Achieving Density

60th Annual Asphalt Paving Conference
March 29, 2016

PRESENTED BY: TODD MANSELL, CATERPILLAR
Why do we chase density instead of manage it?

- Lack of training
- Lack of good communication
- Not sure where to start
How do we Manage Density?

1. Know your lines of communication
2. Know your mix design properties, job specifications, targets
3. Establish an effective and efficient rolling pattern
4. Troubleshoot the root cause(s) when we’re not getting density
5. Plan for unplanned events
   - Plant breakdowns
   - Equipment breakdowns – paver, roller, trucking, MTV
   - Trucking problems
Lines of Communication

Highway 68 Project # 2016-04
PHONE LIST
January, 2016

Emergency 911

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<tr>
<th>Name</th>
<th>Position</th>
<th>Phone</th>
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<tr>
<td>Makesno Sense</td>
<td>Project Manager</td>
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<td>Lotsa Iron</td>
<td>Equipment Manager</td>
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<td>Always On Myphone</td>
<td>Area Superintendent</td>
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<td>Paving Foreman</td>
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<td>Orange Cone</td>
<td>Traffic Control</td>
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<td>Big Mack</td>
<td>Trucking</td>
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<td>Marshall Hammer</td>
<td>Quality Control Manager</td>
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<td>Water truck</td>
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<td>DOT Inspector on site</td>
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<td>Batch room @ drum plant</td>
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<td>Equipment dispatch</td>
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<td>L. Fist</td>
<td>Mechanic</td>
<td>555-234</td>
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Foreman
Superintendent
Truck Boss
Project Manager

Paver
Rollers
Hot Plant
QC Team
Know mix properties

- Marshall mix or Superpave? Relative density or Rice (TMD)?
  - Mix selection - did we submit the best mix for the job based on experience?

- Have we had success or problems with this mix in the past?
  - Do we have experience with getting density with this mix?
  - Is it a harsh mix or a tender mix?

- What is the lab-compacted unit weight of the mix?
What does it take to get density?

Temperature

Temperature

Temperature
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!!!
Time Available for Compaction

Density must be achieved while the mix is still *HOT*
PaveCool or MultiCool tools:

**PaveCool**

Asphalt Pavement Cooling Tool

**Download PaveCool 3.0 (EXE 6 MB)**

November 2015 (CD available upon request)

- PaveCool for Android
- PaveCool for iPhone/iPad
- PaveCool.exe (save this file to your desktop to run PaveCool 3.0 without installing it)

**System Requirements**

- Windows XP, Vista, 7, 8 or 10
- 20 MB disk space

**CoolTool.exe** (same as above)

**PaveCool Help**

**About PaveCool**

- One of the biggest problems in Minnesota's bituminous pavements is a lack of in-place density due to late season paving practices. When bituminous materials are placed in cold...
What are the job specs?

- What is the minimum density requirement for mainline? 92-97%
- Joint density? 90%  Shoulders? n/a
- Smoothness? IRI improvement? 60% - one lift
- How will density be measured and accepted? Cores?
What is a good target density?

- Job spec is 92-97%
- Our job target for final density is 94%
- A good goal for breakdown compaction is 95% of our overall target density

$$0.95 \times 94\% = 89\%$$
Establish an effective rolling pattern

1. Based production and density
2. Equipment Selection
3. Balance paver & roller speed
4. Test Strip
5. Verify during production
3 Phases of Roller Compaction

COMPACTION PHASES

- Breakdown
- Intermediate
- Finish
# What is a rolling pattern?

