Improved Density…What’s it Worth

Vince Aurilio, Executive Director
Ontario Asphalt Pavement Council
Premise:

✓ Compaction is essential for long-term pavement performance
✓ There are many compaction enhancements currently in use
✓ Compaction goals can be improved
“Compaction” is the Single Most Important Factor that Effects the Ultimate Performance of a Hot Mix Asphalt Pavement!
Reasons for Compaction

• To minimize prevent further consolidation
• To provide shear strength and resistance to rutting
• To improve fatigue cracking resistance
• To improve thermal cracking resistance
• To ensure the mixture is waterproof (impermeable)
• To minimize oxidation of the asphalt binder

Compaction also provides a smooth, quiet driving surface

All are elements of durability
Effect of In-Place Air Voids on Life Cycle Cost

- From the past studies, 1% increase in air voids would decrease the service life by an conservative estimate of 10%.

This means ...
- An asphalt overlay constructed to 93% density might be expected to last 20 years while the exact same asphalt overlay constructed to 92% density would only be expected to last 18 years
Effect of In-Place Voids on Life
Washington State DOT Study

<table>
<thead>
<tr>
<th>Compaction Level</th>
<th>In-situ Air Voids, %</th>
<th>Percent Service Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>89%</td>
<td>11</td>
<td>50</td>
</tr>
<tr>
<td>90%</td>
<td>10</td>
<td>60</td>
</tr>
<tr>
<td>91%</td>
<td>9</td>
<td>70</td>
</tr>
<tr>
<td>92%</td>
<td>8</td>
<td>80</td>
</tr>
<tr>
<td>93%</td>
<td>7</td>
<td>90</td>
</tr>
</tbody>
</table>

Graph showing the relationship between percent service life and in-situ air voids at various compaction levels.
Effect of Percentage of Air Voids on Fatigue Life
20°C, 500 microstrain

\[ N_f = -1361.88 \times AV^2 + 15723.35 \times AV + 88162 \]

\[ R^2 = 0.98 \]

UK- AI Study
1.5% increase in density leads to 10% increase in fatigue life.

In-Place Voids vs Fatigue Life
## FHWA Performance Based Mix Design

<table>
<thead>
<tr>
<th></th>
<th>Fatigue Cracking</th>
<th>Rutting</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design Air Voids</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>For every 1% increase</td>
<td>40% increase</td>
<td>22% decrease</td>
</tr>
<tr>
<td><strong>Design VMA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>For every 1% increase</td>
<td>73% decrease</td>
<td>32% increase</td>
</tr>
<tr>
<td><strong>Compaction Density</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>For every 1% lower in-place Air Voids</td>
<td>19% decrease</td>
<td>10% decrease</td>
</tr>
</tbody>
</table>

*Increasing Density Improved Both!*

Courtesy of Nelson Gibson
NCAT Permeability Study

Finer NMAS mixes generally less permeable at equivalent air void levels!

From NCAT Report 03-02

Permeability (x10^-5 cm/sec) vs. In-Place Air Voids (%) graph showing different NMAS sizes.
Permeability can be Catastrophic
Factors in Affecting Compaction

- Base Condition
- Lift Thickness vs. NMAS
- Laydown Temperature
- Ambient Conditions
- Cooling Rates
- Balancing Production Through Compaction
- Paver Operations
## Rolling Factors

<table>
<thead>
<tr>
<th>MAJOR FACTORS AFFECTING ROLLING TIME</th>
<th>allows MORE time</th>
<th>allows LESS time</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAT THICKNESS</td>
<td>THICK</td>
<td>THIN</td>
</tr>
<tr>
<td>MIX TEMPERATURE</td>
<td>HIGH</td>
<td>LOW</td>
</tr>
<tr>
<td>BASE TEMPERATURE</td>
<td>HIGH</td>
<td>LOW</td>
</tr>
</tbody>
</table>
PaveCool Example

- **Key Inputs**
  - Temperature
  - Air
  - Base
  - Mix Delivery
  - Wind Speed
  - Lift Thickness

- **Output**
  - Cooling Curve
  - Estimated Compaction Time
50 mm Lift
10°C Air, Surface Temp
Mix Delivery temp - 150°C
28 minutes to complete compaction operations

60 mm Lift
10°C Air, Surface Temp
Mix Delivery temp - 150°C
39 minutes to complete
Lift Thickness

- Minimum compacted thickness
  - Typically three times nominal aggregate size for fines mixes four times for coarse mixes
  - Provides for...
    - Ease in compaction
    - Minimize aggregate breakage
    - Smoothness
Effect of Temperature on Compaction

Temperature Control is Critical
Compaction Temperature

Set From Temperature – Viscosity? Graph

Mixing Temperature

Set higher than compaction temperature to allow for cooling

How much higher?

Depends on many factors: length of haul, ambient temperature, wind, base temperature, etc.
HMA Pavement Compaction

Good Paving Practices
Focus on **UNIFORMITY!** & **BALANCE!**
Modified Binder

- Asphalt Cement
- Modifier

PG Binder
Breakdown Rolling

• First roller behind paver; gets most of density
• Begin at highest temperature without mat distortion
• Will have to work very close to paver for some mixes, especially at cooler temperatures
• May need rollers in breakdown mode
Pneumatic Rollers

Rubber tire rollers

- Tires must be kept hot
  - Modifiers pick up on cold tires

- Prefer not to use rubber tire rollers with modified binders (US)
What About the Equipment?
Pick-up Problems!
Solutions!
FOR PAVING CREWS

CanSlip2000

A ready to use emulsion of modified recycled Vegetable oil, used to prevent pick up on rubber tire rollers

CanSlip2000 Late Season

Tested to -10°C for end of season use.
Density Acceptance/Quality Control

Measuring Density

Using cores......or a nuclear density gauge
Importance of Tack Coating

- To promote the bond between pavement layers.
  - To prevent slippage between pavement layers.
  - Vital for structural performance of the pavement.
  - All layers working together.
  - Apply along all transverse and longitudinal vertical surfaces.
Good bond between underlying and the new layer being compacted is critical to “confine” the bottom of the new lift and keep it from sliding during rolling.
Consequences of Poor Bond

- Layer independence
- Reduced fatigue life
- Increased rutting
- Slippage
- Shoving
- Compaction difficulty

Direction of traffic?
May & King (2004):
- 10% bond loss = 50% less fatigue life

Roffe & Chaignon (2002)
- No bond = 60% loss of life

- No Bond = 75% loss of life
- 30% bond loss = 70% loss of life
Warm Mix Asphalt

- Reduced Emissions
- Reduced Fumes
- Reduced Fuel Consumption
- Reduced Viscosity/Flow Enhancer
- Improved Workability
- Extend Paving Window
- Cold Weather Paving
- Increase Percentage of RAP
- Improved Quality
Available Technologies

- WAM Foam – Shell/Kolo Veidekke
- Aspha-min- (Zeolite) Hubbard Cont. Co.
- Advera – (Zeolite) PQ Corporation
- Sasobit – Sasol International
- Evotherm – MeadWestvaco
- L.E.A. (Low Energy Asphalt)
- Rediset
- Plant Attachments
Evotherm – City of Toronto
City of Brampton
Lindhurst Street

City of Toronto
Old Finch Road
City of Hamilton - King Street

Paved November 2008
What Will Drive the Market?

- Emissions
- Worker Safety
- Increased use of RAP
- Density Specifications
- Higher Fuel Costs
- Extended Paving Window
- Cold Weather Paving
- The Need to Improve Quality
Acknowledgement: Various Slides Courtesy of Asphalt Institute

Questions