

Global Road Infratech Summit & Expo



Next-Generation Self-Healing Pavements: Performance Enhancement and Self-Healing Behaviour of Asphalt Mixtures Using Microcapsule Encapsulated Rejuvenators

Sachin Gowda^{*a}, Ambika Behl^a, Kadhiravan Shanmuganathan^b

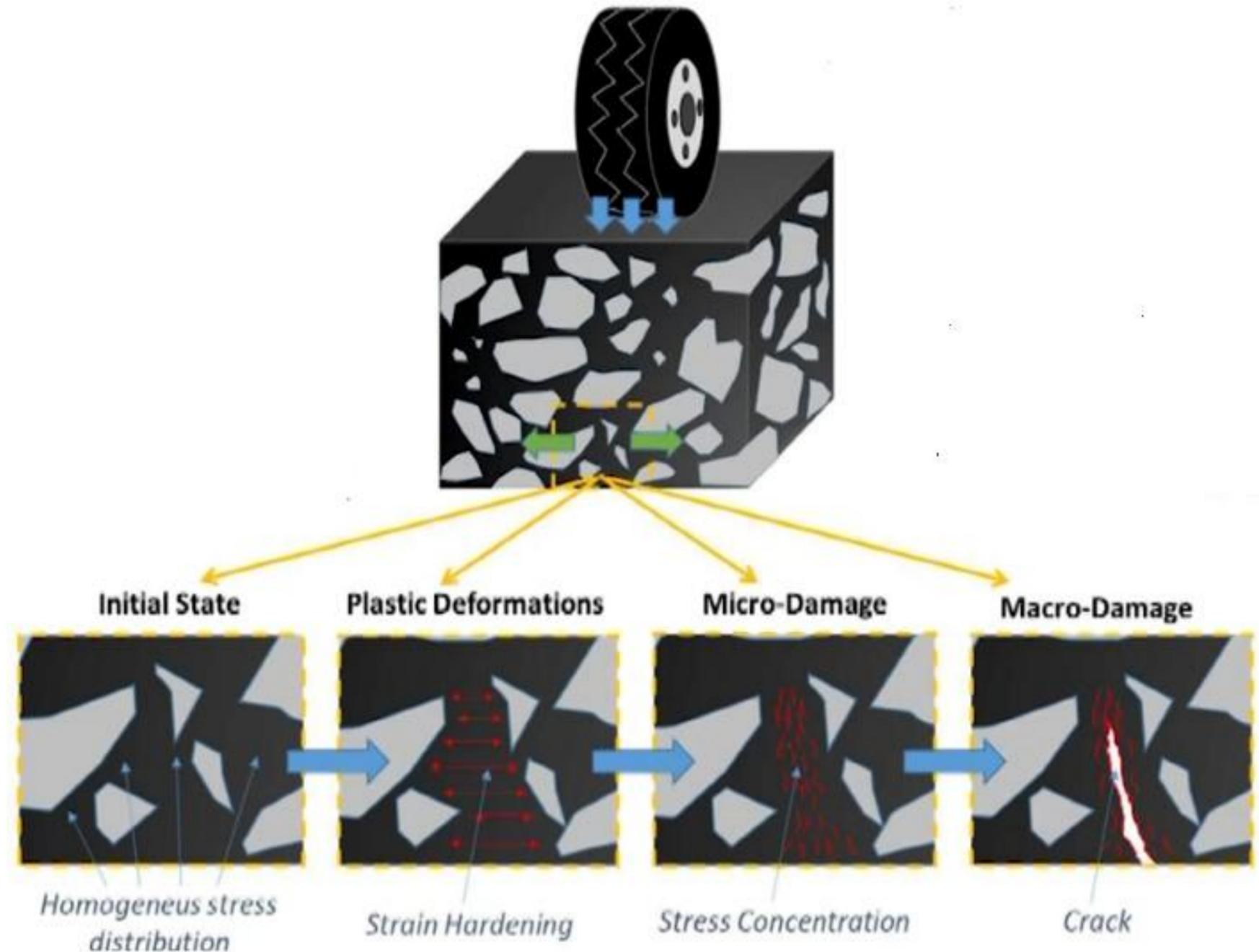
^aCSIR-Central Road Research Institute (CRRI), New Delhi, India

^bCSIR--National Chemical Laboratory (NCL), Pune, India

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Background for the Study

- Oxidative Aging
- Asphaltenes and Maltenes (PAs, NAs, Saturates)
- Rejuvenators
- Application of Rejuvenators
- Encapsulation of rejuvenators



