PERFORMANCE CHARACTERISATION OF WARM MIX ASPHALT MIXES FOR SUSTAINABLE ROAD CONSTRUCTION

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Hot Mix Asphalt

- Hot Mix Asphalt (HMA) is used as a primary paving material in paving industry since many decades. It is a combination of aggregates uniformly mixed and coated with bitumen at around 160 °C.

- HMA is generally produced either in batch mix plant or drum mix plant, through a sequential procedure.
Concerns due to High Production Temperatures of HMA

- High Amount of Energy
- Emissions
- Binder Aging
- Poor Working Environment for Paving Crew
Warm Mix Asphalt

- Warm Mix Asphalt (WMA) is a fast emerging technology that has a potential to reduce the mixing and compaction temperatures of asphalt mixes.
Warm Mix Asphalt

- Asphalt Institute (USA)
  - 10–40°C.
- European Countries
  - 20–40°C
- India (IRC: SP–101 2014)
  - at least 30°C
Benefits Associated with WMA

- Reduces Fuel Consumption
- Reduces Binder Aging
- High Amount of RAP

HMA

WMA

Hot Mix Asphalt
Warm Mix Asphalt

Reduces Emissions
Safer Working Environment
Increased Use of Modified Binders

- Higher resistance to rutting and aging
- Higher fatigue life of mixes
- Better adhesion between aggregate and binder
- Lower temperature susceptibility
- Overall improved performance

Increased traffic

Heavy axle loads

Airey, (2003, 2004); Lu and Isacson, 2000; Akisetty et al., (2009); Kim et al., (2012)
Modified Binders: High Production Temperatures and Emissions

- Modified asphalt binders are *more viscous* compared to straight-run (unmodified) binders.

- Higher viscosity of modified asphalt binders results in *higher mixing and compaction temperatures* (about 10–30°C higher) which are needed to coat the aggregates while mixing and to achieve the required density while compaction.

- Higher mixing and compaction temperatures require *additional burner fuel* during production of HMA and this subsequently leads to *higher emissions*.

- Combination of modified binders and WMA technologies can be a potential solution to lower down the high production temperatures associated with modified binders.
Objectives

- The main objective of this study was to evaluate the performance properties of WMA mixes prepared at different production temperatures with two modified asphalt binders and at different dosages of an organic WMA additive.

- Performance evaluation of control and warm mixes was done in terms of resilient modulus, resistance against permanent deformation, and fatigue damage.
Materials for the study

- **Aggregates** were procured from a quarry in the vicinity of Guwahati.
- 13.2 mm NMAS Bituminous Concrete (BC) gradation was used for evaluation in the study.

- **Binders:**
  - PMB 40
  - CRMB 60

- **WMA Additive:** Sasobit

![Graph showing percentage of passing through sieves for different gradations]
## Physical Properties of PMB and CRMB

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<td>Penetration at 25°C, 0.1 mm, 100g, 5 sec.</td>
<td>30 to 50</td>
<td>39</td>
<td>&lt;50</td>
<td>35</td>
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<td>Softening point, (R&amp;B), °C</td>
<td>Min.60</td>
<td>64.5</td>
<td>Min.60</td>
<td>64.5</td>
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<td>Ductility at 27°C, cm</td>
<td>50</td>
<td>61.6</td>
<td>NA*</td>
<td>NA</td>
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<td>Min.220</td>
<td>300</td>
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<td>Min.50</td>
<td>68</td>
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<td>Separation difference in softening point, R&amp;B, °C</td>
<td>Max.3</td>
<td>1.9</td>
<td>Max.4</td>
<td>2.9</td>
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<tr>
<td>Viscosity at 150°C, poise</td>
<td>3 to 9</td>
<td>7.85</td>
<td>NA</td>
<td>8.90</td>
</tr>
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| Thin Film Oven Test (TFOT) Residue                                  |              |         |              |         |
| Loss in weight, %                                                   | Max. 1       | 0.62    | Max. 1       | 0.56    |
| Increase in softening point, °C                                     | Max. 5       | 4.1     | Max. 5       | 3.5     |
| Reduction in penetration of residue, at 25°C, %                     | Max. 35      | 33      | NA           | NA      |
| Penetration at 25°C, 0.1 mm, 100g, 5 sec, % of original             | NA           | NA      | Min. 60      | 68.57   |
| Elastic recovery of half thread in ductilometer at 25°C, %          | Min.50       | 58      | Min. 35      | 48      |
Sasobit®

- **SASOBIT®** is a long-chain aliphatic hydrocarbon that is produced by Fischer Tropsch process.
- Melting point range: 85°C - 115°C
- At temperatures above the melting point, the additive reduces the viscosity of the binder and at temperatures below melting point it tends to increase the stiffness of the binder.
Selection of Sasobit Doses

- Recommended dosage: 0.8% to 3% by weight of binder.
  - Based on extensive literature review and manufacturers’ recommendations, these dosage rates by weight of binder were selected:
    - Sasobit: 1%, 2% and 3% for neat and modified binders
Preparation of Warm Mixes

