Stop Chasing & Start Managing Density

Session: TH-78

Presented by: Todd Mansell, Caterpillar Inc.
What is “chasing density”

- Measuring, then “thumbs up” or “thumbs down”
- Roller move on…
Why do we chase density?

- “easy way out”
- Lack of communication
- Lack of training
- We know it could be easier, right?
- It can be 5% bonus!!
Managing density

- More cost-effective
- Better quality job
- Control what we can
- Easier on everyone!
Keys to Managing Density

1. Establishing an effective rolling pattern

2. Identifying the root cause(s) of *not* getting density

3. Planning for unplanned events
   - Plant breakdowns
   - Equipment breakdowns – paver, roller, trucking, MTV
   - Trucking problems
Establishing a rolling pattern

1. Planning
2. Equipment Selection
3. Equipment “readiness”
4. Communication
5. Test Strip
What is a rolling pattern?

<table>
<thead>
<tr>
<th></th>
<th>Breakdown</th>
<th>Intermediate</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>%TMD</strong></td>
<td>88-90%</td>
<td>90-92%</td>
<td>92-93%</td>
</tr>
<tr>
<td><strong>Temp</strong></td>
<td>300-260°F</td>
<td>260-200°F</td>
<td>200-160°F</td>
</tr>
<tr>
<td><strong>Coverage</strong></td>
<td>3</td>
<td>2</td>
<td>2 (1 vibe, 1 static)</td>
</tr>
<tr>
<td><strong>Settings</strong></td>
<td>Low A, High F</td>
<td>90 psi</td>
<td>Low A, static</td>
</tr>
<tr>
<td><strong>Finish</strong></td>
<td>150 feet</td>
<td>200 feet</td>
<td>200 feet</td>
</tr>
</tbody>
</table>
Planning

• Estimating
• Bidding
• Project pre-planning
Equipment selection

- Selecting the best roller size, weight, configuration
- Selecting the right number of rollers
Equipment “readiness”

- Is the equipment in ‘work ready’ condition?
- Will that same equipment be available when paving starts?
- Do we have a backup plan for equipment?
Lines of Communication

- Communication protocol should be known in advance for “known situations” and for “what if” situations

- Contact phone list for each job
Compaction Feedback Loop

- Paver Operator
- Roller Operators
- QC Team
- HMA Plant
Test Strip

- Simulate job site conditions – don’t fake it
- Have a post Test Strip meeting
  - What worked? What didn’t?
Rolling patterns

Specific rolling patterns

- Tender mixes
- Stiff or “harsh” mixes
- Low mix temperature
- Variable mix temperature
- Longitudinal joint - confined vs. unconfined edge
To establish a rolling pattern, we MUST know…

1. Different types of rollers available & how they work
2. Amplitude & frequency settings
3. Pneumatic tire roller variables
4. Time available for compaction
5. Number of roller passes to make
6. How far behind the paver the rollers should be
Types of rollers

- Static steel drum
- Vibratory steel drum
- Pneumatic
- Vibratory pneumatic
- Oscillation
Static steel drum
Steel drum static pressure

- PLI is weight at the drum divided by drum width
- Higher weight at the drum gives higher pressure
- Smaller contact area gives higher pressure
Vibratory Steel Drum

- For breakdown, intermediate and finish rolling
- Settings for amplitude and frequency
- Often static mode for finish rolling

*Compacts from the top down*
Amplitude & Frequency Settings

• Amplitude is how hard it hits

• Frequency should be 10 – 14 ipf
Amplitude

Amplitude is directly related to the compactive effort transferred to the mat.
Frequency

- Vibrating drum
- Eccentric weight

Height
Path of vibrating drum center

Low frequency
High frequency

Time and distance (speed is constant)
Impact spacing is closer together in high frequency
Frequency & Resonance

- The natural frequency is called “resonant frequency”
- The roller and pavement can have “system resonance”
Frequency too low or speed too fast?
How fast can my roller go?

