57th Annual Asphalt Paving Conference

Managing Density For Asphalt Pavement

March 26-27, 2013
Soaring Eagle Casino & Resort
Mt. Pleasant, Michigan

www.apa-mi.org
Density vs. Pavement Performance
Cost of Compaction

- Least expensive part of the process
- Compaction adds little to the cost of a ton of asphalt
Importance of Compaction

Effect of Percentage of Air Voids on Fatigue Life
20C, 500 microstrain

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

\[ R^2 = 0.98 \]

UK-AI Study
1.5% increase in density leads to 10% increase in fatigue life.
Field Density Testing
Quality Control & Acceptance of Joint Density

Density Gauge  6-inch Core
Compaction of HMA Pavements

Cores determine density
- Quality control
- Payment
- Different from nuclear
- Correlate readings

25 mm (1")
Compaction of HMA Pavements

Nuclear gauges
- Set up rolling pattern
- Used for quality control
- Adjust rolling when
  - Mix
  - Conditions change
Factors Affecting Compaction
Factors Affecting Compaction

- Mix Properties
  - Aggregate
  - Asphalt
  - Air (Volumetrics)
  - Mix Temperature
- Lift Thickness
- Subgrade & Base Support
- Environmental Factors
- Type and Size of Roller, # of Passes
Effect of Aggregate

- Gradation
  - Continuously-graded, gap-graded, etc.
- Shape
  - Flat & elongated, cubical, round
- Surface Texture
  - Smooth, rough
- Strength
  - Resistance to breaking
  - Abrasion
Aggregate Types

- Natural
- Processed
- Synthetic
- Round (uncrushed)
- Single Crushed Face
- Multiple Crushed Faces
Asphalt Mixtures

Mixtures
- Compaction varies
- Adjust thickness for rolldown
- Match mat thickness
Performance Graded Binders

PG 64-22

147.2 F -7.6 F

“Performance Grade”

Minimum pavement temperature

Average 7-day max pavement temperature

147.2 F - 7.6 F
Loading Rate of Loading

Example
- Mainline pavement
  PG 64-22 → 70 mph
- Toll booth
  PG 70-22 → Slow
- Weigh Stations
  PG 76-22 → Stopping
Effect of Temperature - Mat Too Hot

- Bulges in front of drums
- Mix moves & will not compact
- Roller leaves deep marks

Solution
- Stay back from paver
- Allow mat to cool (stiffen)
Effect of Temperature - Mat Too Cold

- Lower limit 180º F
  - No additional compaction
- No aggregate movement
  - Crushing aggregate
- Solutions
  - Closer to paver
    - Slow paver
    - Add rollers
  - Increase mix temp
Effect of Lift Thickness

- Optimum lift thickness
  - 4x Nominal Maximum Aggregate Size (NMAS)
- Acceptable lift thickness = 3x to 5x NMAS
- Problems Compacting
  - 2x NMAS or less
  - 6x NMAS or more
- Especially critical paving on uneven surfaces
## Asphalt Mix Designation

### Superpave Designation

<table>
<thead>
<tr>
<th>Size (mm)</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>37.5</td>
<td>mm</td>
</tr>
<tr>
<td>25.0</td>
<td>mm</td>
</tr>
<tr>
<td>19.0</td>
<td>mm</td>
</tr>
<tr>
<td>12.5</td>
<td>mm</td>
</tr>
<tr>
<td>9.5</td>
<td>mm</td>
</tr>
<tr>
<td>4.75</td>
<td>mm</td>
</tr>
</tbody>
</table>

### Remember:

- Max Size, mm
  - 50.0
  - 37.5
  - 25.0
  - 19.0
  - 12.5
  - 9.5
Increasing the lift thickness by ½ inch adds 6-7 minutes to available compaction time.

MS-22 Quality Construction
Table 6.03(b)
Effect of Subgrade & Base Support

- Good support critical to obtain proper density
- Spongy or unstable support
  - Provides little resistance to the rollers
  - Mixture not confined, energy dissipated
- Mixture moves & cracks rather than compacts.
Effect of Environmental Factors

Factors affecting how fast the mix cools

- Affects time available for compaction
  - Ambient air temperature
  - Temperature of the existing surface
  - Wind speed
  - Lift thickness
  - As-delivered mix temperature
  - Overcast conditions
Effect of Environmental Factors

Minnesota DOT’s *PaveCool*

- Excellent tool to determine compaction time
  - Based all factors
  - Free download

http://www.dot.state.mn.us/app/pavecool/index.html
Forces of Compaction & Roller Types
Effect of Roller Type, Size, Passes

Roller type and size affects:
- Magnitude of the load
- How the load is applied

Number of passes:
- Increases the density
- To break over point after a # of passes
  - Lowers compaction
  - If continued, damages mat
Forces of Compaction

Compaction forces
- Low force
  - Static pressure
  - Manipulation
- Higher forces
  - Impact
  - Vibration
Roller Types