- Preparation of Warm Asphalt Binders

PMB 40, CRMB 60

Additive

Warm Asphalt Binders

Shear Mixer
Selection of Production Temperatures

- $x$ is the standard production temperature ($^\circ$C).
- Depends on binder type used (PMB: 170 °C; CRMB: 175 °C)
Resilient Modulus Test

- Test was performed according to AASHTO TP 31:1996
- Non-destructive test.
- Test temperatures: 5 °C, 25 °C, and 40 °C
- Compressive load with haversine waveform.
- Loading frequency: 1 Hz, with a recommended load duration (pulse width) of 0.1 s and rest period of 0.9 s.

\[ M_R = \frac{P(\mu + 0.27)}{t\Delta H} \]

- \( M_R \) = resilient modulus (MPa)
- \( P \) = repeated vertical load (N)
- \( \mu \) = Poisson’s ratio
- \( t \) = specimen’s height (mm)
- \( \Delta H \) = horizontal recoverable deformation (mm)
Resilient Modulus Test

- Resilient modulus values were reported over the last 5 loading cycles after the application of 100 load repetitions.
Warm mixes containing Sasobit show comparable performance at 30°C reduction in production temperature with control mixes.
Resilient Modulus (CRMB Warm Mixes)

➢ Warm mixes containing Sasobit showed comparable performance at 30°C reduction in production temperature with control mixes.
Resilient Modulus

- An increase in the Sasobit content improves the resilient modulus at all test temperatures.
- This is due to a well-distributed crystalline structure formed in the binders on addition of Sasobit.
- Reduction in production temperatures reduce the resilient modulus values, likely due to increase in air void content and reduced stiffness at lower temperatures.
Dynamic Creep Test

- It is used for permanent deformation characterisation of asphalt mixes.
- Test was performed according to BS DD:226-1996
- Test temperature: 40°C
- Compressive load with square waveform.
- Total cycle length = 2 s with a load time of 1 s and rest period of 1 s.
- Number of cycles: 1,800
- Result was showed in terms of permanent axial strain.
Dynamic Creep Test Results at 40°C

- Axial strain values of WMA mixes containing 2% and 3% Sasobit are lower than the control mixes even after 30°C reduction.

- Attributed to the higher stiffness of binder imparted by the crystalline network structure formed in the binder with addition of Sasobit.

- Increase from 1% to 3% reduces permanent strain by 30-40%.

- Permanent axial strain increases with decrease in the production temperatures.

- The higher permanent strain at higher air void content is likely due to densification of mixes by the external loading.
Indirect Tensile Fatigue Test

- ITFT is a common test to characterise fatigue damage resistance of asphalt mixes.
- Test was performed according to EN 12697:Part 24
- Destructive test.
- Test temperature: 20°C
- Compressive load with Haversine waveform.
- Total cycle length = 0.5 s with a load time of 0.1s and rest period of 0.4s.
- Load (500 kPa) was continuously applied until the sample failed.
- Fracture life of a sample was reported as a total number of applications that caused a complete fracture in the sample.
Fatigue Test Setup

Failed Sample After Completion of Test
Indirect Tensile Fatigue Test

- Fracture life of warm mixes are higher compared to their respective control mixes up to 20 °C reduction.
- Fracture life increases by 65% at 2% Sasobit at 20 °C reduction.
- This improvement in the fracture life is due to reduction in air void content.
- An increase in Sasobit content from 1% to 2% increases the fracture life of both PMB and CRMB warm mixes.
- Fracture life is found to be maximum at Sasobit dosage of 2%. Excessive stiffening of binder at higher Sasobit dosage of 3% might have caused reduction in fracture life.
Conclusions

- Warm mixes with a Sasobit content of 2% showed a better performance in terms of permanent deformation and fatigue life at 20 °C reduced production temperatures, compared to control mixes.

- WMA mixes prepared even after 30 °C reduction in production temperature showed comparable performance in terms of resilient modulus, permanent axial strain in dynamic creep, and fracture life in comparison to the control HMA mixes.

- A reduction as well as enhancement in performance parameters were observed with incorporation of the organic WMA additive in BC mixes.

- Lower production temperatures help to reduce the fuel consumption and emissions, and thus will also help to earn carbon credits as well as assist in achieving sustainability in road construction sector in India.

- Confidence and long-term benefits need to be gained and analyzed through construction and monitoring of more WMA pavement sections in India.
Preparation of Warm Mixes

- Warm mixes were prepared by adding the different percentages of Sasobit to the OBC.

- 1%, 2% and 3% of Sasobit were selected.

- Mixes were prepared by lowering the standard mixing and compaction temperatures by 0°C, 20°C, 30°C and 40°C.
After cooling, the Sasobit crystallizes and forms regularly distributed, microscopic, stick-shaped particles.
Air Voids

The design air void content (4%) for control mix can be achieved for warm mixes with 2% and 3% additive after reducing the production temperatures in between 20°C to 30°C.