Roller speed = \( \frac{Frequency \ (vpm)}{Impacts \ per \ foot} \)

\[
\text{Speed} = \frac{3,000 \ vpm}{10 \ ipf} = 300 \ fpm
\]

\(300 \div 88 = 3.4 \ mph\)
Match my paver speed to the roller(s)

Effective roller speed = \frac{300 \text{ fpm}}{7 \text{ passes}}

Effective roller speed = 42 \text{ fpm}

Paver can not exceed 42 \text{ fpm}
Calculating impacts per foot (IPF)

Impacts per foot = \frac{\text{Frequency (vpm)}}{\text{Speed (fpm)}}

- Frequency setting of 3,000 vpm
- Rolling speed = 300 fpm

\[
\text{IPF} = \frac{3,000 \text{ vpm}}{300 \text{ fpm}} = 10 \text{ impacts per foot}
\]
Pneumatic tire rollers
Pneumatic Rollers

- Most commonly used for intermediate rolling
- Knead the mix
- Close up surface voids and tension cracks
- *Compacts from the bottom up*
Vibratory pneumatic tire roller

• Adjustable amplitude settings instead of ballast
Pneumatic tire roller

- Adjust tire pressures based on mat thickness
- Ballast weight is usually sand, water or steel plates
Adjusting tire pressures

*High Pressure*

*Low Pressure*
Time Available for Compaction

- Compaction of the mix must be accomplished while the mix is still "HOT"
Asphalt Binder

Hot asphalt binder acts as a lubricant for aggregate to aid in compaction.

Cold asphalt binder becomes the “glue” that bonds the aggregate together.
Temperature is critical

300 - 260 Breakdown rolling
260 - 220 Intermediate rolling
240 - 190 possible “tender zone”
220 - 160 Finish rolling
160 – Stop rolling

Keep steel drums off the mix!!!
PaveCool™ website

About PaveCool
- One of the biggest problems in Minnesota's bituminous pavements is a lack of inplace density due to late season paving practices. When bituminous materials are placed in cool weather, they are difficult to compact properly because the asphalt stiffens too rapidly.
- A computer tool (PaveCool) has been developed to assist contractors, inspectors and engineers to make rapid decisions regarding cool-weather paving. The user enters the time of day, the date and the latitude of the paving job. Next, the type of mixture is entered along with the type of surface being paved.
- The surface temperature, air temperature, wind speed, lift thickness and mixture delivery temperature are then entered. The final input

Download PaveCool

For Windows 7 installation problems, Click Here

Space Requirements
During Installation: Up to 4 MB
After Installation: 2 MB

PaveCool Final Report (PDF 1 MB, 146 pp)

Download PaveCool Freeze

PaveCool Freeze is a modified version of PaveCool that can be used to estimate the time it takes for a pavement to cool to freezing temperatures.
PaveCool™ printout

- Time available for compaction
How to increase TAC

• Increase HMA temperature behind the paver
  • Increase plant production temperature
  • Manage silos
  • Tarp loads
  • Manage windrows
  • Manage trucking

• Increase the thickness of the HMA layer
  – Place one lift instead of two if possible
• Use higher frequency rollers on thin lifts
• Breakdown with a pneumatic tire roller
• Breakdown in echelon with two double drums
Approximate temperature losses

- Mix sitting in trucks ≈ 10°F per hour
- Sitting in windrows ≈ 2°F per minute
- No tarps – not significant, sometimes worse with loose tarps, thicker crust will form
- Keep paver hopper full when waiting for 30 minutes or less, otherwise, build a transverse joint
The mix is too cool – what now?!?!?

1. Call the plant to see what they can do
2. Reduce paver speed
3. Add more rollers
4. Plan for the next day
   - Specify a load out temp when you order mix
   - Check your trucking operation
Number of roller passes

• Determine number of passes with the help of your Quality Control team

• Take density readings after each roller pass

• Determine target density values for each roller

• Trial and error to get most efficient roller pattern
Number of roller passes

Establishing the rolling pattern
# Number of roller passes

<table>
<thead>
<tr>
<th></th>
<th>Breakdown</th>
<th>Intermediate</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Settings</strong></td>
<td>12-ton DDV</td>
<td>14-ton tire</td>
<td>8-ton DDV</td>
</tr>
<tr>
<td><strong>1st Pass</strong></td>
<td><strong>Temp</strong></td>
<td>275</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td><strong>Density</strong></td>
<td>88%</td>
<td>92%</td>
</tr>
<tr>
<td><strong>2nd Pass</strong></td>
<td><strong>Temp</strong></td>
<td>260</td>
<td>245</td>
</tr>
<tr>
<td></td>
<td><strong>Density</strong></td>
<td>90%</td>
<td>92.5%</td>
</tr>
<tr>
<td><strong>3rd Pass</strong></td>
<td><strong>Temp</strong></td>
<td>252</td>
<td>230</td>
</tr>
<tr>
<td></td>
<td><strong>Density</strong></td>
<td><strong>91%</strong></td>
<td><strong>93.0%</strong></td>
</tr>
<tr>
<td><strong>4th Pass</strong></td>
<td><strong>Temp</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Density</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Put it all together!