- Steel-Wheeled
- Pneumatic
- Vibratory
Static Steel-Wheeleded Rollers

4 -14 ton rollers applies static force
• 3-Wheel
• Vibratory rollers in static mode
• Lighter rollers for finish rolling
• Drive wheel must face paver
  • “Climbs” uncompacted mix
  • Tiller wheel pushes mix
• Drums must be smooth and clean
  • Water spray & scraper bars
  • Critical for polymer modifiers
• Avoid rollers used on agg base
Pneumatic Rollers

- Kneading action reorients aggregate
- Tire pressures:
  - ~80 psi (cold) for compaction
  - ~50 psi (cold) for finish rolling
  - Range not to exceed 10 psi
- Tires must be hot to avoid pickup
- Tires must be smooth - no tread
- Not used for
  - Porous friction
  - SMA
  - Polymer modified mixes
Pneumatic Rollers

- Force is:
- Weight on tire divided contact area
  - Expressed as PSI
- Change PSI by changing:
  - Tire pressure
  - Ballast
- Low tire pressure
  - Low force
  - High tire pressure
  - High force
Pneumatic Rollers

- Front-rear axles offset
  - Manipulates mix
  - Under & between tires
- Tighten finish
  - To resist moisture
- Lowering pressure
  - Increases manipulation
- Increasing pressure
  - Increases static force
Pneumatic Rollers

Keep tires hot and clean:
- Drive back & forth on cold mat
  - Up to 30 minutes
  - Internally heat tires
- Keep moving to keep tires hot
- Skirts may be needed to retain heat
- Scrubbers must be used
  - Knock off any accumulation
  - Only use release agent
- Once pick-up starts
  - Marks will not come out
  - Tires difficult to clean
Vibratory Rollers

- Commonly used for initial rolling
  - Breakdown
  - Largest compaction increase
- “Heavy” rollers
  - Heavy duty components & frames
  - 8-18.5 tons, 57-84 in wide
  - 50-200 lbs/linear inch (PLI)
- Frequency: 2700-4200 impacts/min
- Amplitude: 0.016-0.032 in
  - Thin overlays (≤ 2 in)
  - Low amplitude or static mode
- Operate at least 10 impacts/foot
  - 2-4 mph
Vibratory Rollers

Effectiveness

• Movement of drum initiates particle motion
• When particles are moving
  • Resistance to deformation is reduced
• Force applied by weight of drum plus inertia
  • Produces a greater compactive effect
• Achieving more compaction per pass than static rollers
Vibratory Rollers - Amplitude

- Spinning eccentric weight causes drum movement
- Falling drum adds to compactive force
- Distance drum moves is called amplitude
- Amplitude determines impact force
Vibratory Rollers - Amplitude

- Amplitude too high
- Travel speed too fast
- Vibrating cool mat
  - Roll closer to paver
- Finish rolling too cool
  - Roll closer to intermediate roller
- Finish roller too light
Vibratory Rollers - Frequency

- Frequency
- Drum impacts per minute
- Match travel speed to frequency
- Best results when impact spacing is 10-14 per foot
Vibratory Rollers - Frequency

Vibrating Reed Tachometer
- Checks the accuracy of the roller’s frequency reading
- Contains a group of reeds with a specific natural frequency
- As a single vibrating drum passes VRT
  - Observe which reed is vibrating
  - Check value off the machine tachometer
Vibratory Rollers - Frequency

Impact Spacing (I) = \frac{\text{Roller Speed, fps}}{\text{Frequency, Hz}}
## Drum Impacts per Foot

<table>
<thead>
<tr>
<th>Frequency</th>
<th>2 MPH</th>
<th>3 MPH</th>
<th>4 MPH</th>
<th>5 MPH</th>
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<tbody>
<tr>
<td>2000 vpm</td>
<td>11.36</td>
<td>7.58</td>
<td>5.68</td>
<td>4.55</td>
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<tr>
<td>2200 vpm</td>
<td>12.50</td>
<td>8.33</td>
<td>6.25</td>
<td>5.00</td>
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<tr>
<td>2400 vpm</td>
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<td>9.09</td>
<td>6.82</td>
<td>5.45</td>
</tr>
<tr>
<td>2600 vpm</td>
<td>14.77</td>
<td>9.84</td>
<td>7.39</td>
<td>5.91</td>
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<tr>
<td>2800 vpm</td>
<td>15.91</td>
<td>10.61</td>
<td>7.95</td>
<td>6.36</td>
</tr>
<tr>
<td>3000 vpm</td>
<td>17.05</td>
<td>11.36</td>
<td>8.52</td>
<td>6.82</td>
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<tr>
<td>3200 vpm</td>
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<td>12.12</td>
<td>9.09</td>
<td>7.27</td>
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<tr>
<td>3400 vpm</td>
<td>19.32</td>
<td>12.88</td>
<td>9.66</td>
<td>7.72</td>
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<tr>
<td>3600 vpm</td>
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<td>13.64</td>
<td>10.22</td>
<td>8.18</td>
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<td>3800 vpm</td>
<td>21.59</td>
<td>14.39</td>
<td>10.80</td>
<td>8.63</td>
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<tr>
<td>4000 vpm</td>
<td>22.72</td>
<td>15.16</td>
<td>11.36</td>
<td>9.10</td>
</tr>
</tbody>
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Sequence of Roller Operations & Roller Procedures
Sequence of Roller Operations

