Solstice

FUNCTIONALISED POLYMERS FOR HIGH PERFORMANCE AND SUSTAINABLE PAVEMENTS

A life cycle assessment of advanced additives in flexible pavement.

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EXECUTIVE SUMMARY

As India accelerates infrastructure development, the road construction sector faces a dual challenge—meeting performance expectations while reducing environmental impact.

This whitepaper presents a Life Cycle Assessment (LCA) comparing conventional and advanced additives used in polymer modified bitumen (PmB). LCA is a globally recognised methodology used to measure environmental impact across every stage of a product or process lifecycle.

The analysis demonstrates that **functionalised polyolefin (FPO)** can reduce carbon emissions by up to 10.4%, while delivering equivalent pavement performance. 10.4% saving in CO_2 emissions is equivalent to avoiding emissions from 3150 liters of petrol per kilometer of paved road.*

*As per the EPA calculator - epa.gov/energy/greenhouse-gas-equivalencies-calculator

THE PHASES INVOLVED ARE:

Phase 1

GOAL AND SCOPE

- Objectives
- Functional unit
- System boundaries and unit operations

Phase 2

LIFE CYCLE INVENTORY (LCI)

- Data collection
- Data verification
- Inputs/outputs between environments and unit processes of study

Phase 3

LIFE CYCLE IMPACT ASSESSMENT (LCIA)

- Modeling of products system
- Contribution to impact categories (characterization)
- Normalization and weighting

INTERPRETATION

- Conclusion and recommendations

The findings point to a clear conclusion: **Lower-carbon infrastructure can be achieved today through smarter material choices.**

KEY TAKEAWAYS

- Up to 10.4% reduction in CO_2 emissions per kilometre of road
- Lower energy consumption during production and processing
- Equivalent durability and performance vs traditional solutions
- Flexible application across manufacturing stages

PROBLEM

India's aggressive highway expansion is increasing emissions from material production, transport, and construction processes.

OPPORTUNITY

Material innovation enables immediate emissions reduction—without redesigning infrastructure or altering specifications.

SOLUTION

Functionalised Polyolefin (FPO) as an alternative to SBS in Polymer Modified Bitumen (PmB):

- Lower processing temperatures
- Reduced mixing time
- Flexible integration (PmB or HMA stage)

EVIDENCE

- Up to 10.4% CO_2 reduction per km
- Reduced energy consumption across manufacturing and paving
- Equivalent performance (fatigue, rutting, IRI)

IMPACT

- Immediate alignment with MoRTH sustainability focus, IRC performance standards, and India's Net Zero commitments
- Scalable, implementation-ready decarbonisation pathway

ALIGNING WITH NATIONAL STANDARDS & SUSTAINABILITY GOALS

This study directly supports India's evolving infrastructure and sustainability framework:

MoRTH (Ministry of Road Transport & Highways):

- Emphasis on sustainable construction practices and reduced energy consumption.
- Encouragement of innovative materials improving lifecycle performance.

IRC (Indian Roads Congress):

- Performance-driven specifications (fatigue, rutting, durability).
- Increasing focus on lifecycle-based evaluation and material efficiency.
- National Sustainability Goals.

India's Net Zero 2070 commitment:

- Reduced carbon intensity in infrastructure development.
- Promotion of energy-efficient construction technologies.

CONCLUSION

FPO-based solutions align with both performance compliance (IRC) and policy direction (MoRTH + climate targets)—making them immediately relevant for adoption.

THE CHALLENGE

India's highway expansion has significantly improved connectivity and economic growth. However, road construction remains energy-intensive and carbon-heavy, driven by:

High-temperature material processing.

Fuel-intensive manufacturing and transport.

Large-scale use of bitumen and aggregates.

India's infrastructure growth has delivered economic benefits—but at a cost:

- High-temperature bitumen processing (~180°C)
- Long mixing durations (~15 hours)
- Fuel-intensive logistics and plant operations

Traditional approaches optimise cost and performance—but not lifecycle emissions.

