Increasing AC In Hot Mix Asphalt

Ontario Asphalt Pavement Council
Partners in Quality Road Tour

April, 2018

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Director Quality
Aecon Infrastructure
• Superpave Mix Design
  • Test procedure and materials change with traffic loading
    • More Robust for Higher Traffic Loading
  • Overall North American experience with Superpave has seen a reduction in AC%
    • Some US States Have Adjusted Superpave Design Process for Higher Traffic Pavements
      • Reduced Gyrations = Increased AC
    • Other States – Innovative Design and Construction Process
      • Balanced Mix Design
      • HMA Regression
• Higher AC = Longer Pavement Life
  • Problems on projects regularly linked to lean mixes.
    • Early Age Fatigue Cracking
    • Overall Reduction in Expected Life

• Why Longer Pavement Life?
  • Increased AC film thickness =
    • Slower oxidization of AC in Mix
    • Reduction in cracking potential of pavement
      • Increased Fatigue resistance
      • Increased flexibility
• Other Benefits
  o Higher in-place density during placement
    • AC acts as lubricant
    • Highly Polymerized AC’s can be difficult to compact
      o Extra AC helps offset difficulties
  o Higher Compaction = Reduction in permeability
    • Lower in-place air voids
    • Slower Oxidization of AC
Higher AC % Encouraged by MTO

- AC for bid purposes
  - If % AC content exceeds bid AC, Additional AC cost is paid as extra to contract
- Recent Specification changes default to fine graded mix design

Municipal Specifications - Higher AC contents

- Some municipalities have resisted implementing Superpave
  - Concerns about lean Superpave Mixes
- Minimum AC contents being specified for mix types
  - Marshall and Superpave
- Mixes finer than 12.5 mm being specified for surface.
  - 9.5mm mixes
Industry

- OAPC / ORBA supports all Initiatives that will improve Pavement Quality
- AC Suppliers Strongly Support Increased AC Content

Everyone Wants Benefits expected from Higher AC

- Increased AC Content alone may not provide the desired benefits
  - AC Content is only one factor in pavement performance
  - Interaction of individual materials, HMA mix design, and placement needs to be considered.
    - Changes in proportions cause reactions
  - With Current Mix Design Processes and Specifications
    - Reactions can be Positive or Negative
• Mix Design Practice – 101
  o Combine available aggregates and AC to achieve...
    o Densest possible aggregate structure within gradation specification limits, while..
    o Maintaining the Specified Volumetric Properties
      • Air Voids
      • VMA
      • VFA
      • Dust Ratio

Densest Structure achieved closest to 0.45 power Maximum Density Line
• Mix Design Practice – 101

  o Designer uses available aggregates.
    o Each HMA supplier uses their own suite of aggregates year after year.

    o Competition prevents implementation of material changes that could increase cost

  o Designer selects optimum blend of aggregates and AC for mix JMF

  o Selected JMF May Not Align With Current Owner Initiatives for Higher AC
    o MTO AC for Bid purposes
    o Municipal minimum AC contents
• Mix Design Practice – 101
  o Designer can make limited adjustments to increase Voids and make room for more AC
    o Move gradation away from Zero Air Void line
      o Keep mix on fine side of envelope
        o + 1% Passing 4.75mm = +0.1% Voids
    o Reduce dust content in Mix
      o -1% Passing 75 um = +0.75% Voids
  o Use more cubical aggregates – Potential Cost Increase
- Designer Can Adjust Gradation to Allow More AC
  - Finer Mixes Have Higher AC, but...
    - Higher Aggregate Surface Area
    - Higher Surface Area May Offset Benefit of Increased AC%

- Increase in AC Should Result in Increase in Film Thickness
  - Slower Oxidization
  - Increased flexibility
• Is Higher AC an Assurance of Pavement Performance?

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>25 mm</th>
<th>19 mm</th>
<th>12.5 mm</th>
<th>9.5 mm</th>
<th>4.75 mm</th>
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<tr>
<td>PB (%)</td>
<td>4.00</td>
<td>4.5</td>
<td>5.20</td>
<td>5.50</td>
<td>7.80</td>
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• Aggregate gradation selected at middle of specification –
• Actual mixes will vary.
• AC % based on current MTO AC for Bid Purposes for 25mm, 19mm, 12.5mm
<table>
<thead>
<tr>
<th>Hot Mix Type</th>
<th>25 mm</th>
<th>19 mm</th>
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<tbody>
<tr>
<td>SA (Sf/lb)</td>
<td>25.9</td>
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<td>7.80</td>
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<tr>
<td>Abs (%)</td>
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<td>0.85</td>
<td>0.85</td>
<td>0.85</td>
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<tr>
<td>PBe (%)</td>
<td>3.18</td>
<td>3.69</td>
<td>4.39</td>
<td>4.70</td>
<td>7.02</td>
</tr>
</tbody>
</table>
- Example Gradings show Film Thickness is effectively the same for each mix type.
- Film Thickness will increase with increased AC if gradation is not adjusted.

