A Practical Approach to Managing Density

Presented by Todd Mansell, Cat Paving

Why do we chase density?

• Lack of training
• Lack of good communication
• Not sure where to start
What is “chasing density”

“thumbs up” or “thumbs down”

Benefits of Managing Density

• More cost-effective
• Better quality
• Easier on everyone!
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

<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
<th>Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maleko Sensee</td>
<td>Project Manager</td>
<td>555-554</td>
</tr>
<tr>
<td>Luis Frontera</td>
<td>Equipment Manager</td>
<td>555-554</td>
</tr>
<tr>
<td>Alaquion Mychone</td>
<td>Area Superintendent</td>
<td>555-554</td>
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<tr>
<td>Ruste Tenezches</td>
<td>Paving Foreman</td>
<td>555-554</td>
</tr>
<tr>
<td>Orange Cone</td>
<td>Traffic Control</td>
<td>555-554</td>
</tr>
<tr>
<td>Glitter Mack</td>
<td>Trucking</td>
<td>555-554</td>
</tr>
<tr>
<td>Marshall Hammer</td>
<td>Quality Control Manager</td>
<td>555-554</td>
</tr>
<tr>
<td>Th stato Frontra</td>
<td>Water truck</td>
<td>555-554</td>
</tr>
<tr>
<td>Ravenzoe Andropce</td>
<td>DCT Inspector on site</td>
<td>555-554</td>
</tr>
<tr>
<td>Hot Mover</td>
<td>Batch room @ 8am plant</td>
<td>555-554</td>
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<td>Rollo Mole</td>
<td>Equipment Dispatch</td>
<td>555-554</td>
</tr>
<tr>
<td>I. F.</td>
<td>Mechanic</td>
<td>555-554</td>
</tr>
</tbody>
</table>
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
Time Available for Compaction

Density must be achieved while the mix is still *HOT*

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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!!!*
**MultiCool**  Website and Android App

- Google Play App store
- http://www.eng.auburn.edu/users/timmdav/MultiCool/FinalRelease/Main.html

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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?
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

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

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<th>Finish</th>
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<tbody>
<tr>
<td>%TMD</td>
<td>90-92%</td>
<td>92-94%</td>
<td>94+ %</td>
</tr>
<tr>
<td>Temp</td>
<td>300-260°F</td>
<td>260-200°F</td>
<td>200-160°F</td>
</tr>
<tr>
<td>Coverage</td>
<td>3</td>
<td>2</td>
<td>2 (1 vibe, 1 static)</td>
</tr>
<tr>
<td>Settings</td>
<td>High A, Low F</td>
<td>90 psi</td>
<td>Low A, static</td>
</tr>
<tr>
<td></td>
<td>126 feet</td>
<td>200 feet</td>
<td>200 feet</td>
</tr>
</tbody>
</table>

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

\[0.95 \times 94\% = 89\%\]
Types of rollers

- Static steel drum
- Oscillation
- Vibratory steel drum
  - Offset drums
- Vibratory pneumatic
- Pneumatic
- Combination

Static Steel Drum

- PLI – pounds per linear inch
- Narrower drum = higher pressure

\[ \text{PLI} = \frac{\text{Axle load}}{\text{Drum width}} \]

\[ \text{Contact Pressure} = \frac{\text{Axle load}}{\text{Contact area}} \]
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 x impacts per foot

Roller speed is constant
Impacts per foot, Frequency & Roller Speed

10 to 14

Calculate roller speed

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

\[
\text{Speed} = \frac{3,000 \text{ vpm}}{10 \text{ ipf}} = 300 \text{ feet per minute}
\]
Calculating impacts per foot (IPF)

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

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

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)
Balanced Roller Vibration

- Optimum compaction occurs when all forces are accepted by the asphalt layer
- Balance between forces of compaction and asphalt layer
- Forces out of balance create drum bounce
- Inefficient operation = drum bouncing
- Solve bouncing:
  - change speed
  - lower amplitude
  - higher frequency
  - one drum static
  - both drums static

Offset drums

**Advantages**
- Offset drums cover width of layer in fewer passes
- May be a good option on thin mats that cool quickly
- Following curbs, radius

**Disadvantages**
- Effectively a single drum roller
  More passes may be required
- Less uniform compaction (PWL)
Pneumatic Rollers

• Most commonly used for intermediate rolling

• Knead the mix

• Close up surface voids and tension cracks

• Efficient building density

Manipulation or kneading action

• Manipulation occurs due to overlapping tires

• Some forces move sideways

• Tightens surface texture
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

Screed compaction

• Sometimes referred to as “pre-compaction”

1. Vibratory screeds
   – On/off
   – Adjust frequency of vibration

2. Tamper bar screeds
   – Single tamper
   – Double tamper
Vibratory screeds

- With vibration on, typically 80 to 84% density
- No vibration 78 – 82%
- Key is setting vibratory frequency correctly
- Surface texture improved

Tamper bar screeds

Eccentric Bearings
Tamper Motors
Tamper Bars
Tamper bar screeds

- Setting amplitude & frequency are key
- Approx. 88-92%
- 45-120 ipf
- 15-20 fpm
- Tamper vs. Vibratory pros & cons for each

Test Strip

- Simulate job site conditions – don’t fake it
- Have a post Test Strip meeting
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