With increasing regulatory and sustainability pressures, the industry must now focus on reducing lifecycle emissions, not just upfront costs.

WHY LCA?

LCA provides a holistic view of environmental impact, covering:

Raw material extraction

Manufacturing processes

Transportation and logistics

Construction activities

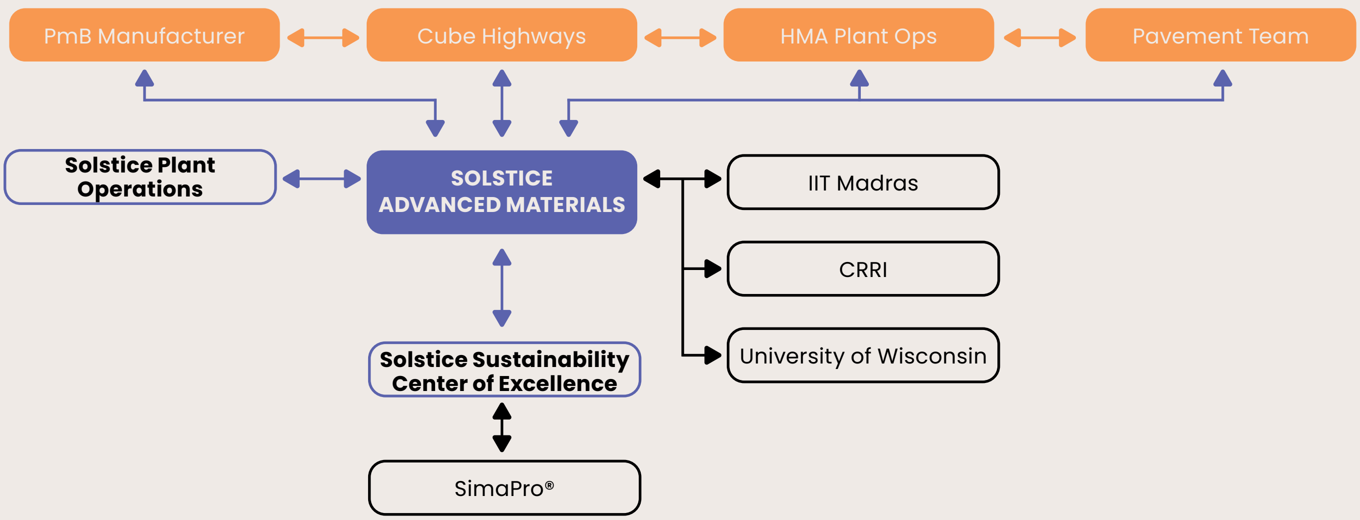
This study adopts a **'cradle-to-construction'** approach, enabling accurate measurement of emissions from material sourcing through to final pavement laying.

A critical component of any LCA is the Life Cycle Inventory (LCI)— the collection and validation of operational data such as material inputs, fuel consumption, electricity use, transport distances, process temperatures, equipment utilisation, and waste generation.

LCI is often the most time-intensive and rigorous stage of the process. Its accuracy is essential to ensuring robust, credible, and decision-useful sustainability outcomes.

WHY DATA QUALITY MATTERS

Accurate lifecycle decisions depend on accurate operational data. Rigorous inventory collection ensures dependable carbon footprint comparisons. The data presented has been arrived at after several interactions with the following stakeholders in the LCIA value chain.



The schematic in Figure 1 shows the stages and system boundary that was used. Extension of the system boundary to include maintenance and end-of-life (RAP addition) would be a planned future study to encompass a cradle-to-cradle scope.