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<td><strong>6.304</strong></td>
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</table>
• Specifying Minimum AC / Artificially Increasing AC
  • May Not Guarantee Better Performance

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<td>75</td>
<td>6.0</td>
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<tr>
<td>PB</td>
<td>5.2%</td>
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</table>

12.5mm Mix: Gradation Middle of Specification
- Gradation Adjusted to Increase AC
  - Designer adjusts proportions of available aggregates
  - Unlikely to make changes that will increase mix cost by adding or changing aggregates

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<td>------------------</td>
<td>--------------------------------</td>
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<td>SA (Sf/lb)</td>
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<td>Abs</td>
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<td>PBe</td>
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<td>12.5mm Middle of Specification</td>
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<td>6.377</td>
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Has the 0.3% Extra AC Added provided a benefit?
• Mix Design Practice

• Performance Prediction Shortcomings
  o Focus on Developing Optimum Design Blend using....
    o Available Aggregates
    o Available AC
  o Do Not focus on Predicting Performance of HMA
  o Do Not Incorporate Measures to Predict Pavement Life
• Minimal guidance to identify poor performing mixes
  o VMA Curve – Identify potential instability / Rut prone mix
    o Unstable mix if AC Content set beyond bottom of curve (AI-MS2)
  • JMF AC must be established before bottom of curve
  • No guidance for mixes with Poor Fatigue resistance
Innovations for Better Performance

• Performance Based Mix Design
  o Superpave intended to have a level 2 and 3 Design Procedures
  o Laboratory Performance Testing of Mix designs based on Traffic Level
  o Not yet implemented and branded specifically as a part of Superpave Design.
    • Many test procedure options
    • No Consensus on the “Best Test”

• Some agencies have developed performance test requirements.
  • Have data from previous testing
- Texas DOT - Balanced Mix Design
  - Performance Based Design

- Considers Impacts of AC Content on Mix
  - Increased AC results in Higher Tendency for Deformation
  - Reduced AC Results in Higher Cracking Potential
Performance Tests
  Deformation
    • Hamburg Wheel Tracking Test (WHTT) AASHTO T 324
    • Provides Expected depth of rutting expected with traffic

Fatigue
  • Texas Overlay Tester (OT) Tex-248-F
    • Provides Expected Cracking of mix based on repeated loading

• Used in Texas for many years to monitor performance
  • Good understanding of relationship with local materials
  • Acceptance Limits Based on Performance Experience
Balanced Mix Design

• Mix Design Completed as Typical
  • Gyratory Samples fabricated at incremental AC contents
  • Optimum AC Selected at 4% Air Voids

• Gyratory Samples at each AC content tested for
  o Rutting Performance
  o Fatigue Resistance / Cracking Prediction

• Results Plotted Against Acceptance Limits
6. If JMF AC at 4% Voids in Initial Design Falls in Acceptable Ranges
   - Mix Accepted
   - If Not
     - Mix Reformulated
• AC Content of Mix can be adjusted within established AC Range
  • To provide best overall performance
  • To address specific performance concerns
    • Soft AC
    • Historical performance
    • Traffic Loading
• Change of Mindset Required
  • Air voids established for balanced design not necessarily 4%
  • Could be higher or lower than established in initial Design
  • Acceptance during production
    • Air Void range adjusted to fit new target AC percent
Advantages of Performance Based Mix Design

- Identify high AC limit for mix that will allow acceptable rutting depth
- Identify low AC limit for mix to prevent early age cracking.
  - Benefit for RAP Mixes
- Mix AC content can be set to provide best performance for expected conditions.
Restrictions to Implementation in Ontario
  - Specialized equipment required.
    - High cost
    - Unproven in Ontario
  - Unfamiliar test procedures
  - Will take a few years before industry gears up

MTO Currently Conducting Research
  - Developing Understanding of Test Methods Most Appropriate for Ontario Conditions
  - Potential Development of Performance Based Mix Design in Future
• Is AC Content the only thing that influences Pavement Performance?
  • Compaction
  • MTO recognizes benefit
    Recent Increase in LL% for Compaction – 92%
    Consistent with Majority of US States

![Normalized Compaction Targets by State](Source: AASHTO 2007 SOM Survey)
• 1.5% increase in density leads to 10% increase in fatigue life. (UK-AI Study)

