SHOULD MUNICIPALITIES PAVE MORE WITH STONE MASTIC ASPHALT (SMA) MIXTURE? A REVIEW OF DESIGN & CONSTRUCTION CHALLENGES

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Presentation Outline

- What is Stone Mastic Asphalt (SMA)?
- SMA Applications
- SMA Design Overview
- Industry’s SMA Experience
  - MTO
  - Municipal
- Equipment Options
- Best Practices
- Summary
- Acknowledgements
What is Stone Mastic Asphalt (SMA)?

“Stone Mastic Asphalt (SMA) is tough, stable, rut-resistant mixture. The mixture has a gap-graded aggregate skeleton with coarse aggregate stone-on-stone contact to provide strength.

A rich mortar binder, the mastic portion to provide durability.

The mix must be blended volumetrically to ensure stone-on-stone contact.”
SMA Applications

- Application Locations Include:
  - MTO Surface Course Directive (PLNG-C-003)
    - Directs The Use of Surface Course Types on Provincial Highways
    - Selects SMA for Highways with greater than 3M ESAL or 5000 AADT
    - Gives consideration for the purpose of noise reduction in urban residential areas.
  - Enhanced rutting resistance, water spray reduction, and noise reduction.
SMA Applications – Key Benefits

The Key benefits of SMA Include:

- Excellent rut resistant properties;
- Excellent durability – *(slow ageing)* compared to conventional hot mix asphalt mixtures.
- Good flexibility and resistance to fatigue – *(performs well during low temperature conditions)*;
- High skid resistance – due to its rough texture;
- Open Graded surface reduces tire splash and noise;
- Additional Uses – as base course mix, including high stressed pavement applications.
SMA is generally more expensive than a typical dense-graded HMA due to its higher material, production and construction costs. It requires use of higher quality skid resistant aggregates and additives, higher binder content, and use of modified binders. However, the benefits from improved pavement performance and its frictional resistance properties make it more economical in the long term by reducing rehabilitation needs and extending service life.
SMA Design Overview

- Governing Specifications
  - AASHTO MP8-00: Standard Specification for Designing Stone Matrix Asphalt (SMA)
  - OPSS 1151.PROV and OPSS 1151.MUNI: Material and Construction Requirement for Stone Mastic Asphalt
  - MTO LS – 311 Stone Mastic Asphalt Mix Design

- Mix Design Procedures
  - Superpave Gyratory Compactor (SGC)
  - $N_{\text{design}}$ of 100 gyrations
    - Reduced to 70 gyrations if LA abrasion value for course aggregate is greater than 30
  - Mortar Testing
    - Dynamic Shear Rheometer, RTFO, PAV
SMA Design Overview – Philosophy

Flow Chart for SMA Mix Design

- Select Aggregates
- Determine Proper Aggregate Gradation
- Check Gradation for Minimum VMA
- Select Asphalt Content for Desired Air Void Level
- Evaluate Moisture Susceptibility and Draindown
## SMA Design Overview

### Gradation Envelope

<table>
<thead>
<tr>
<th>Sieve</th>
<th>SMA 12.5 mm</th>
<th>SMA 9.5 mm</th>
</tr>
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<tbody>
<tr>
<td>mm</td>
<td>Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>19.0</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>12.5</td>
<td>90</td>
<td>100</td>
</tr>
<tr>
<td>9.5</td>
<td>50</td>
<td>80</td>
</tr>
<tr>
<td>4.75</td>
<td>20</td>
<td>35</td>
</tr>
<tr>
<td>2.36</td>
<td>16</td>
<td>24</td>
</tr>
<tr>
<td>0.075</td>
<td>8</td>
<td>11</td>
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### Mix Properties

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
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<tr>
<td>Air Voids %</td>
<td>4.0</td>
</tr>
<tr>
<td>Voids in Mineral Aggregate, VMA %</td>
<td>17 Minimum</td>
</tr>
<tr>
<td>VCA_{mix} %</td>
<td>Less than VCA</td>
</tr>
<tr>
<td>Tensile Strength Ratio %</td>
<td>70 Minimum</td>
</tr>
<tr>
<td>Draindown %</td>
<td>0.3 Maximum</td>
</tr>
</tbody>
</table>

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### TABLE 5
SMA Minimum Asphalt Content for Aggregates With Varying Bulk Specific Gravities