1. Types of rollers
2. Amplitude & Frequency – steel drum
3. Pneumatic tire roller settings
4. Time Available for Compaction
5. Number of roller passes
## Sequence & Timing

<table>
<thead>
<tr>
<th>%TMD</th>
<th>Breakdown</th>
<th>Intermediate</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>88-90%</td>
<td>90-92%</td>
<td>92-93%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Temp</th>
<th>300-260°F</th>
<th>260-200°F</th>
<th>200-160°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coverage</td>
<td>3</td>
<td>2</td>
<td>2 (1 vibe, 1 static)</td>
</tr>
<tr>
<td>Settings</td>
<td>Low A, High F</td>
<td>90 psi</td>
<td>Low A, static</td>
</tr>
<tr>
<td></td>
<td>150 feet</td>
<td>200 feet</td>
<td>200 feet</td>
</tr>
</tbody>
</table>
How far back??
Length of the Roller Pass

\[ \text{Speed} = \frac{\text{Distance}}{\text{Time}} \]

- **Roller speed based on frequency**
- **Time available for compaction**

**Solve the equation for distance**
Length of the Roller Pass (cont’ d)

**Distance** = Speed \times Time

Roller speed = 3.0 \text{ mph} @ 3,000 \text{ vpm}

3.0 mph \times 88 \text{ fpm} = 264 \text{ fpm}

Time = 3 \text{ minutes before tender zone}

Roller distance = 264 \times 3 = 792 \text{ ft}
Length of the Roller Pass (cont’d)

QC tells us we need a 7-pass pattern

Roller distance = 792 ft in 3 minutes

We lose some distance changing direction

assume 0.80 efficiency

\[ 792 \times 0.80 = 633 \text{ feet traveled in 3 min.} \]

\[ \frac{633}{7} = 90 \text{ feet} \]

Length of roller pass = 90 feet
Compaction of Stiff & Tender Mixes

- Stiff Mixes
  -- Compact at high temperature

- Warm Mix

- Other Mix Types

- Tender Mixes
  -- Compact at high temperature and achieve the required density before the tender zone is reached.
Compaction of Stiff & Tender mixes

• Stiff mixes
  – generally very stable and can take high compactive forces
  – compact easier at higher temperatures
  – use higher amplitudes

• Tender mixes
  – temperature sensitive through a specific temperature range
  – achieve density before tender zone – rolling in echelon OR
  – wait until mix cools below tender zone and resume rolling
Pneumatic breakdown on a stiff mix
Pneumatic breakdown
Compacting tender mixes

• Roll in echelon to achieve density before the mix cools to the tender zone

• Wait until the mix cools below the tender zone and resume compaction

• Do NOT run a steel drum in the tender zone
Rolling in Echelon (side-by-side)

• Use two rollers in echelon as close behind the paver as possible and take advantage of TEMPERATURE

• Rollers can make more passes before the mix cools

• Can often be done without the need for a finish roller

• Ideal to use same size rollers to eliminate crossing over
Echelon – steel drum
Echelon - pneumatics
Efficient rolling patterns

1. Pneumatic breakdown for stiff mixes
2. Rolling in echelon
3. Roller drum width selection
4. Rolling the longitudinal joint
Roller drum width

- Select the optimum drum width for the job to get coverage before the mix cools
- Fewer passes = higher production & profit
- Narrower drums generally have higher PLI
- Need to consider production vs. increased compactive effort
12-foot wide lane: 84” x 2 passes

Roller A

Roller B

6” Overhang

6” Overlap

6” Overhang

12’ wide mat
12-foot wide lane: 79” x 2 passes

Roller A

Roller B

6” Overhang

1” Overlap

12’ wide mat

6” Overhang
12-foot lane: 67” x 3 passes

- Roller A
- Roller A and/or B
- Roller B

6” Overhang
13” Overlap
13” Overlap
6” Overhang

12’ wide mat
Rolling the longitudinal joint
Keep end gates on the paver down
Proper amount of overlap

½” to 1” overlap
Fluff Factor (roll down)

2”

\( \frac{1}{2} \)

1.5” after compaction
Compaction of the unsupported edge

The drum should be extended over the unsupported edge by approx. 6”
Unsupported edges

6” overhang
Compaction of the supported edge

The drum should overlap the existing lane by approx. 6”
Matching lanes: Roll from hot side

