Latest RAP Study Results

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Presentation Overview

• Background
• Overview of Study
• Results to Date
• Discussion
• Impact of Findings
Background

• RAP is a valuable high quality construction material – not a waste material
• Recycled Hot Mix (RHM) has a long history of demonstrated performance
• Optimizing RAP use makes pavements more sustainable
• MTO began their recycling program in 1978, early projects had RAP contents that were as high as 70 percent.
• Performance of HMA containing RAP was found to be directly related to the penetration of the recovered binder.
• Higher RAP contents, under-asphalting of the mix was a common problem.
Background

• RAP is routinely used in HMA by nearly all 50 states and considered standard asphalt paving practice.
• Abundant quantity of technical data indicating that when properly specified and produced RHM asphalt is equivalent in quality and structural performance to conventional HMA.
• FHWA supports and promotes the use of recycled highway materials in pavement construction in an effort to preserve the natural environment, reduce waste, and provide a cost effective material for constructing highways.
• FHWA/EPA report RAP is the most frequently recycled material
<table>
<thead>
<tr>
<th>Planning and Programming</th>
<th>Design</th>
<th>Construction</th>
<th>Maintenance, Preservation and Rehabilitation</th>
<th>In-Service Evaluation</th>
<th>End of Service Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Traffic and Environmental data information</td>
<td>• Information on materials, traffic, costs, environment, etc.</td>
<td>• Environment during construction</td>
<td>• Standards</td>
<td>• Periodic monitoring of structural adequacy, roughness, surface distress, and surface friction</td>
<td>• Recycling and reuse of materials for reconstruction</td>
</tr>
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<td>• Assess network deficiencies</td>
<td>• Design alternatives</td>
<td>• Specifications</td>
<td>• Treatments</td>
<td>• Salvage Value</td>
<td>• Records</td>
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<td>• Budgets</td>
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<td>• Records</td>
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<td>• Establish priorities</td>
<td>• Optimization</td>
<td>• Schedules</td>
<td>• Construction operations</td>
<td>• Restoration</td>
<td>• Zero Waste Management</td>
</tr>
<tr>
<td>• Schedule projects</td>
<td>• Sustainability</td>
<td>• Quality control/quality assurance</td>
<td>• User costs</td>
<td>• Assess performance</td>
<td></td>
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<tr>
<td>• Priorities</td>
<td>• User costs</td>
<td>• Records</td>
<td></td>
<td>• Prioritize</td>
<td></td>
</tr>
</tbody>
</table>

“Working” Management Loop

Database

Research Loop

Information

Research
Overview of Study

• Use of Reclaimed Asphalt Pavement (RAP) in Hot Mix Asphalt (HMA) is a common practice in Ontario
• Can current practices be improved?
• Opportunity to consider higher rates of recycling?
• Is there a difference between RAP from Northern Ontario versus Southern Ontario
• Opportunity to foster innovation and sustainability?

WANT TO EXAMINE WHAT HAPPENS AS WE ADD RAP AND CHANGE AC TYPE
Overview of Study

• Evaluate the impact that RAP has on two common Ontario mixes, SP12.5 and SP19
• Understand how the addition of RAP to HMA alters the performance of the mix
• Examine if HMA can be tested to determine the % RAP
• Determine if performance tests can be used to back-calculate Performance Grades for mixes containing RAP
• Consider application of RAP for both Southern and Northern Ontario roads.
• Provide some new guidelines on the usage of RAP
Overview of Study

• Carry out a comprehensive literature review on the state-of-the-art of RAP usage.
• Evaluate consensus properties of aggregates.
• Recover and characterize asphalt cement in RAP.
• An extensive laboratory-based study was designed to evaluate mix properties including performance tests such as:
  • Dynamic modulus testing
  • Thermal Stress Restrained Specimen Test (TSRST)
  • Fatigue beam
  • Disk-shaped Compact Tension Specimen
Methodology

Design

Sieving

Batching

Mixing
Methodology

Conditioning → Compacting → Coring → Testing
Concerns Using RAP

- Effects on moisture susceptibility of the mix.
- Endurance against fatigue and thermal cracking.
- Mix stiffening and premature aging of the HMA.
- Adjustment of binder grade ("binder bumping").
- Inability to meet consensus properties.
- Losing desired performance grade of binder.
- Reduced workability and "compactability" in the field.
- Need for new plant technologies.
- Variability in the RAP.
Understanding RAP