• Reduced Air Voids = Increase in Fatigue Life

Table 1. Effect of Air Voids on Fatigue Performance

<table>
<thead>
<tr>
<th>Study</th>
<th>Lab/Field Experiment</th>
<th>Mix Type</th>
<th>Air Voids Evaluated</th>
<th>Increase in Fatigue Life for 1% Decrease in Air Voids</th>
</tr>
</thead>
<tbody>
<tr>
<td>UCB (Epps and Monismish 1969)</td>
<td>Lab</td>
<td>British Standard</td>
<td>4 - 14%</td>
<td>20.6%$^1$</td>
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<tr>
<td></td>
<td></td>
<td>California Fine</td>
<td>5 - 8%</td>
<td>43.8%$^1$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>California Coarse</td>
<td>2.5 – 7%</td>
<td>33.8%$^1$</td>
</tr>
<tr>
<td>UCB (Harvey and Tsai 1996)</td>
<td>Lab</td>
<td>California Dense-Graded</td>
<td>1 - 3% 4 - 6% 7 - 9%</td>
<td>15.1%$^1$</td>
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<tr>
<td>WesTrack (Epps et al. 2002)</td>
<td>Lab</td>
<td>Fine</td>
<td>4, 8, 12%</td>
<td>13.5%$^1$</td>
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<td>Fine-Plus</td>
<td>4, 8, 12%</td>
<td>13.3%$^1$</td>
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<td>Coarse</td>
<td>4, 8, 12%</td>
<td>9.0%$^1$</td>
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<tr>
<td></td>
<td>Field</td>
<td>Fine/Fine-Plus</td>
<td>4, 8, 12%</td>
<td>21.3%$^1$</td>
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<td>4, 8, 12%</td>
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<tr>
<td>AI (Fisher et al. 2010)</td>
<td>Lab</td>
<td>9.5 mm Dense-Graded</td>
<td>4 – 11.5%</td>
<td>9.2%</td>
</tr>
</tbody>
</table>

$^1$ (Seeds et al. 2002)

• Research Data Suggests - Best Expected Performance With
  • Higher AC
  • Lower Air Voids
  • Higher Compaction
Established Mix design air voids reduced from 4% to 3% in production by addition of approximately 0.3-0.5% asphalt binder from optimum

Similar process to rich bottom mixtures used in perpetual pavements.

Difference..

AC % increase is limited to achieve 3% air voids (1% AV Reduction)
• Regression Mix Design
  o Mix Design JMF Established at N Des = 96% (4% Air Voids)
    o “Regressed” *Production* AC Content = AC Content at 3% Air voids
      o Typical 0.3% to 0.5% Increase in AC
      o Original VMA requirements must be met
        o Encourages Consideration of VMA in Lab design
        o Restricts Selection of Mixes with Marginal VMA

JMF AC Must Allow for VMA change with Regressed AC Content
• Production Acceptance
  • Regressed AC %
    • Example from Chart below
      • Voids regressed from 4% to 3%
      • JMF = 5.4%, Regressed AC = 5.8%
  • Regressed AC % Production limit +/- 0.35%
  • Air Voids @ N Des = 97% (3%): +/- 0.9%
  • VMA Limits – No Change
  • Compaction Lower Limit 92.5%
• Advantages
  
  o Controlled AC Increase
    o 0.3 to 0.5% increase – Mix Specific Adjustment
      o Film Thickness Increased – Increase in Fatigue Life
  
  o Controlled 1% Reduction for In Place Air voids
    o Increase in Fatigue Life
  
  o Higher Pavement Compaction
    o Increased AC promotes higher density across mat
      o Reduced Oxidization
      o Increased Fatigue Life
  
  o Optimum Aggregate Structure
    o Optimum HMA Design selected at @ N Des = 96%
    o Structure Selected Must Allow for Regressed AC and VMA
Summary

- Initiative for Higher AC and Better Performance is Supported by All Owners current options are limited without changes.
  - Specify higher AC %
  - Hope to get more better performing mixes
    - Success Rate??????

- Changes in Gradation to meet minimum AC%,
  or,
  - Specifying Smaller Nominal Size Mixes with Higher AC%,
    - Higher Surface Areas
    - Do Not necessarily get higher film thickness to promote performance

- AC % in a mix is only one part of the performance equation.
  - Compaction and Air Voids need to be considered as well
Summary

- Performance Based Mix Design Is Ideal Solution
  - Specific Blend of Aggregates and AC can be verified.
  - Mix Design AC % can be adjusted for specific concerns
    - Premature Cracking
    - Instability problems
      - Rutting, shoving etc.
  - But....
    - Test procedures accepted across Ontario are not yet available
    - May take a number of years before industry is up to speed
    - Balanced Mix design will require change in mindset for Air Voids.
Summary

• Regression May Provide An Easily Implemented Option
  • Benefits
    o AC content increased with an increase in film thickness
    o Higher Field Density
    o Reduced Air Voids
    o Design incorporates optimum aggregate structure
    o All benefits point to increased fatigue resistance
      o Reduced cracking and longer lasting pavements.

• Can easily fit into current specifications with minor changes to limits
  • Aligns Well With Current Acceptance Processes
Thank You

- Questions??