Compaction Best Practices

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Why do we care about compaction?

- Density,
- Smoothness,
- Permeability,
- Public,
- Strength,
- Power.

Fatigue and low temperature cracking.
How do we ensure adequate compaction?
Forces must be equal and opposite
- Sub-grade,
- Sub-base,
- Existing pavement structure.

Remove Weak Materials

Sub-grade

Address drainage problems
Compact sub-grade

Sub-base

Courteous Contractor

Sub-base density checks
Importance of VMA

- Improve Mechanical Stability
- Improve Resistance to Permanent Deformation
- Reduce Moisture/Air Penetration
- Improve Fatigue Resistance
- Reduce Low-Temperature Cracking Potential

Reference Density Comparison

For 4.0% Voids Mix Design

Recent Finding in Idaho

The Department will use the average $G_{mm}$ (aka Theoretical Maximum Specific Gravity or ‘Rice’) of the test section corresponding to the Contractor’s JMF to determine densities for the specified mix production paving.
Use C-JMF target asphalt content $G_{mm}$
Do not use Acceptance Test Strip $G_{mm}$

- For example, if ATS is target of 5.7% AC but produced at 5.3% AC the $G_{mm}$ will rise significantly.
- Measured compaction shall be versus corresponding $G_{mm}$ @ 5.3% AC, not the 5.7% AC $G_{mm}$.

Example: Core Gravity = 2.320

- ATS @ 5.7% AC = 2.478 ($G_{mm}$)
  Density with 5.7% = 93.6
- Production @ 5.3% AC = 2.478
  plus 4(0.004) = 2.494 ($G_{mm}$)
  Density with 5.3% = 93.0

Permeability and rutting

Lack of smoothness

Chatter marks
Building smooth & strong HMA pavements

Balancing Production

How do we get compaction

- Proper equipment,
- Proper use,
- Proper understanding.

Types of rollers

- Vibratory (a/k/a Breakdown)
- Pneumatic (a/k/a Rubber tire)
- Static Steel Wheel (a/k/a Finish)
Eccentric Weight System

1) Oil level sight gauge
2) Eccentric weight shaft bearings
3) Three-position counterweight
4) Amplitude selection wheel
5) Fixed eccentric weight
6) Pod-style housing

Frequency, \( f \) = the number of hertz (cycles/s)--a single cycle is one full rotation of the eccentric weight. Frequency = \( 1/T \)

Amplitude, \( A \) = the maximum deviation from position at rest -- one-half the total movement.
Amplitude

DIRECTION OF TRAVEL

Impact

Spacing

High Frequency

Low Frequency

Reed tachometer, vibrations per minute (vpm)

35 (x100)

Informational Charts

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Typical Values</th>
<th>Effect on Dynamic Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>1,600 to 3,600 vibrations per minute</td>
<td>Frequency $\alpha$ (Dynamic Force)$^2$</td>
</tr>
<tr>
<td>Amplitude</td>
<td>0.25 to 1.02 mm (0.01 to 0.04 inches)</td>
<td>Amplitude $\alpha$ Dynamic Force</td>
</tr>
</tbody>
</table>

Typical Vibratory Settings (from TRB, 2000)
Vibratory Steel Wheel Roller Parameters (after TRB, 2000)

<table>
<thead>
<tr>
<th>HMA Mat Characteristic</th>
<th>Frequency</th>
<th>Amplitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thin Lifts (&lt; about 30mm (1.25 inches))</td>
<td>Operate in static mode. Under vibratory mode, as the pavement increases in density the drums may begin to bounce, which may cause the HMA to shove and become less dense. Also, some of the aggregates may be crushed.</td>
<td></td>
</tr>
<tr>
<td>Lifts between 30 mm and 65 mm (1.25 and 2.5 inches)</td>
<td>High frequency</td>
<td>Low amplitude</td>
</tr>
<tr>
<td>Lifts beyond 65 mm (2.5 inches)</td>
<td>High frequency</td>
<td>Higher amplitude</td>
</tr>
<tr>
<td>Stiff (more viscous) HMA</td>
<td>High frequency</td>
<td>Higher amplitude</td>
</tr>
</tbody>
</table>