- Breakdown Rolling
- Intermediate Rolling
- Finish Rolling
Roller Operations - Temperature Zones

**Compactive Force**

**Pressure Impact Vibration**

**Pressure Manipulation**

**Pressure**

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**Temperature Ranges**

- **Temperature Ranges**
  - 300° - 260°F
- **Pressure Manipulation**
  - 250° - 220°F
- **Pressure**
  - 200 - 180°F
Breakdown Rolling

- Initial compaction operation
- Gets most of the density
- Begin at highest temp without mat distortion
- Work closely to paver
- Dual drum vibratory works best
  - Both drums powered
  - Pressure
  - Impact
  - Vibration
Breakdown Rolling

- Traditionally 3-wheel steel
- D/D vibratory most common
- Vibration most productive during breakdown
- Pneumatics
  - Used on base courses
  - Leveling courses
    - Forces mix into cracks
    - Compacts without bridging minor ruts
  - Leave deep marks -- hard to roll out
Intermediate Rolling

- Final step in getting density and initial smoothness
- Mat hot enough to allow aggregate movement
- Mat already close to final density
- Too much force will fracture aggregate
- Typical roller type:
  - Traditionally pneumatic
  - Vibratory at low amplitude and/or static mode
Finish Rolling

Main purpose
• Minimal compaction
• Smoothness
• Removal of any marks
• Once smooth, stop rolling

Typical roller types:
• Tandem steel-wheel
• Pneumatic w/lower pressure
• Vibratory static mode only
Establishing Rolling Pattern
Rolling Pattern

• Speed & lap pattern for each roller
• Number of passes for each roller
  • One trip across a point on the mat
  • Set minimum temperature each roller finishes pattern

• **IMPORTANT:**
• Paver speed must not exceed compaction operation!!!
  • Paver makes single pass
  • Roller pattern requires 3-7 passes
General Rolling Procedures

Reversing Directions
• Avoid straight stops
• Turn toward center of mat
• Don’t turn drum while stopped
• Next pass should roll out any marks created by reversing
General Rolling Procedures

For best results
- Roll at highest temperature without excessive displacement
- Stay close to paver
  - Monitor weather
- Keep up but not too fast
  - Adj paver speed
General Rolling Procedures

Overlaps
- 6” overlap assures uniform compaction
- Include overlap when selecting drum width
- Roller should cover mat in 3 overlapping passes
General Rolling Procedures

Rolldown
- Paver lays thicker lift
- Roller compacts to the design thickness
- Superpave mixes rolldown ~ 25%
- SMA, PFC & other open-graded mixes rolldown ~15%
General Rolling Procedures

Rolling a Crown
- Never straddle crown
- Work from bottom toward crown both sides
- Strengthens mat to support roller on slope
- Overlap crown 6” on last pass
General Rolling Procedures

Parking
- Never park on a hot mat
- Leaves a transverse bump that cannot be rolled out
- When servicing:
  - Roll back to cooler mat
  - Service vehicles on mat < 175° F
Achieving Density on HMA Joints
Longitudinal Joint Types

Notched Wedge

Butt
Longitudinal Joint Types

Butt Joint (paver construction)

Butt Joint (milled or cutback)

Notched Wedge Joint
Proper Overlap:
- 1.0 ± 0.5 inches
- Exception: Milled or sawed joint should be 0.5 inches

Rolldown
- 15-25% based on mix
Rolling Unsupported Edge?

**Option 1**
Hang over 4-6”

**Option 2**

1st Pass 4”-6” inside

2nd Pass hang over 4”-6”
Option 1
1st Pass Hangs Over 4-6 inches
Option 2:
Stay Back 4-6 inches on 1\textsuperscript{st} pass, then roll 2\textsuperscript{nd} pass w/ slight overhang

- Concern:
  - Developing stress crack?
- Merit:
  - Min lateral movement?
Don’t Starve the Joint
Rolling the Supported Edge

1st pass off the joint approx 6-8 inches

2nd pass overlaps on cold mat 3-6 inches
Alternate Method

1\textsuperscript{st} Pass over the Supported Edge

Roller in vibratory mode with edge of drum overhanging 2 to 4-inches on cold side.

Concern with this method is if insufficient HMA laid at joint, then bridging occurs (roller supported by cold mat)
Transverse Joint Starting a Lane

- Roll transverse
- Roll static
- Start drum on cold side
- Move over in 6” - 8” increments until drum is all on hot side
Transverse Joint Starting a Lane

Checking Transverse Joint

Rolling Transverse Joint

Safety and Traffic Control Concerns
Reference Materials on the Topic:

**MS-2:** Mix Design Methods

**SP-2:** Superpave Mix Design

**MS-4:** The Asphalt Handbook

**MS-22:** HMA Construction

http://www.asphaltinstitute.org
Thank You

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