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<th>Intermediate</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12-ton DDV</td>
<td>14-ton tire</td>
<td>8-ton DDV</td>
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<tr>
<td>Settings</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>1st Pass</td>
<td>Temp 275</td>
<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>2nd Pass</td>
<td>Temp 260</td>
<td>245</td>
<td>193</td>
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<tr>
<td></td>
<td>Density 90%</td>
<td>93%</td>
<td>94% (static)</td>
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<tr>
<td>3rd Pass</td>
<td>Temp 252</td>
<td>230</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Density 91%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4th Pass</td>
<td>Temp</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Density</td>
<td></td>
<td></td>
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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

Use Paving Production Calculator or calculate by hand
Paver speed to place 2,500 tons/day

- Total daily tonnage
- Plant output
- Paving window
- Truck capacity
- Cycle time

Paver speed using end dumps (75%)

- Lift thickness
- Paving width
- Loose density

36 fpm
Amplitude App $\approx 0.020'' - 0.029''$

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 = 10
- Drum width = 79”
- Frequency = 2,520
- 2 Passes (test strip)

29 fpm < 36 fpm (7-pass pattern)

Roller ground 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 \text{ fpm}

252 \div 88 = 2.8 \text{ mph}
Calculated **Effective** Roller Speed

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

Actual roller speed = 36 fpm

Effective Roller speed = 36 fpm \( \times 0.80 = 29 \text{ fpm} \)

Paver can not exceed **29 fpm**

**Need 36 fpm from paver to get 2,500 tons per day!!**

What can I do now!?!?

1. Slow down paver to **29 fpm**
2. Set roller at a higher frequency
3. Get an 84” wide roller
4. Get an additional 79” roller
Try High Frequency setting 3,800 vpm

- Lower amplitude

MUST verify if we meet 89% with 2 passes

43 fpm

43 fpm > 36 fpm

Roller speed at higher frequency

- Higher frequency ≈ lower amplitude which requires an additional pass to get same density

34 fpm

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

12-foot wide lane: 79” x 2 passes
12-foot lane: 67” x 3 passes

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

- 6” Overhang
- 13” Overlap
- 12’ wide mat

Roller speed (breakdown 84”)

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

42 fpm > 36 fpm
Establish an effective rolling pattern

1. Based production and density
2. Equipment Selection
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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

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Length of the Roller Pass

**Distance = Speed \times Time**

**Speed Calculation**

Frequency = 2,640 vpm

We want 10 impacts per foot

\[ \frac{2,640}{10} = 264 \text{ fpm} \]

Time available for compaction (MultiCool or measure it)
MultiCool from 275°F to 252°F

Time \approx 3 \text{ minutes}

Length of the Roller Pass (cont’d)

Roller speed = 264 \text{ fpm}
Time = 3 \text{ minutes}

Distance = \text{Speed} \times \text{Time}
= 264 \times 3
= \textbf{792 ft} \text{ (in 3 minutes)}
Length of the Roller Pass (cont’d)

We lose some distance changing direction

Assume 80% roller efficiency

792 x 0.80 = 633 feet traveled in 3 minutes

We have a 5-pass pattern (from test strip) to cover the mat twice

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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## 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
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
Tender Mix

Rolling 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

Other Mix Types

- Warm Mix
  - Similar to conventional hot mix (for WMA injection process)
  - Chemical (wax) similar to conventional, but may “set” quickly at end
- SMA – high temperature, high amplitudes
- Polymer-modified
  - High temperature compaction
  - SBS, anti-strip
- Open-graded (OGAC, PFC, etc.)
  - Need to “seat” the mix. Often static roll or gently vibrate
- Other mix types??
Rolling the longitudinal joint

Keep end gates on the paver down
Proper Amount of Horizontal Joint Overlap

\[ \frac{1}{2} \text{ " to 1" overlap } \]
Fluff Factor (roll down) \( \frac{1}{4}'' \) per 1"

\[
\begin{align*}
2\frac{1}{2}'' & \quad 2'' \text{ after compaction}
\end{align*}
\]

Unsupported edges

6” overhang
Supported edge – roll from hot side

Roll from hot side
Locking in the joint

Locking in the joint
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. Length of roller pass (Distance = Speed x Time)
4. Different roller trains to consider - echelon, pneumatic breakdown
5. Compaction Troubleshooting guide

Troubleshooting situations

• Mix temperature
• Paver speed, roller speed
• Verify roller settings of Amplitude, Frequency, Speed
• Equipment not working as expected (low VPM, no vibe)
• Nuclear gauge not calibrated/out of calibration
• Sand changes at plant affects TMD (Rice), VMA
• AC content, fines return at plant, gradation
Asphalt Compaction Troubleshooting

**Are compaction goals being achieved?**

- **No**
  - *Is the mix temperature behind the paver hot enough? (> 280°F)*
    - **No**
      - Notify the Job Supervisor immediately.
    - **Yes**
      - Move them into hot zone.
  - **No**
    - **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.
      - If mix is too cool, notify the Job Supervisor immediately.
      - 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**
  - Record the following:
    - Mix temp behind paver
    - Number & type of rollers
    - Roller settings (freq/amplitude)
    - Pattern (if coversages)
    - Air temperature
    - Base temperature
    - Asphalt lift thickness
    - Mix type
    - Average percent compaction
    - Roller operators’ names

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**Plan for unplanned events**

- Plant breakdown
- Trucking
- Paver or roller breakdown
- Long delays
Plan for Excellent Compaction!

• Collect information
• Set targets
• Calculate paving speed
• Calculate roller speed
• Balance tons, paver, rollers
• Confirm test strip
• Check, check, check…
• Make changes as needed

Thank you for your attention & participation!

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