Ref. Navarro et al, 2016

Concept of Microcapsule encapsulation

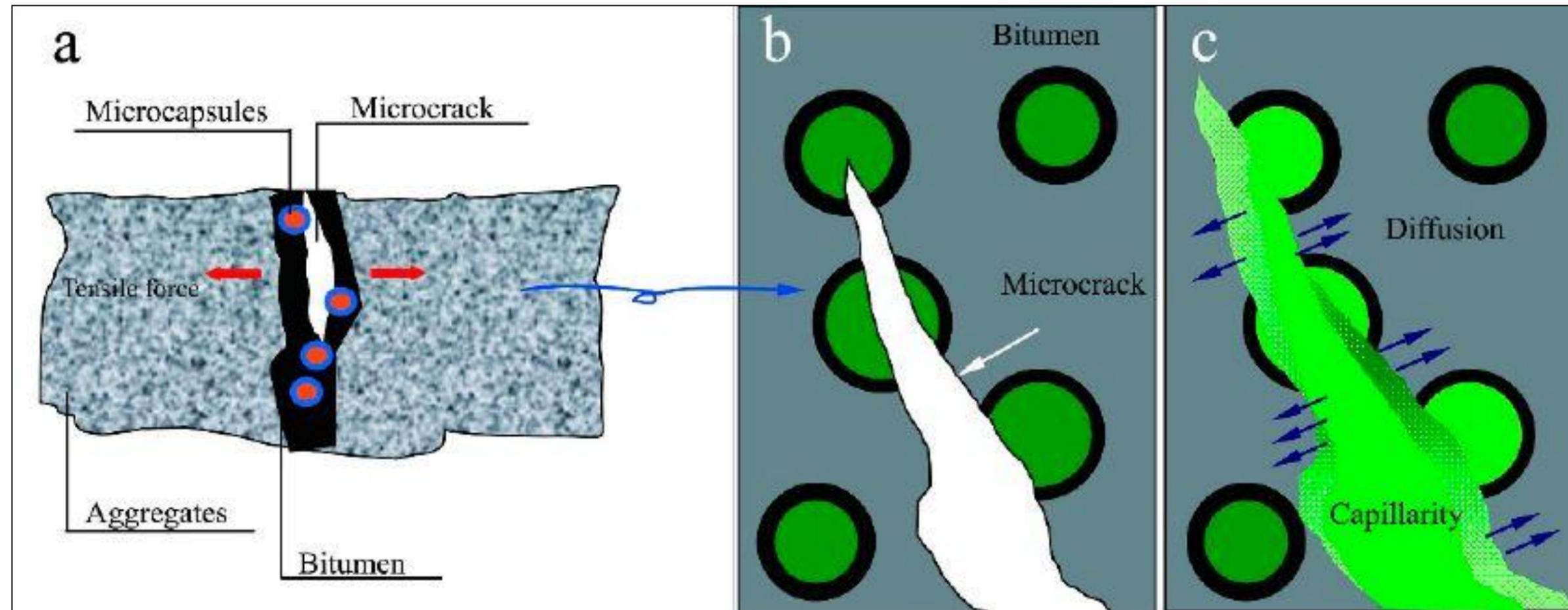
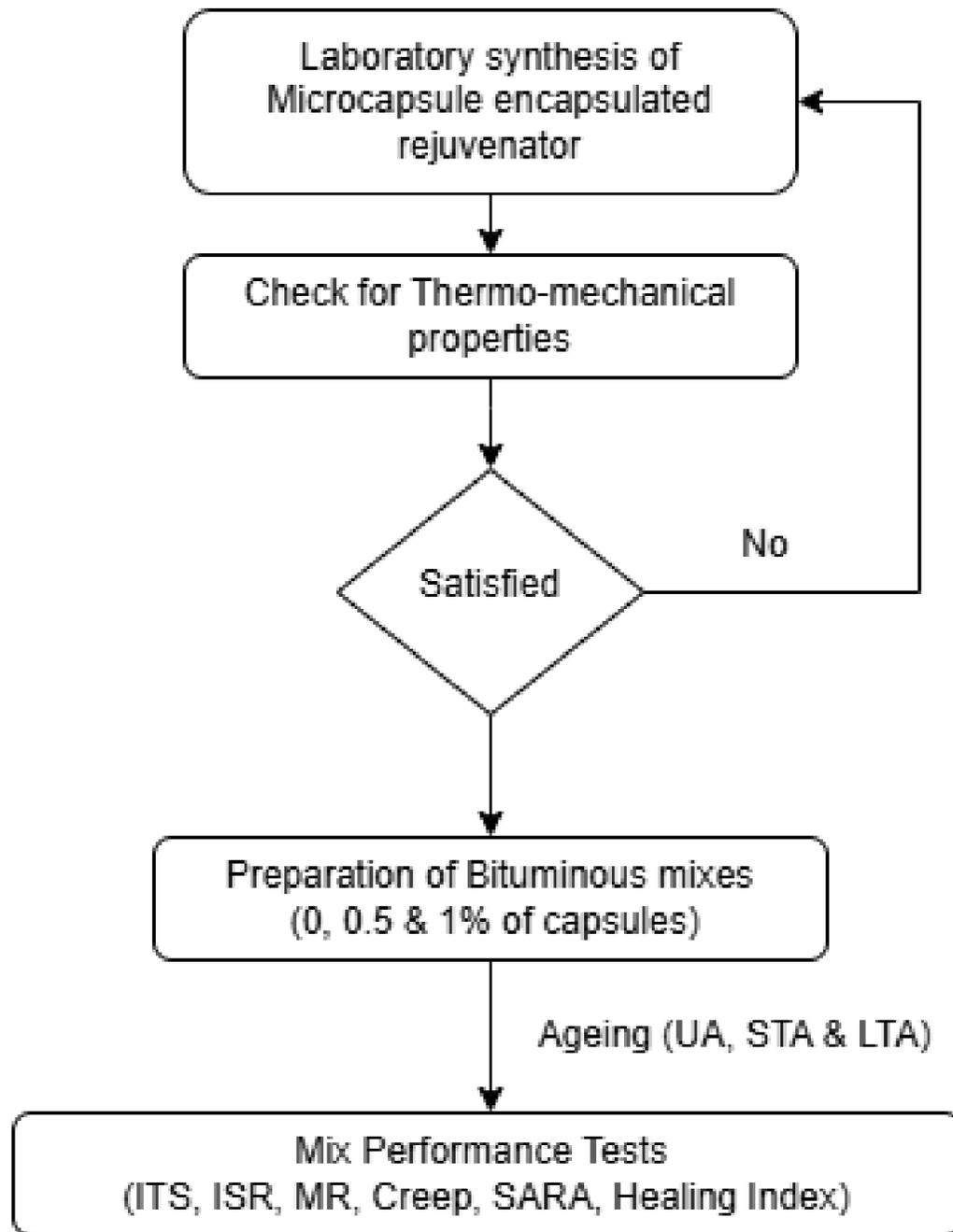


Figure: (a) the structure of asphalt consisting of bitumen and aggregates; (b) microcrack generation and microcapsules broken; and (c) the self-healing of aged bitumen by leaked rejuvenator with the help of diffusion and capillarity actions.

Ref. Jun-Feng Su et al, 2016

Methodology



Steps for Microcapsule Preparation

Step 1: Preparing the Sodium Alginate Solution

Step 2: Mixing with Rejuvenator Oil

Step 3: Dropping into the Hardener (CaCl_2)

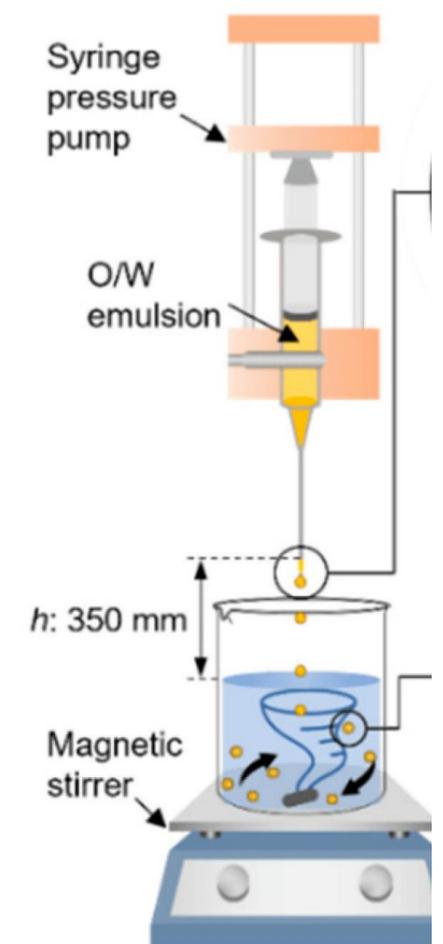
Step 4: Cross-Linking (Bead Formation)

Step 5: Collecting the Capsules

Step 6: Drying



Figure: Laboratory Synthesized Calcium Alginate Capsules.