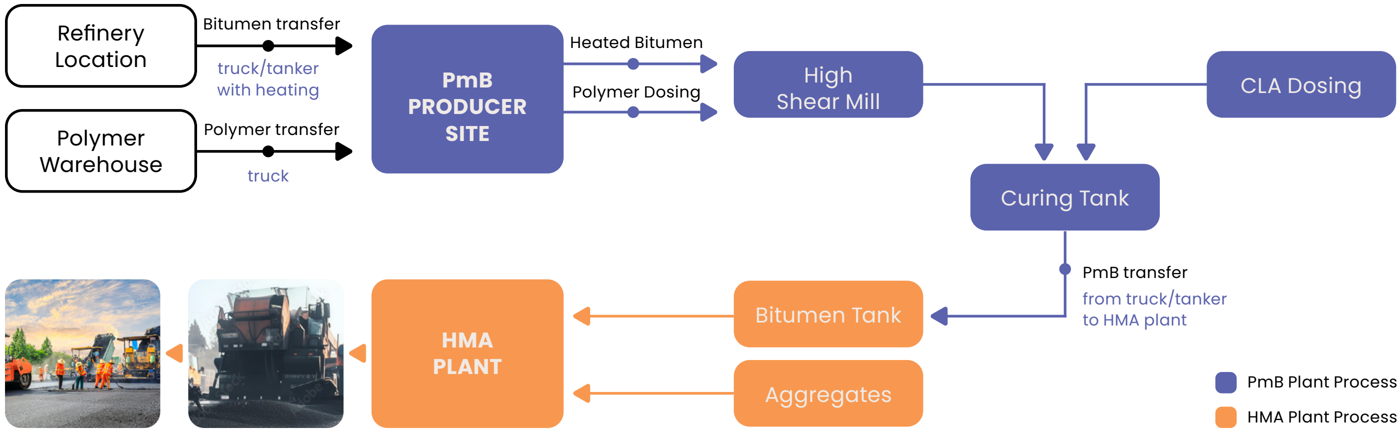


Figure 1: *System boundary and stages in pavement construction process.*

OBJECTIVE

To evaluate whether advanced additives can reduce carbon emissions in road construction without affecting performance.

WHAT WAS COMPARED

PARAMETER	CONVENTIONAL APPROACH	ADVANCED APPROACH
Additive type	SBS (Styrene-Butadiene-Styrene)	Functionalised Polyolefin (FPO)
Application	PmB Stage	PmB / Direct HMA Addition
Focus	Performance	Performance + Sustainability

PROJECT SCOPE

- **Location**: Kamalpura on Jaipur-Mahua Highway, Rajasthan
- **Road length**: 1 km
- **Width**: 8.75 m
- **Layer thickness**: 40 mm

ASSESSMENT FRAMEWORK

- **Tool**: Simapro® 10.2.0.2 (LCA modelling)
- **Database**: Eco-invent
- **Metric**: Global Warming Potential (CO_2 equivalent)
- **Scope**: Cradle-to-construction assessment

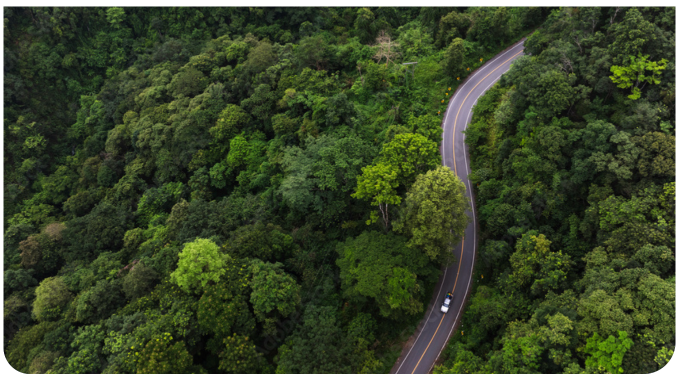
KEY INSIGHT 1:

Significant emissions reduction

The study highlights a clear environmental advantage with advanced additives:

SOLUTION	EMISSIONS (tCO_2e per km)
SBS	~70.78
FPO (PmB stage)	~63.39
FPO (Direct addition)	~62.69

10.4% lower emissions with FPO.