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Review: Types of rollers

- Static steel drum
- Oscillation
- Vibratory steel drum
- Vibratory pneumatic
- Pneumatic
- Combination
Static Steel Drum

- PLI
- Smaller contact area = higher pressure
Oscillation

- Back and forth drum movement
- Maintains contact with surface
- Less aggressive compaction
Vibratory Steel Drum

- Breakdown, intermediate and finish rolling
- Settings for amplitude and frequency
- Static mode for finish rolling

Build density from the top down
Amplitude = compactive effort
Frequency = speed

Speed is constant

Low Frequency

High Frequency
Frequency & Roller Speed & Impacts per foot

10 to 14
Calculating impacts per foot (IPF)

\[
\text{Impacts per foot} = \frac{\text{Frequency (vpm)}}{\text{Actual roller speed (fpm)}}
\]

\[
\text{IPF} = \frac{3,000 \text{ vpm}}{300 \text{ fpm}} = 10 \text{ impacts per foot}
\]
Re-arrange the equation to solve for speed

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

Speed = \frac{3,000 \text{ vpm}}{10 \text{ ipf}} = 300 \text{ feet per minute}
Connecting Amplitude and Frequency

Higher Amplitudes associated with Lower Frequencies

High Amplitude (<0.80 mm) = Low Frequency (>2800 vpm)

Medium Amplitude (0.5 mm – 0.8 mm) = Medium Frequency (2800-3400 vpm)

Low Amplitude (0.2 mm – 0.5 mm) = High Frequency (3400 vpm)
Optimum compaction occurs when all forces are accepted by the asphalt layer.

Balance between forces of compaction and the asphalt layer.

When compaction is balanced, most of the vibratory force is transmitted into the mat.
Balanced Roller Vibration

- Forces out of balance create drum bounce
- Inefficient operation
- Solve bouncing:
  - change speed
  - lower amplitude
  - higher frequency
  - one drum static
  - both drums static
Pneumatic Rollers

- Most commonly used for intermediate rolling
- Knead the mix
- Close up surface voids and tension cracks
- Efficient building density

Build density from the bottom up
Manipulation

- Manipulation occurs due to overlapping tires
- Some forces move sideways
- Tightens surface texture

Overlapping tires develop overlapping areas of contact pressure, creating manipulation forces.
Pneumatic tire rollers

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

Higher Pressure

Lower Pressure
Keep Tire Pressures Equal

- Keep tires hot
- Within 30°F of pavement
- Tire pressures equal
- Warm up before paving
Vibratory pneumatic tire roller

Adjustable amplitude settings instead of ballast
Combination

Vibratory steel drum & pneumatic tires
Establish an effective rolling pattern

1. Based production and density
2. Equipment Selection
3. Balance paver & roller speed
4. Test Strip
5. Verify during production
Planning

- Pre-paving planning
  - Tons per day
  - Paver speed
  - Roller speed
  - Target densities, IRI

- Tools available
  - NAPA IS-120
  - Paving Production Calculator App
  - Amplitude Selection App
  - PaveCool App
Balancing Paver Speed & Roller Speed

- Expected 2,500 tons/day
- 8-hr paving window
- End dumping (18-ton)
- 12-ft paving lane – highway
  - Unconfined edges on first lane
- 2-inch overlay
- 12.5mm polymer-modified mix
- Given 3 rollers
  - 79” steel vibratory x 2
  - 82” pneumatic
Paver speed to place 2,500 tons/day

The Production Planning Calculator can be used for project planning prior to the start of paving and compaction.

The calculator will help establish a balance between:

a) Plant output and Trucking;
b) Plant output and Effective Paver Speed; and
c) Effective Paver Speed and Effective Compactor Speed.

It can also be used to calculate yield per truck or total daily yield. Included is a slope calculator and a windrow dimension calculator.

NOTE: The Production Planning Calculator should not be used for cost estimating. The calculator is designed to assist in project planning and is only as accurate as the raw data entered in the interactive sections. Always verify production estimates obtained from the use of this calculator.
Paver speed to place 2,500 tons/day

- Total daily tonnage
- Paving window
- Truck capacity
- Cycle time
Paver speed using end dumps

- Lift thickness
- Width
- Loose density

36 fpm
Determine Number of Passes Required

- Experience
- Test Strip
- Amplitude Selection App
  - Inputs to App
  - Confirm with Test Strip
- CB54XW 79” drum
  - Low Amp = 0.012”
  - High Frequency = 3,800 vpm
  - High Amp = 0.032”
  - Low Frequency = 2,520 vpm
Roller Speed: High Amplitude/Low Frequency