<table>
<thead>
<tr>
<th>Combined Aggregate Bulk Relative Density</th>
<th>Minimum Asphalt Content Based on Mass, %</th>
</tr>
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<tbody>
<tr>
<td>2.40</td>
<td>6.8</td>
</tr>
<tr>
<td>2.45</td>
<td>6.7</td>
</tr>
<tr>
<td>2.50</td>
<td>6.6</td>
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<tr>
<td>2.55</td>
<td>6.5</td>
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<tr>
<td>2.60</td>
<td>6.3</td>
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<tr>
<td>2.65</td>
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<tr>
<td>2.70</td>
<td>6.1</td>
</tr>
<tr>
<td>2.75</td>
<td><strong>6.0</strong></td>
</tr>
<tr>
<td>2.80</td>
<td><strong>5.9</strong></td>
</tr>
<tr>
<td>2.85</td>
<td>5.8</td>
</tr>
<tr>
<td>2.90</td>
<td>5.7</td>
</tr>
<tr>
<td>2.95</td>
<td>5.6</td>
</tr>
<tr>
<td>3.00</td>
<td>5.5</td>
</tr>
</tbody>
</table>
SMA Design Overview — The Draindown Challenge

- Fibres as stabilizing additives in SMA mixtures prevents draindown or separation of the binder from the aggregate skeleton during mix storage, hauling and placement. Cellulose and mineral fibre compositions in Ontario SMA mixes are typically 0.3 and 0.4 percent respectively by weight of the mix.

- Pelletized fibres could be used in-place of cellulose fibres, but challenges with blending methods and other impacts on production; e.g. melting point of the pelletized fibres and pumping the fibre modified binder must be overcome.
MTO adopted the use of SMA as a premium surface course mix on its major highways in 2002.

2005 MTO noted low initial friction on SMA pavements.

In 2005 MTO/OAPC Task Group was formed to investigate different alternatives to improve the initial surface friction of SMA pavements.

2007 MTP paused the use of SMA to address concerns with low early age friction.
INDUSTRY’S SMA Experience – MTO

- 2009 & 2010 MTO Completed SMA Trials
- 2011 MTO Completed embedded grit trials on QEW
- 2012- 2013 MTO Contracted entire SMA Contracts with coated gritting
- 2014 MTO re-instated SMA for use as a premium surface course mix.
Industry / MTO Task Group formed in Fall of 2005

- Early age friction concern is a temporary condition.
  - Friction increased to acceptable levels after 30 to 50 days
  - MTO unwilling to accept use of SMA due to risk

- Task Group Initiated Research
  - Trail mixes with varying AC%, Mineral Filler %, and aggregate gradation.
Industry / MTO Task Group Conclusions

- Loss of friction - thick Asphalt Mastic Coating on Aggregate.
- Lab Testing and Placement Trials found mix adjustment alone was not enough. (0.3% reduced AC / less dust)
- Water Blasting and Post Construction Grit Not Consistent
- Applying grit on surface pre compaction most effective.
INDUSTRY’S SMA Experience – MTO ON Gritting

- Embedded Gritting Trials – 2011
  - 2 Trails completed on QEW
    - Grit Applied to Hot Surface Pre Compaction
    - 2 Adjacent Contracts
      - Aecon Construction – QEW @ Bronte Road
      - Dufferin Construction – QEW @ Third Line

- FN measured on gritted surface and Non Gritted control sections
  - 26 to 59% increase in early friction
  - 6 to 8 week friction tests - 2 to 11%
INDUSTRY’S SMA Experience – MTO ON Gritting

- Pre Compaction Grit Embeds Into and / or Abrades Surface Mastic
  - Grit is pre-coated with 0.8 to 1.0% AC
  - Grit applied at a rate of 0.75 ± 0.1 kg/m²

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Requirement, % Passing</th>
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<tbody>
<tr>
<td>4.75 mm</td>
<td>100</td>
</tr>
<tr>
<td>2.36 mm</td>
<td>90 - 100</td>
</tr>
<tr>
<td>1.18 mm</td>
<td>50 - 65</td>
</tr>
<tr>
<td>600 μm</td>
<td>25 - 35</td>
</tr>
<tr>
<td>150 μm</td>
<td>0 – 5</td>
</tr>
<tr>
<td>75 μm</td>
<td>0 - 3</td>
</tr>
</tbody>
</table>

Gritted Surface - Initial Placement / 1 Roller Pass

Gritted Surface – After Compaction and Sweeping
Some Lessons Learned from various SMA Project Experiences Include:

- Grit application rate of 1.0kg/m² causes excessive dust;
- Grit without AC coating sticks to roller and causes bumps;
- Static compaction with Roller problematic;
- Vibratory compaction required – adjustments for roller frequency and amplitude critical;
- Grit temperature needs to be optimum – If too hot, grit clumps in spreader;
INDUSTRY’S SMA Experience – Municipal

- Some Completed SMA Projects Since 1990:
  - City of Ottawa – Road 174 EB and Transit Way Ramps;
  - City of Toronto – Hwy 2A (1997);
  - Windsor – Huron Church Road (May 2002);
  - Hamilton – Burlington Street (Oct. 1999), Red Hill Valley Parkway (2007);
  - Region of York – Bloomington Sideroad (2005)
INDUSTRY’S SMA Experience – Municipal

- Municipalities Say:
  - They are happy with SMA mixtures placed on appropriate projects.
  - Successes Outweigh the Problems Encountered
    - Ensure substrate construction is adequate
      - Good performance where quality base materials used
    - Limit Use of SMA as a rehabilitation Overlay
      - Must Consider the Substrate
      - Reflective cracks / heaving
    - Limit Use in areas of existing services
      - Service repair will require removal of SMA
SMA – Optional Equipment
SMA – Optional Equipment
The following recommendations apply to producing good SMA Mixtures:

- Maintain a tight tolerance on the production temperature, taking care not to overheat the mix;
- Stabilize and maintain consistent plant production temperature;
- Preheat plant, conveyors, and other moving parts with hot aggregate prior to adding polymer-modified asphalt;
- Maintain stockpiles properly and monitor gradation of incoming aggregates;
- Calibrate mineral filler, fiber, and anti-strip agent feed systems to plant production rate and maintain interlock system; and
- Establish and maintain adequate mixing time taking into consideration that longer mixing times may be required for the use of mineral filler and fiber.
The following recommendations are critical for placement and compaction of SMA mixtures:

- Assure that a minimum air temperature of 10°C is maintained when placing SMA;
- Start with a clean haul vehicle;
- Use only approved release agents, such as water-based liquid soap or dry soap powder;
- Drain all excess release agents from truck beds;
- Use tarps on truck beds and make sure they fit truck bed securely so as to prevent excessive cooling during haul;
- Provide area for truck clean-out after unloading;
- A material transfer device or other auxiliary equipment may be used to provide consistent mix temperature, avoid segregation, and improve continuity of operation;
- Maintain continuous paving operation;
- Minimize starts and stops of paver;
- Keep roller close to paver;
- Static rolling is recommended;
- Vibratory rollers, if used, should only be operated in low amplitude and high frequency mode;
- Keep augers going;
- Complete rolling before mixture reaches a temperature of approximately 140°C when using a modified asphalt and 130°C with a neat asphalt;
- Don’t stop the roller on the hot mat;
- Pneumatic-tired rollers should not be used;
- Exercise care in folding wings of the hopper to ensure that cold mixture from the edge of the paver hopper is not dumped onto the conveyors;
- Perform placement and compaction to minimize temperature loss in the mixture;
- Consider the use of a vibratory roller for breakdown rolling, but use it with caution;
- Use two or three rollers as necessary to achieve a minimum density of 94 percent Maximum Density;
- Roll mat quickly while mixture is hot;
- Minimize hand work; and
- Use special care in inspection and construction of longitudinal joints to ensure proper alignment and compaction.
The following QA recommendations apply to obtaining good SMA mixtures:

- Frequently monitor aggregate stockpiles and/or hot bin for gradation;
- Frequently monitor binder, especially modified binder;
- Construct a trial or demonstration section to allow contractor the opportunity to demonstrate ability to produce the JMF, required density, etc;
- Frequently monitor plant produced mixture properties, particularly volumetric properties;
- Frequently monitor in-place density results;
- Correlate nuclear density to cores to improve accuracy of the gauge;
- Consider sand as an aid to seating the nuclear gauge to improve the accuracy of the readings; and
- Monitor product quality continuously during production.
Summary & Conclusions

- SMA requires an understanding of the material – It is different from typical hot mix.
- SMA Successfully Used on Municipal Pavements since 1990
- Municipalities have an opportunity to resume SMA use.
- SMA Specifications have been updated based on Task Group Recommendations and Research Completed. Opportunities exist to:
  - Revise the grit sand and mineral filler gradation and physical property requirements;
  - Review difficulties in keeping grit off Pavement marking locations; and
  - Conduct demonstration studies on draindown evaluation (cellulose vs pelletized fibres.)
Acknowledgements

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Thank You!
Any Questions?