Ref. Norambuena-Contreras J et al, 2022

Physical Properties of Microcapsules

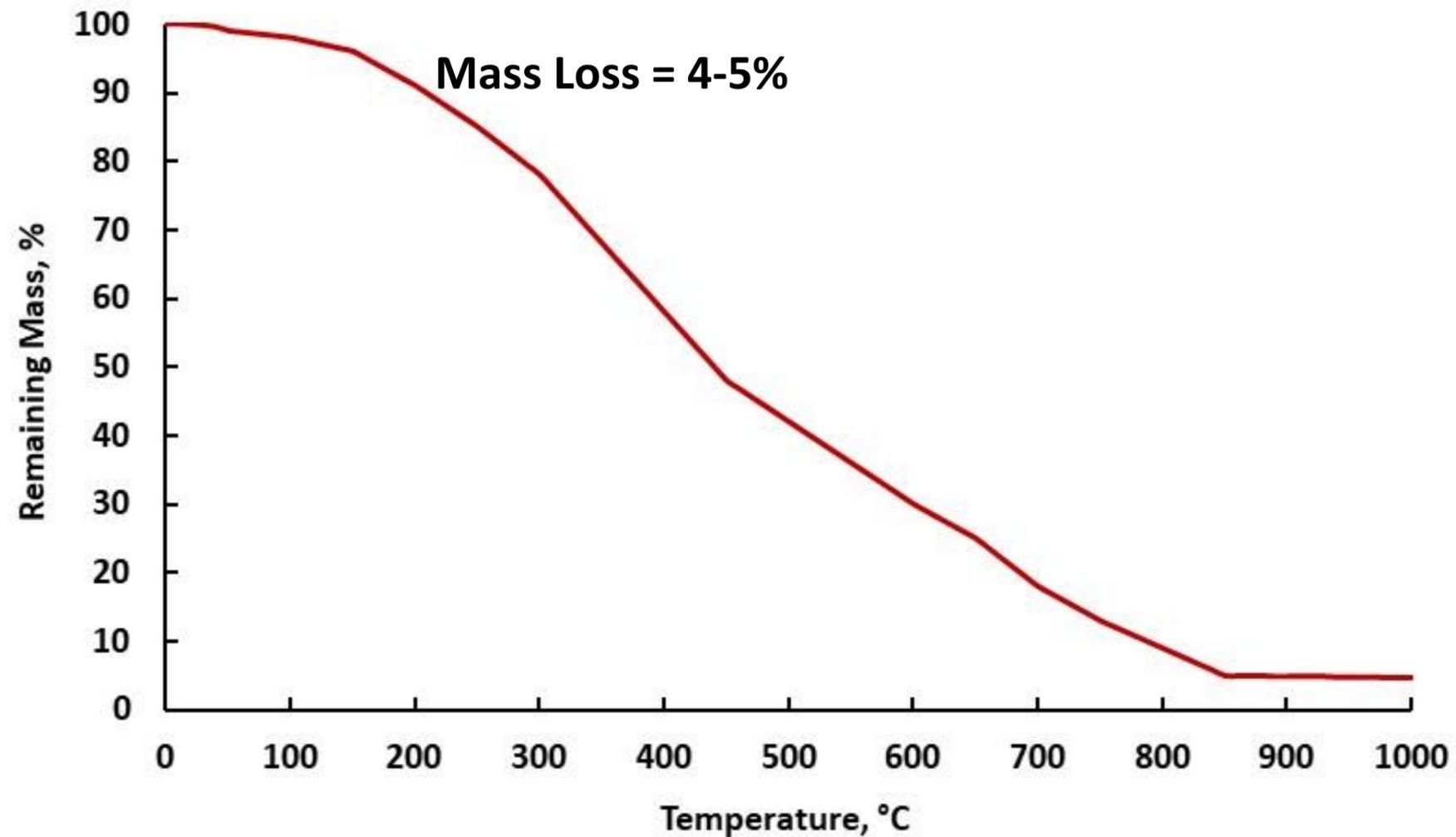


Figure: TGA Analysis

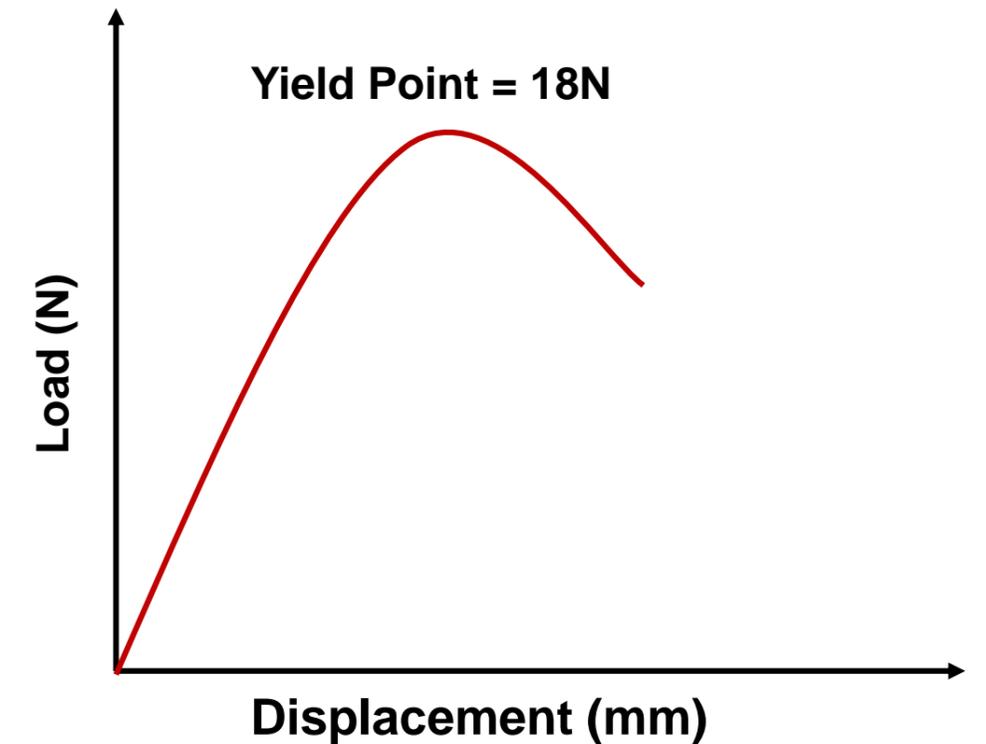


Figure: Load-Displacement Curve

Mix Design

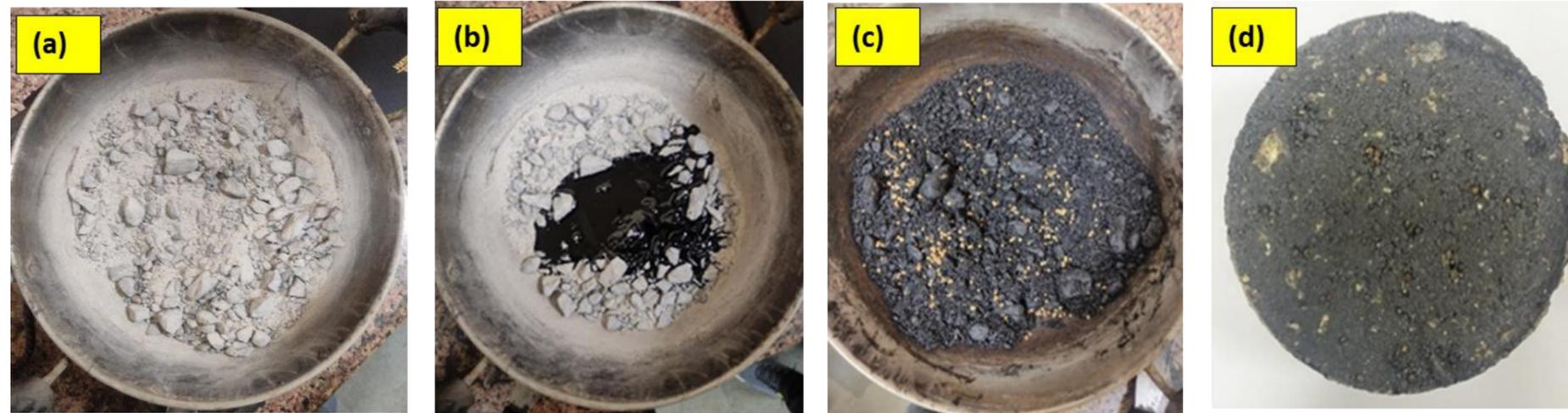


Figure : (a) Preheated Aggregates, (b) blending of bitumen with Preheated Aggregates, (c) Addition of microcapsules to asphalt mix, and (d) compacted specimen containing microcapsules, bitumen, and aggregates.