Steel Drum

6” (150 mm)

Cold side (Existing lane)  Lane 2
“Locking in” the joint
Tools you have

• Finding the Time available for Compaction
  – PaveCool™

• Calculating roller speed (10 to 12 ipf)
  – formula, NAPA IS-120 guide

• Calculating the length of roller pass (formula)

• Different roller trains to consider

• Compaction Troubleshooting guide
What to watch for in the field

1. Mix temperature behind the paver
2. Roller speed – (brisk walking speed 10 ipf)
3. Distance of rollers behind the paver
4. Amplitude and frequency settings
5. Consistent rolling pattern
Production paving

- Communication must be ongoing – Nextel, two-way radio…

- Situations can be better managed if they are not a surprise or before they become a crisis
Keys to Managing Density

1. Establishing an effective rolling pattern

2. Identifying the root cause(s) of *not* getting density

3. Managing the compaction operation during unplanned events
   - Plant breakdowns
   - Equipment breakdowns – paver, roller, trucking, MTV
   - Trucking problems
Not getting density: Root Cause

• Identify root cause(s) when density is *not* being achieved

• Systematic approach:
  – most likely reasons and easiest to check to less likely and more difficult to check

• Flowchart on the next slide is not “all inclusive”, but it covers many of the most common reasons
Asphalt Compaction Troubleshooting

**Are compaction goals being achieved?**

- **No**
  - *Is the mix temperature behind the paver hot enough? > 280°F*
  - **No**
    - If mix is too cool, notify the Job Supervisor immediately.
  - **Yes**
    - Keep the steel drum rollers OFF the mix until the tender behavior stops or they will tear up the mat. You can use a rubber tire in tender zone without doing any damage.

- **No**
  - Are the rollers close to the paver?
  - **Yes**
    - Record the following
      - Mix temp behind paver
      - Number & type of rollers
      - Roller settings (freq/amplitude)
      - Pattern (# coverages)
      - Air temperature
      - Base temperature
      - Asphalt lift thickness
      - Mix type
      - Average percent compaction
      - Roller operators’ names
  - **No**
    - Move them into hot zone.

- **Yes**
  - Is the mix exhibiting tender behavior under the roller(s)?
  - Verify that the nuke gauge lift thickness setting is less than the actual lift thickness being placed.

- **No**
  - Verify that the roller settings of amplitude, frequency and speed are correct per test strip.
  - Check with the lab or plant to see if binder content of the mix and/or gradation changes have occurred.
  - Verify the nuke gauge calibration with the mix and lift thickness.

- **Yes**
  - Typically lowest amplitude for lifts less than 2” thick. Higher amplitudes for lifts > 3” thick.

- **If changes have occurred**, assess the impact of these changes on compaction. Call the QC Manager if necessary. Got your phone list??

*Know the recommended compaction temperature for the mix design being used. Know the Time Available for Compaction.*
Keys to Managing Density

1. Establishing an effective rolling pattern

2. Identifying the root cause(s) of *not* getting density

3. Managing the compaction operation during unplanned events
   - Plant breakdowns
   - Equipment breakdowns – paver, roller, trucking, MTV
   - Trucking problems
Managing for unplanned events

- Plant breakdown
- Equipment breakdown
  - Paver
  - Roller
  - Trucks
- Trucking problems
- Other…
Plant breakdown
Paver breakdown

- Unplanned
- Mix on road
- Mix in MTV
Roller breakdown

- Stop paving?
- Other equipment on site?
- Change rolling pattern & slow down – 2 rollers?
- Back-up equipment?
Trucking problems

- Interrupted trucking
- Delays longer than 30 minutes
- Build a new transverse joint
What do we do tomorrow?

- Process improvement
- How do we use continuous learning to improve tomorrow’s work?
- Small steps = big gains
- Recognize achievement
Plan for Excellent Compaction!

- Consider variables
- Choose amplitude & frequency
- Calculate paving speed
- Calculate compaction speed
- Confirm test strip
- Run cooling curve for tender zone
Summary

• Have a plan

• Communicate

• Establish a rolling pattern

• Manage the compaction operation via feedback loop with job data

• Be prepared for the unexpected
Thank you for your attention

© Caterpillar 2013  All rights reserved.

CAT, CATERPILLAR, their respective logos, “Caterpillar Yellow” and the POWER EDGE trade dress, as well as corporate and product identity used herein, are trademarks of Caterpillar and may not be used without permission.