- Impacts per foot
- Drum width
- Frequency = 2,520
- 2 Passes (test strip)

29 fpm

29 fpm < 36 fpm
Roller speed calculated by hand

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

Roller Speed \( = \) \( \frac{2,520 \text{ vpm}}{10 \text{ ipf}} \) \( = \) 252 fpm

252 ÷ 88 = 2.8 mph
Calculated Roller Speed

Actual roller speed = \( \frac{252 \text{ fpm}}{7 \text{ passes}} \)

Actual roller speed = 36 fpm

Effective Roller speed = 36 fpm \times 0.80 = 29 fpm

Paver can not exceed 29 fpm

Need 36 fpm to get 2,500 tons per day!!
What can I do now?!?

- Slow down paver to 29 fpm
- Set roller at a higher frequency
- Get an 84” wide roller
- Get an additional 79” roller
Roller Speed: Low Amplitude/High Frequency

- Frequency = 3,800 vpm
- Low amplitude
- Requires 3 passes (test)

43 fpm > 36 fpm
Roller speed at higher frequency

Higher frequency $\approx$ lower amplitude which requires an additional pass to get same density.

34 fpm < 36 fpm
Roller selection – do we have a choice?

- Mix of roller types
- Drum width, weight, amplitude, frequency
- Number of rollers
Roller drum width considerations

- 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. ability to get density.
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
12-foot lane: 67” x 3 passes

12’ wide mat

Roller A

Roller A and/or B

Roller B

6” Overhang

13” Overlap

13” Overlap

6” Overhang
Roller speed (breakdown 84”)

- Wider drum
- Lower frequency
- Higher amplitude
- Passes (test strip)

42 fpm > 36 fpm
Test Strip

1. Based production and density
2. Equipment Selection
3. Balance paver & roller speed
4. Test Strip
5. Verify during production
Test Strip

- Simulate job site conditions – don’t fake it
- Have a post Test Strip meeting
Rolling patterns based on the situation

- Tender mixes
  - Steel stay off!
- Stiff or harsh mixes
  - Pneumatic breakdown
  - Echelon rolling
- Longitudinal joint
  - Confined vs. unconfined edge
Number of roller passes

- Determine target density values for each roller
  - 95% of target for breakdown roller is a good target

- Determine number of passes with QC team
  - Take density readings after each roller pass

- Trial and error to ‘fine tune’ roller pattern
## Number of roller passes

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<td></td>
<td>12-ton DDV</td>
<td>14-ton tire</td>
<td>8-ton DDV</td>
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<td><strong>Settings</strong></td>
<td>High A, Low F</td>
<td></td>
<td>1 vibe, low A, high F, 1 static</td>
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<tr>
<td><strong>1st Pass</strong></td>
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<td>250</td>
<td>200</td>
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<tr>
<td></td>
<td>Density 88%</td>
<td>92%</td>
<td>94% (vibe)</td>
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<tr>
<td><strong>2nd Pass</strong></td>
<td>Temp 260</td>
<td>245</td>
<td>193</td>
</tr>
<tr>
<td></td>
<td>Density 90%</td>
<td>93%</td>
<td>94% (static)</td>
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<td><strong>3rd Pass</strong></td>
<td>Temp 252</td>
<td>230</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Density 91%</td>
<td>93.5%</td>
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<tr>
<td><strong>4th Pass</strong></td>
<td>Temp</td>
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<tr>
<td></td>
<td>Density</td>
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How far back?? Breakdown
Length of the Roller Pass

Speed = \frac{Distance}{Time}

Roller speed based on frequency (ipf)

Time available for compaction (PaveCool)

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

Distance = Speed x Time

- Roller speed = 2,640 vpm / 10 ipf = 264 fpm
- Time to cool comes from PaveCool (or measure it)
PaveCool from 275°F to 252°F
Distance = Speed x Time = 264 x 3 = 792 ft

Roller speed = 264 fpm
Time = 3 minutes
Roller distance = 264 x 3 = 792 ft
Length of the Roller Pass (cont’d)