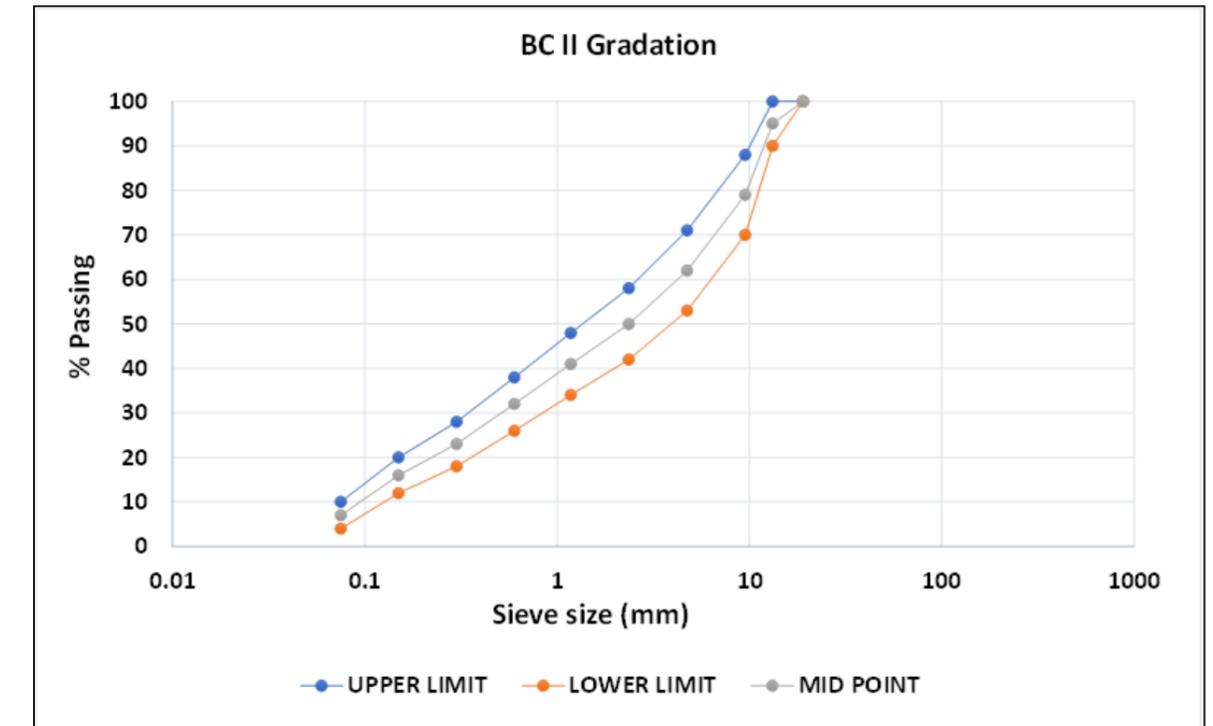


Figure: Gradation for BC-II Mix Used.

Table: Properties of the bitumen used

Description of test	Reference Standard	Result
Softening Point, ° C	ASTM D 36 – 14	51.6
Ductility, cm	ASTM D 113-17	>100
Penetration, mm	ASTM D5M-20	42.44
Specific Gravity	ASTM D70-21	1.06
Viscosity at 135° C, cS	ASTM D4402-15	463

Table: Properties of the coarse aggregates used

Property	Reference Standard	Result
Combined Index (FI+EI)	IS 2386 (Part 1):1963	31.04
Aggregate Impact Value	IS 2386 (Part 4):1963	18.03
Los Angeles Abrasion Value	IS 2386 (Part 4):1963	26.30

Distribution of Capsules within Mix

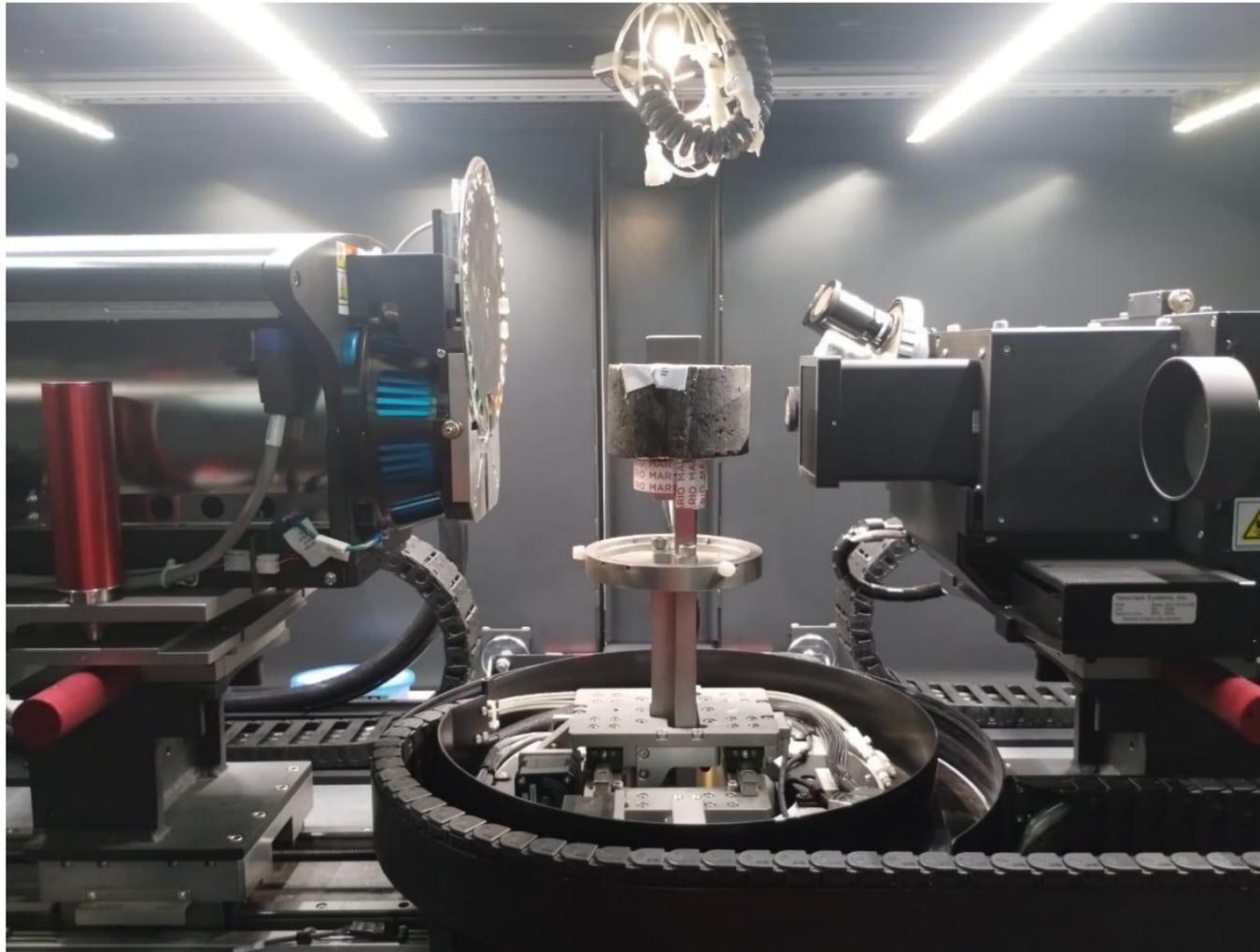


Figure: FDXM -IRCC Four-Dimensional X-ray Microscopy (FDXM)