KEY INSIGHT 2:

Energy efficiency drives impact

The emissions reduction is primarily driven by lower energy requirements:

PARAMETER	SBS	FPO
Processing Temperature	~180°C	~155°C
Mixing Time	~15 Hours	~3 Hours
Process Complexity	High	Reduced

Lower energy demand directly translates to reduced fuel use and emissions.

KEY INSIGHT 3:

Operational flexibility

FPO offers greater flexibility in application and can be added during bitumen modification (PmB stage) or can be directly introduced at the asphalt mixing plant in bitumen tank (HMA stage).

This enables:

- Simplified logistics.
- Reduced processing steps.
- Improved operational efficiency.

KEY INSIGHT 4:

Performance is maintained

Extensive field testing confirms that sustainability does not compromise performance.

Performance metrics evaluated:

- Fatigue resistance.
- Rutting resistance.
- Surface smoothness (IRI).

RESULT

FPO-based pavements demonstrate performance equivalent to traditional SBS solutions, meeting all relevant standards.

VALUE CHAIN IMPACT

BITUMEN MODIFIER

- Lower energy processing.
- Reduced viscosity -> lower motor load.
- Improved storage stability.

HOT MIX PRODUCER

- Lower production temperatures.
- Reduced fuel consumption.
- Extended haul distances.

PAVING CONTRACTOR

- Faster paving cycles.
- Reduced fuel use.
- Improved workability.

ROAD OWNER / AUTHORITY

- Longer lifecycle performance.
- Reduced emissions footprint.
- Lower maintenance risks.

OUTCOME

Sustainability gains across the entire value chain.

WHAT THIS MEANS FOR THE INDUSTRY

Policy makers

- Enable low-carbon material specifications.
- Integrate LCA-based decision frameworks.
- Accelerate climate-aligned infrastructure.

Consultants & designers

- Specify materials based on lifecycle performance, not just cost.
- Support sustainability-driven tender frameworks.

Contractors

- Reduce fuel costs and improve efficiency.
- Simplify operations with flexible material use.

Developers / Asset owners

- Achieve ESG goals without redesign.
- Improve long-term asset value.

THE BIGGER OPPORTUNITY

Material innovation is one of the fastest and most scalable ways to reduce emissions in infrastructure.

Unlike structural redesign or policy shifts, this approach can be implemented immediately within existing systems

FUTURE OUTLOOK

This study focuses on emissions up to construction. Future evaluations will include:

- Maintenance cycles
- Recycling and reclaimed asphalt usage
- Long-term lifecycle performance

This will enable a complete 'cradle-to-use' sustainability model for road infrastructure.

As infrastructure demand grows, the focus must shift from building more to building responsibly.

This study demonstrates that advanced additives such as FPO can deliver measurable carbon reduction, improve process efficiency, and maintain high performance standards.

The transition to lower-carbon roads can begin today—with smarter material decisions.

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ABOUT SOLSTICE TITAN™

Solstice Titan is a family of polyolefin-based products that can be blended with asphalt binders to build durable and sustainable pavements at lower overall costs.

- Enables meaningful reductions in production and compaction temperatures — while maintaining and often improving pavement performance. By modifying the binder at a molecular level, it improves lubricity and aggregate packing, allowing asphalt mixtures to reach target densities with less thermal energy and less compaction effort.
- Functions as both a rheology modifier and a lubrication enhancer. While it increases high-temperature stiffness to resist rutting, it simultaneously improves aggregate packing density during compaction. This dual functionality strengthens the internal structure of the asphalt layer rather than simply increasing viscosity.
- Helps reduce capital investment and operational downtime as it does not require high shear mixing equipment and can be incorporated within one to two hours.

Incorporating Solstice Titan into your paving projects help you align with innovative practices to enhance performance and durability, cost saving, and significantly contribute to sustainability efforts.

For more information on how Solstice Titan can benefit your next project, please visit our website for more resources and to get in touch with our team of experts.

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