• Addition of RAP increases stiffness of the mix.
• Results have been contradictory in whether the addition of RAP results in diminished performance in regard to thermal and fatigue cracking.
• Age or stiffness of the binder does not attribute to the performance of the new mix for RAP contents up to 20%.
• Moisture susceptibility of the mix does not increase due to the addition of higher percentages of RAP.
• RAP source can have an effect on the performance of the final mix.
• Type of aggregate in the RAP can play a significant role in the performance of the HMA mix.
# Understanding RAP

## Table 1: RAP Content and SP12.5/SP19 Course Compatibility

<table>
<thead>
<tr>
<th>RAP Content</th>
<th>SP12.5 (Surface Course)</th>
<th>SP19 (Binder Course)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Southern</td>
<td>Northern</td>
</tr>
<tr>
<td>0%</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>15%</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>20%</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>30%</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>40%</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Results to Date

% Passing

Sieve opening (mm)

- 0% RAP
- 20% RAP
- 40% RAP
- Minimum
- Maximum
Results to Date

- The angularity, in terms of crushed faces, decreases as the percentage of RAP added increases for southern mixes.
- Percent crushed faces decreases by 2.6 percent with the addition of 40 percent RAP.
Results to Date

- Sand equivalent, the value increases as the percent RAP increases.
- RAP mixtures have less proportion of clay-like materials, which benefit the binding of AC with the aggregate.
Results to Date

- Voids in the Mineral Aggregate (VMA) and Voids Filled with Asphalt (VFA) decrease as the percent RAP increases.
- Percentage of virgin asphalt added decreases, but more fines from the RAP fill the spaces between particles.
Results to Date

- For the Dust Proportion (DP), an increase of almost 60% was observed for the RAP mixtures as compared to the virgin mixes.
- This result is probably related to the lower effective binder content for the RAP mixtures.
Results to Date

- All TSR values were above the minimum 80 percent required.
- The lowest results were obtained from the 40% RAP mixes, which are about 4% below the result obtained for the virgin mix.
Thermal Stress Restrained Specimen Test

- Resistance to thermal cracking.
- Beam 250x50x50mm.
- Cools specimen at -10°C/hour.
- Restrain from contraction.
- Fractures as internally generated stress exceeds tensile strength.
- Measure fracture stress and temperature.
Dynamic Modulus

- Varying temperature and loading frequency.
- Sinusoidal axial compressive stress applied to a specimen.
- Measure recoverable axial strain response.
- Calculate modulus and phase angle
Fatigue Beam

- Temperature 20.0 +/- 0.5°C.
- Beam 380x50x63mm.
- Fatigue resistance / Flexural bending.
- Graph number of cycles vs. strain.
- Determine fatigue life.
Disk-Shaped Compact Tension Test

- Measure fracture resistance.
- Disk 150x50mm.
- Low temperature PG + 10ºC.
- Fracture energy: area under the curve Load (kN) vs Crack Mouth Opening Displacement CMOD (mm), normalized by the area of the fractured surface.
Results to Date

<table>
<thead>
<tr>
<th>Mix Type</th>
<th>Mean Fracture Stress (MPa)</th>
<th>Mean Failure Temp (°C)</th>
<th>Mean Max. Load (KN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP12.5mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-58-28</td>
<td>2.0</td>
<td>-30</td>
<td>5.1</td>
</tr>
<tr>
<td>0-52-34</td>
<td>1.7</td>
<td>-34</td>
<td>4.3</td>
</tr>
<tr>
<td>20-58-34</td>
<td>2.6</td>
<td>-34</td>
<td>6.4</td>
</tr>
<tr>
<td>40-58-28</td>
<td>2.2</td>
<td>-29</td>
<td>5.5</td>
</tr>
</tbody>
</table>

- ANOVA and t-test did not show significant difference.
- Three replicates per mix type.
Discussion

- It is possible to design efficient mixes containing RAP.
- All the specified properties for the Superpave design are met, as well as the consensus properties.
- RAP addition affects the angularity of coarse aggregate, could have an effect in the rutting of RHM.
- Dust proportion is affected with the addition of RAP.
- RAP content does not affect the fracture resistance.
- Up to 40% RAP can be added without affecting the low temperature PG of the mix.
State-of-the-art Infrastructure
Impact of Findings

Serviceability

Cost

Environmental Impacts

Conventional Pavement

Warm Asphalt

Recycled Pavement/Using By-Products
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Thank you!

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