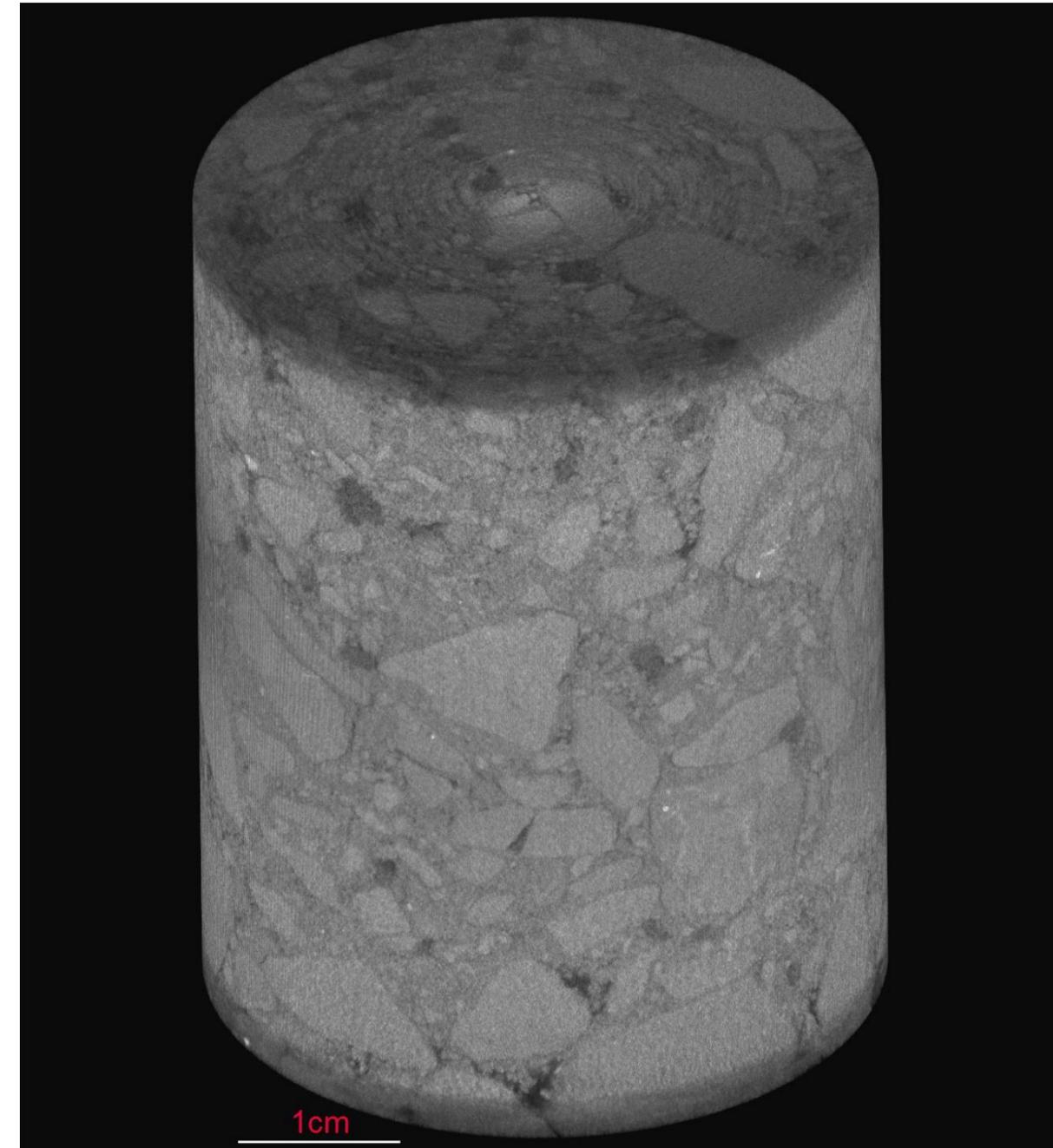


Figure: 3D rendering of asphalt mix sample

Performance Test Results

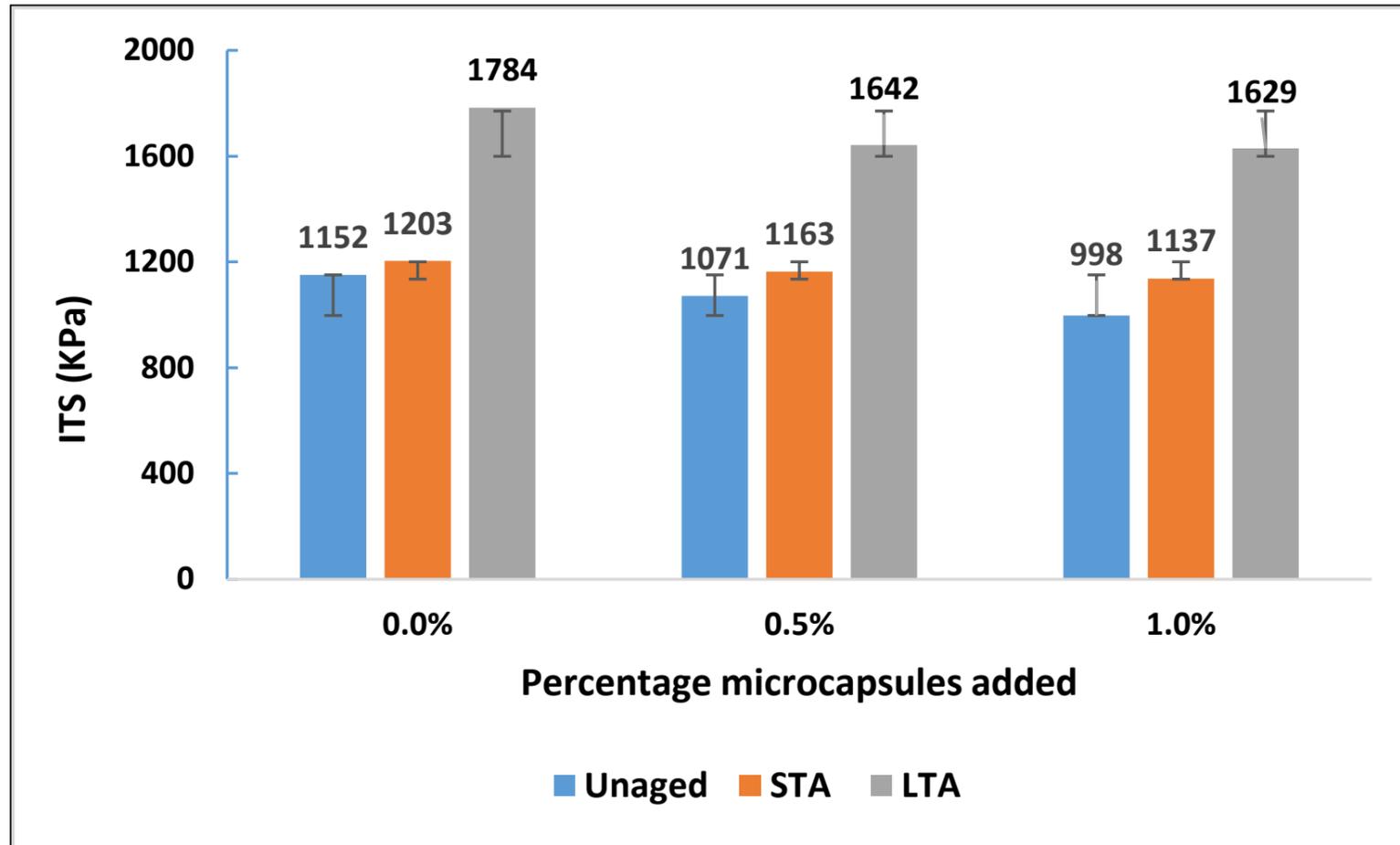


Figure: Variation of ITS (in Kpa) @25°C with a percentage increase in microcapsules addition

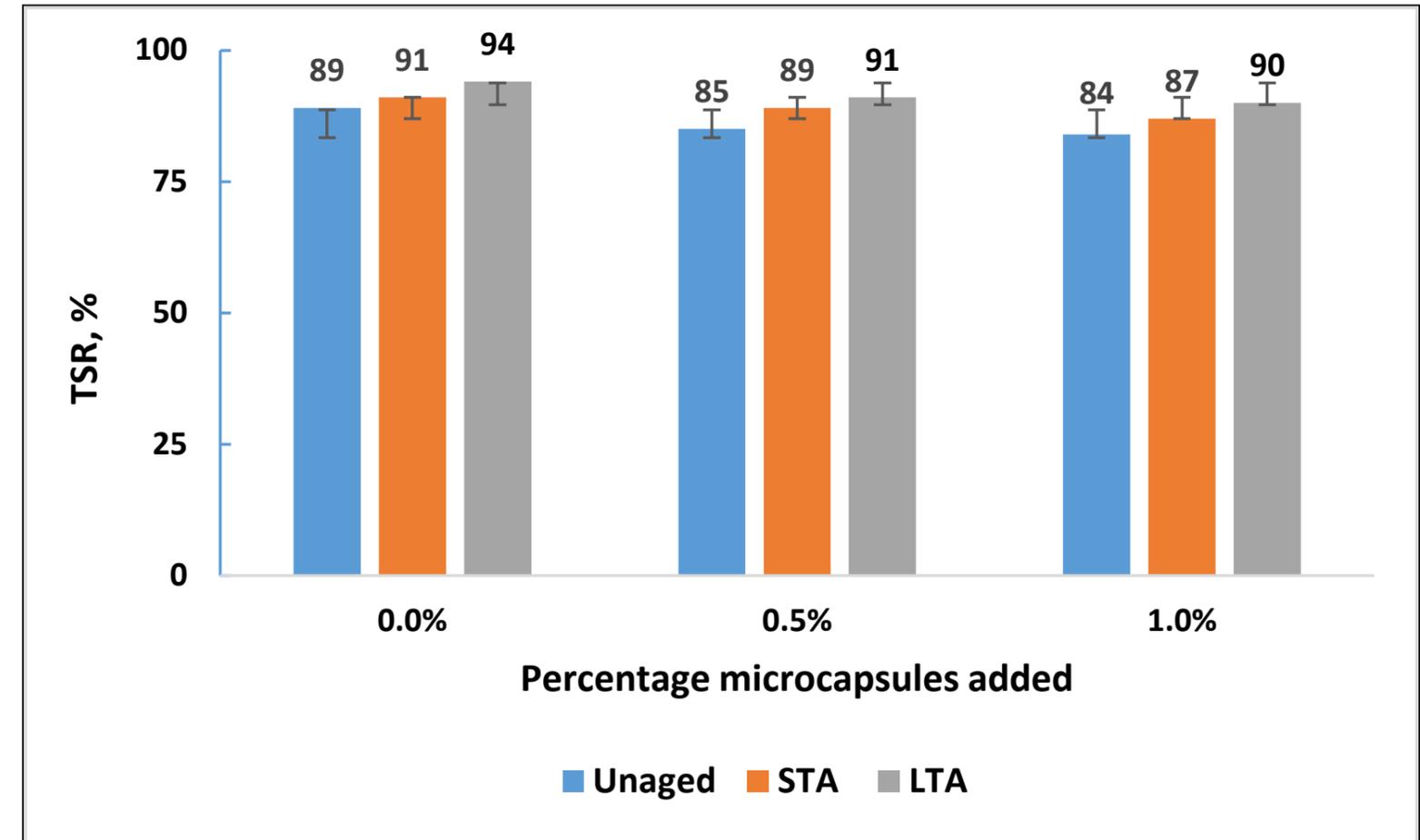


