding are required.
- Machine foundations and vibration-sensitive structures where damping and toughness can be useful.
- Marine and coastal structures exposed to moisture and chloride-related deterioration, subject to appropriate exposure verification.
- Sustainable pavement systems incorporating bottom ash or recycled fine aggregate, subject to specification and performance testing.

XIII. ADVANTAGES

- Reduced water and chloride ingress in suitable mixtures.
- Improved flexural performance, toughness and crack-bridging capacity.
- Improved abrasion and impact resistance.
- Improved bond between old and new concrete in overlay applications.
- Potential improvement in selected freeze-thaw and aggressive-environment conditions.
- Very-early-strength systems can shorten bridge-deck lane closures.
- Natural rubber latex provides a bio-based alternative to synthetic latex.
- Compatibility with fibres and selected waste materials such as bottom ash and recycled aggregate.

XIV. LIMITATIONS AND CHALLENGES

- Rapid slump loss may require fast construction or workability-control measures.
- Excessive latex can increase air entrainment and reduce compressive strength.
- Higher latex contents may delay cement hydration.
- Very-early-strength cement systems can show batch-to-batch variability.
- Low curing temperatures can retard early strength development.
- Plastic-shrinkage cracking remains a risk in high-performance overlays.
- Natural rubber latex is not resistant to every chemical exposure; sulfuric-acid exposure requires caution.

- Polymer-modified systems can have higher initial material costs.
- Long-term field validation is still required for several newer NRL and waste-material combinations.

XV. COMPARATIVE REVIEW OF PREVIOUS STUDIES

TABLE I
COMPARATIVE REVIEW OF PREVIOUS STUDIES

Study	Material/System	Main focus	Reported application/finding
Sprinkel (1999) [1]	SBR-LMC-VE	Bridge overlay / early strength	Traffic reopening in about 3 h under reported field conditions
Moodi et al. (2018) [3]	SBR / epoxy LMC	Strength and durability	Polymer content strongly affects performance
Muhammad & Ismail (2012) [7]	NRL concrete	Acid and sulfate exposure	Improved sulfate resistance; acid exposure requires caution
Al-Luhybi et al. (2023) [4]	SBR + recycled fine aggregate	Physical and mechanical properties	Latex offsets part of recycled-aggregate performance loss
Han et al. (2024) [6]	SBR + emulsifier/superplasticizer	Summer workability	Admixture system improves slump retention
Kantatham et al. (2024) [5]	NRL + bottom ash	Sustainable rigid pavement	1.0% NRL gave best investigated bottom-ash mix
Mathew & Joseph (2025) [2]	NRL + fibres + fly ash	High-performance concrete	Improved flexural, impact, abrasion and durability behaviour

XVI. DISCUSSION

Taken together, the reviewed studies [1]–[7] show a more consistent improvement in durability-related behaviour than in compressive strength. Frequently reported benefits include lower water absorption and permeability, improved chloride resistance, stronger bonding, better abrasion resistance, and improved flexibility and flexural response. These characteristics support the use of LMC where service life and serviceability are important alongside strength.

A recurring conclusion is that the best latex content depends on the particular mixture. There is no single optimum that can be transferred directly between studies because latex chemistry, cement type, aggregate characteristics, replacement levels and test methods differ. In the bottom-ash study [5], 1.0% NRL performed best among the tested combinations.

The high-performance-concrete study [2] investigated 0.5–2% NRL and found that the higher contents could slightly reduce compressive strength.

The literature also shows that research is moving beyond isolated material properties toward practical construction needs. Very-early-strength LMC targets shorter lane closures [1]; hot-weather studies [6] address loss of workability; NRL research [2] explores bio-based modifiers; and bottom-ash and recycled-aggregate studies [4], [5] examine resource efficiency and waste reuse. Future development will likely depend on balancing these objectives through integrated mix design.

XVII. FUTURE SCOPE

- Long-term field monitoring of NRL-modified bridge decks and pavements under Indian climatic and traffic conditions.
- Development of standardized mix-design procedures and codal guidance specifically for NRL concrete.
- Optimization of latex dosage with fibres, fly ash, silica fume and other supplementary cementitious materials.
- Full life-cycle assessment comparing NRL-LMC, SBR-LMC, conventional concrete and other overlay systems.
- Combined temperature, fatigue, chloride and chemical exposure studies.
- Improved admixture systems for slump retention without sacrificing strength.
- Field validation of bottom-ash and recycled-aggregate NRL concrete at larger pavement scales.
- Predictive models linking latex content, pore structure, permeability and service life.

XVIII. CONCLUSION

The literature reviewed here suggests that latex-modified concrete is a useful candidate for transportation infrastructure, concrete repair and rehabilitation. Reported benefits include lower permeability, better durability and bonding, improved flexural behaviour, and greater abrasion and impact resistance. Special formulations can also develop strength rapidly enough to support early reopening of bridge decks. NRL broadens the sustainability options for LMC because it is a bio-based alternative to petroleum-derived synthetic polymers.

The reviewed studies [2], [5] indicate that NRL may contribute to a denser microstructure and improved durability, flexural response and impact behaviour, particularly when combined with fibres.

Mixtures incorporating bottom ash or recycled fine aggregate may also support more efficient use of materials. These findings are specific to the materials and conditions tested, so further laboratory and field validation is needed before applying them broadly.

LMC should be designed and built as a controlled material system rather than treated as a simple additive to conventional concrete. Successful results depend on choosing a suitable latex and dosage, maintaining workable fresh concrete, preparing the substrate correctly, applying an appropriate curing regime and checking performance against the intended exposure. In bridge and pavement rehabilitation, LMC is especially relevant when improved durability and shorter traffic closures are important project requirements.

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Figure note: The figures in this paper are original schematic illustrations prepared for this document to explain the material, mechanism and applications; they are not experimental micrographs.