Typical Data for Vibratory Tandem Rollers

<table>
<thead>
<tr>
<th>Vibratory Steel Tandem (ton)</th>
<th>Oper. Wt. (lb.)</th>
<th>Drum Diam. (ft.)</th>
<th>Drum Width (ft.)</th>
<th>Static Drum (pli)</th>
<th>Dynamic Drum (pli)</th>
<th>VPM</th>
<th>Nom. Amp. (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.0-8.0</td>
<td>14,700</td>
<td>3.6</td>
<td>4.6</td>
<td>130</td>
<td>260</td>
<td>2,900</td>
<td>0.025</td>
</tr>
<tr>
<td>9.5-11.0</td>
<td>20,500</td>
<td>3.9</td>
<td>5.6</td>
<td>158</td>
<td>384</td>
<td>2,600</td>
<td>0.03</td>
</tr>
<tr>
<td>&gt; 13.0</td>
<td>30,000</td>
<td>4.9</td>
<td>6.9</td>
<td>186</td>
<td>423</td>
<td>2,400</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Check Your Settings Daily
Do not vibrate thin lifts of Asphalt

Skirted pneumatic roller

Tire inflation pressure vs. ground contact pressure

Courtesy of Caterpillar Paving Products
## Tire pressure matters

- Intermediate, breakdown, & longitudinal joint compaction
- Finish rolling removes marks and gets a touch more density with pounds per lineal inch (PLI) ~ 280

### Inflation Pressure and Ground Contact Pressure at Various Wheel Loads and Ply Ratings

<table>
<thead>
<tr>
<th>Ply Rating</th>
<th>Wheel Load (lb)</th>
<th>Tire Pressure (psi)</th>
<th>Contact Area (in²)</th>
<th>Ground Contact Pressure (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>1,250</td>
<td>130</td>
<td>16</td>
<td>78</td>
</tr>
<tr>
<td>14</td>
<td>2,300</td>
<td>35</td>
<td>41</td>
<td>56</td>
</tr>
<tr>
<td>14</td>
<td>2,300</td>
<td>130</td>
<td>26</td>
<td>88</td>
</tr>
<tr>
<td>10</td>
<td>2,800</td>
<td>90</td>
<td>38</td>
<td>73</td>
</tr>
<tr>
<td>* 14</td>
<td>2,800</td>
<td>130</td>
<td>30</td>
<td>92</td>
</tr>
</tbody>
</table>

* Indicates special conditions or notes.
Ballasting finish roller to get PLI > 330

Densification up close

UNIT TOTAL APPLIED FORCE (UTAF)

‘What is a method of expressing a vibratory roller’s impact force on the asphalt pavement?’, Alex.

Unit Total Applied Force (UTAF)

- Increase with lift thickness.
- Vary with mix characteristics.
Desirable UTAF Ranges

<table>
<thead>
<tr>
<th>Course</th>
<th>UTAF (lb. / in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1” Surface Course</td>
<td>290 - 370</td>
</tr>
<tr>
<td>1 – ½” Binder Course</td>
<td>330 - 420</td>
</tr>
<tr>
<td>3” Base Course</td>
<td>400 - 500</td>
</tr>
<tr>
<td>4” plus Base Course</td>
<td>440 - 600</td>
</tr>
</tbody>
</table>

What we have learned

Hot Mix Asphalt motor speedways

Oil & chip
Oil & chip

Placement Equipment

Screed Unit

Courtesy of Caterpillar Paving Products

Courtesy of Blaw-Knox Ingersoll Rand Paving Products
Vibrator RPM & Stroke (Amplitude)

- Fewer impacts per meter = less compaction
- More impacts per meter = increased compaction

Extrusion
Compression
Compaction
Striking Off

Courtesy of Blaw-Knox Ingersoll Rand Paving Products

Hello Idaho… with love from IL

Auger Extensions Missing

Compaction problems along the longitudinal joint
Compaction problems along the longitudinal joint

Longitudinal joint compaction problem solutions

- Specify minimum longitudinal joint density based on maximum achievable.
- Standardize density based on road type and mix type.

Pick a number and let ingenuity of contractor solve the problem;
- 90.0% minimum unconfined.
- 92.0% minimum confined.
Longitudinal joint solution

Echelon Paving, Part II

Timing: Deliveries

How you will feel with longitudinal joint density specification and without