Figure: Variation of TSR (in %) with a percentage increase in microcapsules addition

Performance Test Results

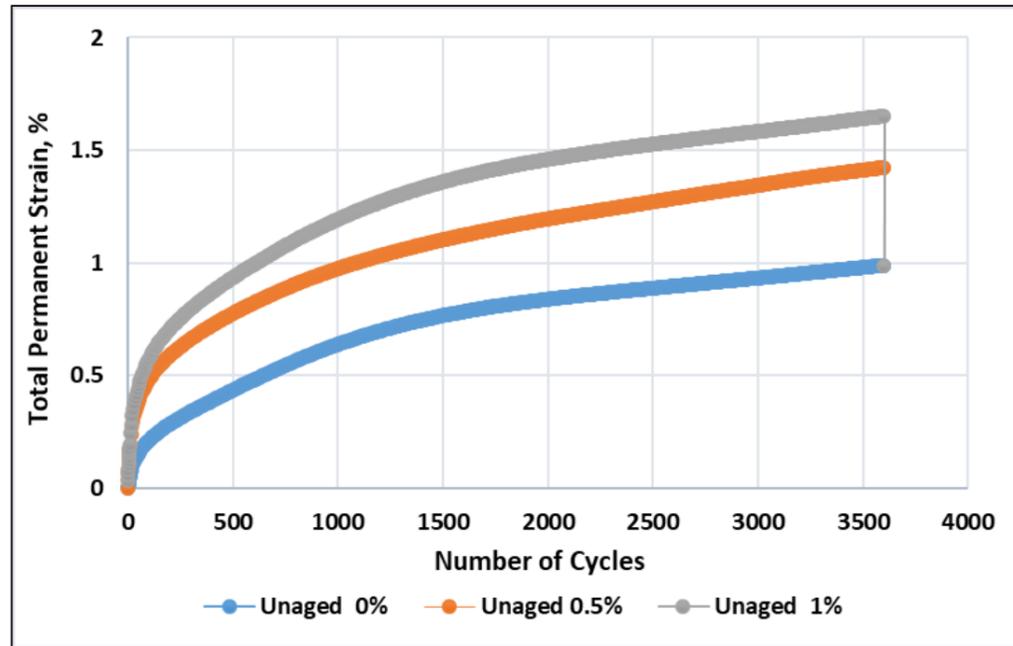


Figure: Dynamic creep test results for unaged asphalt mixes with 0%, 0.5%, and 1% of microcapsules.