We need a 5-pass pattern from Test Strip
Roller distance = 792 ft in 3 minutes
We lose some distance changing direction ≈ assume 0.80 efficiency
792 x 0.80 = 633 feet traveled in 3 minutes
633 / 5 = 126 feet

Length of roller pass = **126 feet**

**If conditions change - re-calculate the length of roller pass**
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

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Efficient 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
Compacting tender mixes

- Does not compact in specific temperature range or zone
- Roll in echelon
- Resume compaction below tender zone temp
- Do NOT run a steel drum in the tender zone
Rolling in Echelon (side-by-side)

- Take advantage of TEMPERATURE
- Make more passes before the mix cools
- Can be done without a finish roller
- Ideal to use same size rollers
Echelon with same & different rollers
Echelon - pneumatics
Longitudinal Joint - Build it Right

- Paver leaves straight edge to match
- Makes consistent joint overlap possible
- Can use edge cutter
Excessive Overlap

- Poor compaction, loose rock at joint
- Joint needed raking prior to compaction
- Real solution is to control end gate overlap
Keep end gates on the paver down
Have auger extensions when needed
What we’re trying to avoid...

- Excessive head of material
- Segregation at end gate (joint)
- Lack of mix at joint
Proper Amount of Horizontal Joint Overlap

$\frac{1}{2}$ ” to 1” overlap
End Gate Overlap

- End gate down to create straight edge
- Overlap cold side 1/4in
- Correct pre-compaction height
- End gate up causes rounded edge, segregation and fractured aggregate
Fluff Factor (roll down)  $\frac{1}{4}''$ per 1''

2½ ''

2'' after compaction
No Raking

- End gates set properly
- Correct overlap
- Correct height match
- Sufficient material to joint
Which side was paved first?

The amount of mix needed at the joint

Hot mix pushed over lane 2

Lane 1

Lane 2
Proper Overlap and Height Match – no raking
Rolling Pattern tools you have...

1. Finding the Time available for Compaction - PaveCool, measure
2. Calculating roller speed 10-14 ipf (formula, NAPA IS-120, Apps)
3. Calculating the length of roller pass (Distance = Speed x Time)
4. Different roller trains to consider - echelon, pneumatic breakdown
5. Compaction Troubleshooting guide
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

Are the rollers close to the paver?

No

Is the mix exhibiting tender behavior under the roller(s)?

Yes

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.

No

Check with the lab or plant to see if binder content of the mix and/or gradation changes have occurred.

No

Verify the nuke gauge calibration with the mix and lift thickness.

If mix is too cool, notify the Job Supervisor immediately.

Move them into hot zone.

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.

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??

**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

*Know the recommended compaction temperature for the mix design being used. Know the Time Available for Compaction.*
Troubleshooting situations

1. Mix temperature
2. Paver speed, roller speed
3. Verify roller settings of Amplitude, Frequency, Speed
4. Equipment not working as expected (low VPM, no vibe)
5. Nuclear gauge not calibrated/out of calibration
6. Sand changes at plant affects TMD (Rice), VMA
7. AC content, fines return at plant, gradation
Mix Temperature: 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
- Use higher frequency rollers on thin lifts
- Breakdown with a pneumatic tire roller
- Breakdown in echelon with two double drums or pneumatics
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
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
Verify Roller Settings

- Settings per test strip?
  - Amplitude
  - Frequency
  - Speed (10-12 ipf)

- Is the equipment in good working condition?
Managing for unplanned events

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

- Mix on road
- Mix in MTV
- Finish rolling & build a joint?
Roller breakdown

- Stop paving?
- Backup roller on site?
- Have we calculated a paving speed and rolling pattern for the remaining rollers?
Trucking problems

- Interrupted trucking
- Delays longer than 30 minutes
- Build a new transverse joint
Plan for Excellent Compaction!

- Collect information
- Set targets
- Calculate paving speed
- Calculate roller speed
- Balance tons/hr, paver, rollers
- Confirm test strip
- Check, check, check…
- Make changes as needed
Thank you for your attention!

Questions?

Asphalt Pavement Association of Michigan