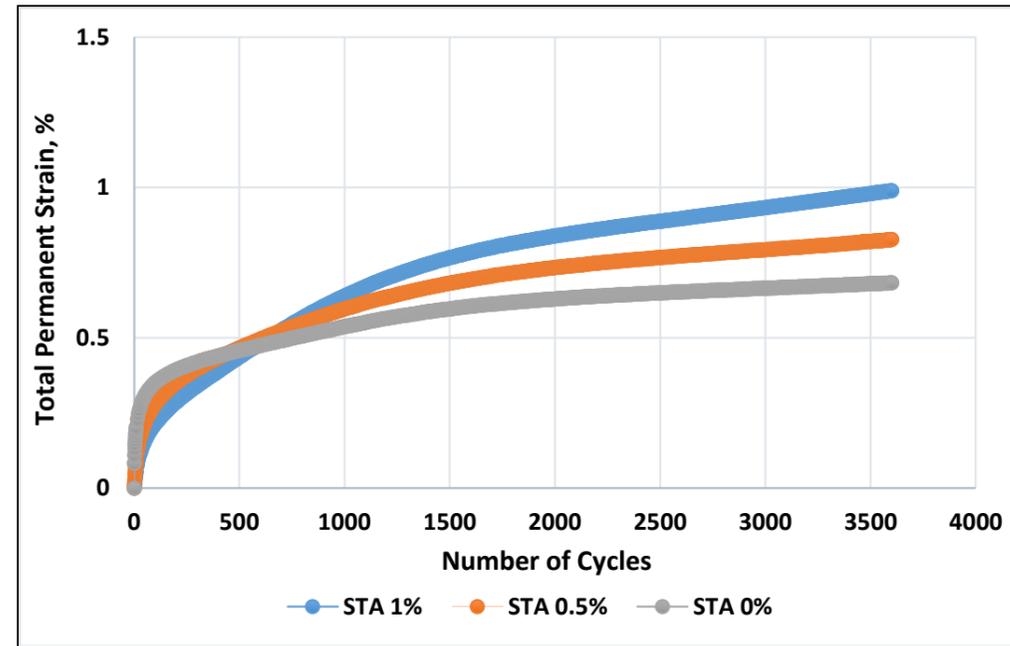


Figure: Dynamic creep test results for STA asphalt mixes with 0%, 0.5%, and 1% of microcapsules.

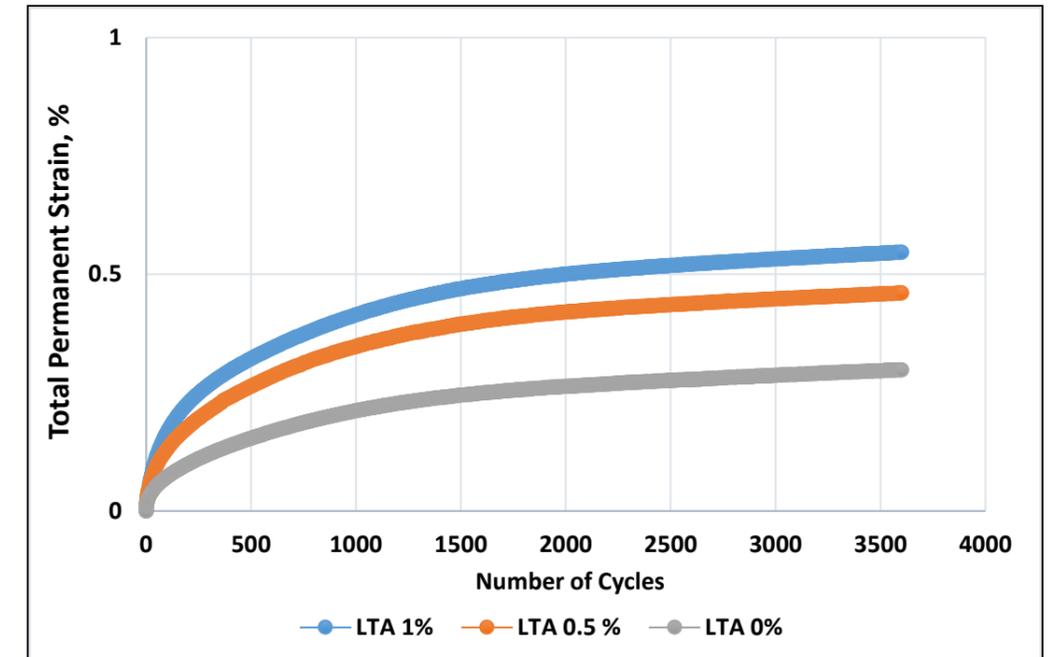


Figure: Dynamic creep test results for LTA asphalt mixes with 0%, 0.5%, and 1% of microcapsules.

Performance Test Results

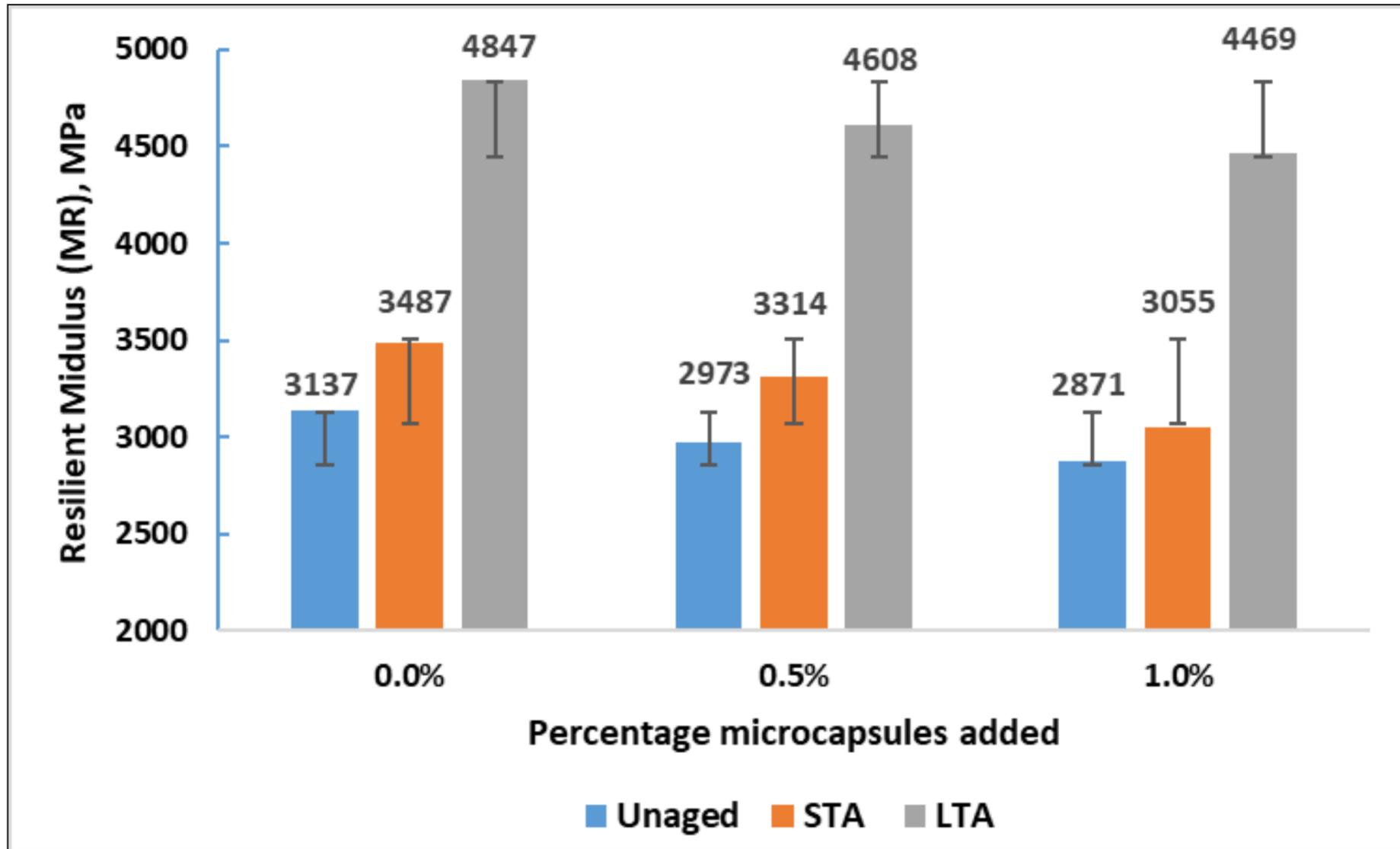


Figure: Variation of Resilient Modulus with a percentage increase in microcapsules addition

Healing Index



Figure: SCB Test Set-up

$$HI = (F_h / F_0) \times 100$$

where:

F_h is the critical load at fracture after the healing process, and

F_0 is the initial critical load at fracture.

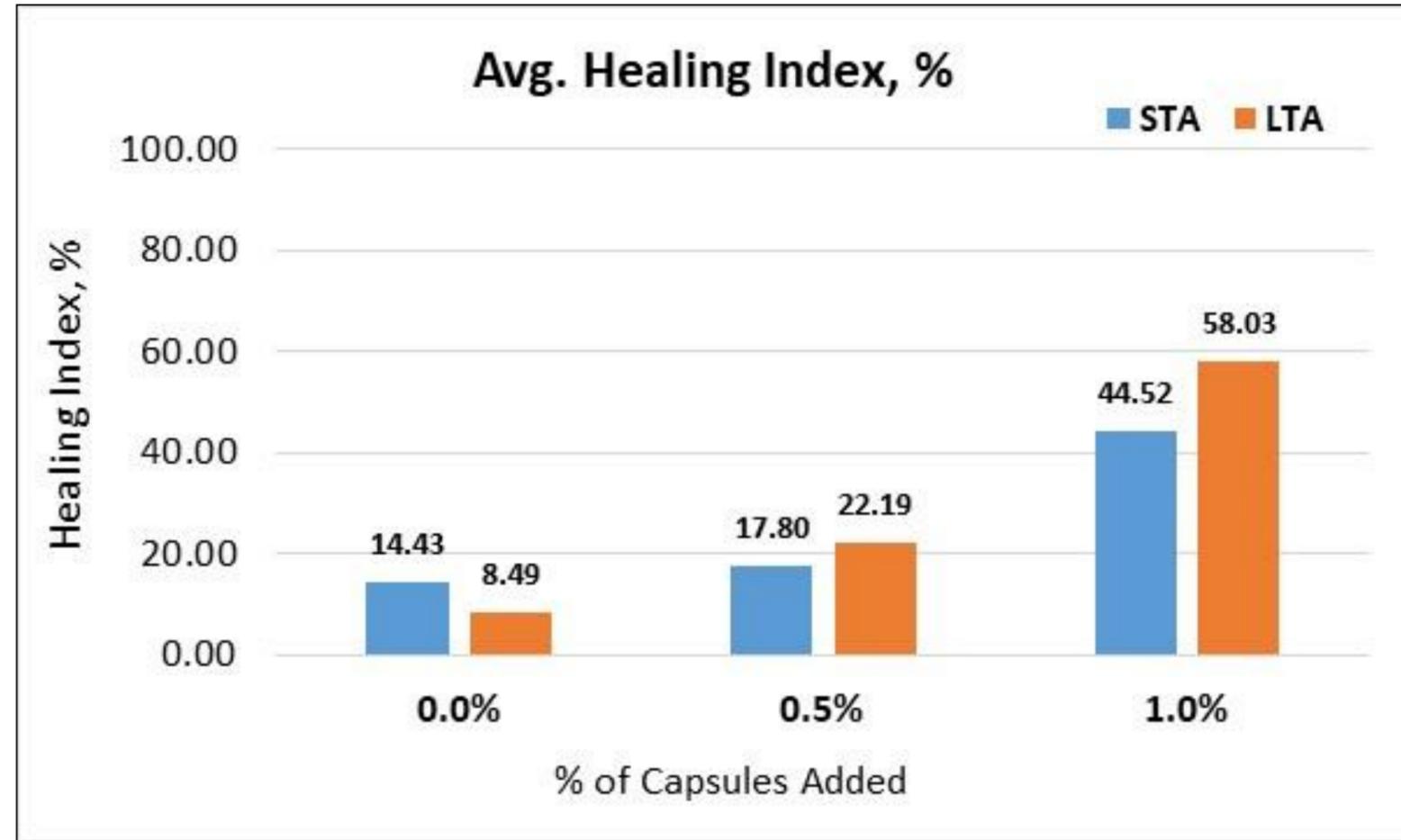


Figure: Healing Index test results for STA & LTA asphalt mixes with 0%, 0.5%, and 1% of microcapsules.

Conclusions

- Capsules (Calcium alginate with rejuvenator oil) showed: High thermal stability (up to 200°C), Adequate strength (18 N) to survive mixing and compaction
- No significant impact on volumetrics or moisture resistance, Slight decrease in resilient modulus at higher dosages
- **SARA analysis** showed improved bitumen chemistry: ↑ maltenes, ↓ asphaltenes → better flexibility
- Minimal effect on rutting despite a slight increase in permanent strain
- Upto 60% healing was observed in LTA samples with 1% dosage of capsules

Limitations & Challenges

- Lack of long-term field performance data
- Worked on Limited Rejuvenators with Limited Dosage
- Cost and scalability of advanced materials
- Agency acceptance and specifications

Way Forward

- Pilot test sections under Indian climatic conditions
- Life-cycle cost analysis for technology selection
- Development of guidelines and specifications

Acknowledgments

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