Construction of Quality Hot Mix Asphalt Pavements - 1 Day Course

Compaction

Bob Horan, P.E.
Senior Regional Engineer
Mechanicsville, Virginia

Importance of Compaction

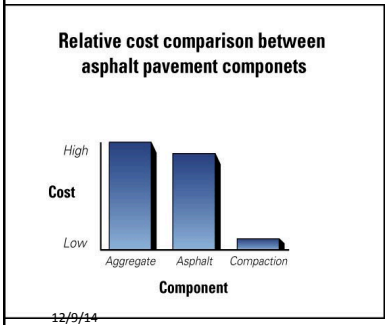
- Compaction is the final step in construction of a quality HMA pavement
- Good compaction is critical to obtain expected service life
- It is good practice to:
  - Have a density specification
  - Test for density regularly
  - Make density part of the pay factor

Importance of Compaction

"I would rather have a poor asphalt mixture that is well-compacted than a good asphalt mixture that is poorly compacted!"

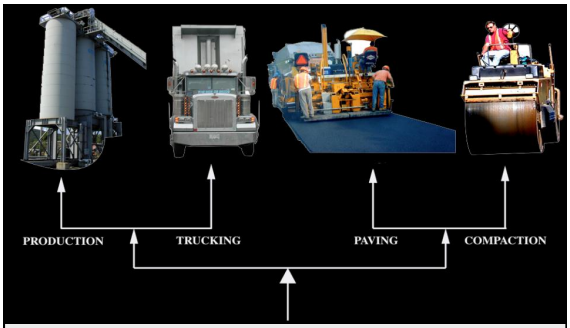
Quote: Paving Expert

Cost of Compaction



- Least expensive part of the paving process
- Aggregates and binders are expensive in comparison
- Compaction adds little to the cost of a ton of asphalt

4



Balancing the Paving Operation

Starting Compaction

Goals of Compaction

- **What are we trying to accomplish?**
  - Consolidate HMA mat
  - Increase density
  - Reduce air voids
  - Remove roller marks

Density and Air Voids are directly related:
100 – Density % = air voids %
Density of 92% of MSG = 8% air voids

12/9/14

Reasons for Compaction

To ensure the proper air void content, which will:

- **Helps prevent further consolidation**
- **Helps provide shear strength or resistance to rutting**
- **Helps improve fatigue cracking resistance**
- **Helps ensure the mixture is waterproof (impermeable)**
- **Helps prevent excessive oxidation of the asphalt binder**

12/9/14

Factors Affecting Compaction

- **Mix Properties**
  - Aggregate
  - Asphalt Binder
  - Mix Temperature
- **Lift Thickness**
- **Subgrade & Base Support**
- **Environmental Factors**
- **Roller Types, Size and Speed**

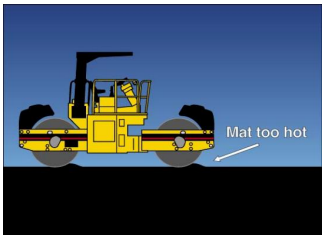
12/9/14

Effect of Temperature on Compaction

Effect of Temperature on Compaction

Effect of Temperature on Compaction

Mat Too Hot!

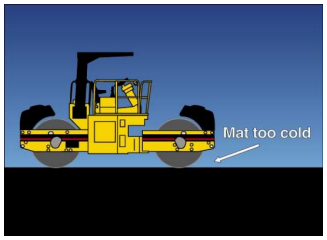


- Look for bulges in front of drums
- Mat will move around and not compact
- Roller leaves deep marks
- Stay back from paver until mat cools

12/9/14

Effect of Temperature on Compaction

Mat Too Cold!



- Lower limit around 180°F to finish compaction
- Roller doesn't leave a mark
- No aggregate movement possible
- May be breaking aggregate or damaging mat

12/9/14

Effect of Lift Thickness on Compaction

- **Optimum lift thickness = 4 x Nominal Maximum Aggregate Size (NMAS)**
- **Acceptable lift thickness =**
  3x to 5x NMAS
- **Problems Compacting - 2x NMAS or less**
  6x NMAS or more
- **Guidelines especially critical if surface to be laid upon is uneven.**

12/9/14

Lift Thickness Example

- **Let's say NMSA of the asphalt mix is 0.5 in (12.5 mm)**
- **Optimum lift thickness (4 X NMAS)**
  = 4 x 0.5 in = 2 in (50 mm)
- **Acceptable lift thickness**
  = 3 x 0.5 in = 1.5 in (37.5 mm)
  = 5 x 0.5 in = 2.5 in (62.5 mm)

12/9/14

Effect of Subgrade and Base Support on Compaction

- **Good support makes it possible to obtain proper density**
- **Spongy or unstable support provides little resistance to the rollers.**
- **The mat simply displaces and cracks rather than compacts.**

12/9/14

Effect of Environmental Factors on Compaction

Several factors come into play regarding how fast the mix cools onsite, affecting time available for compaction:

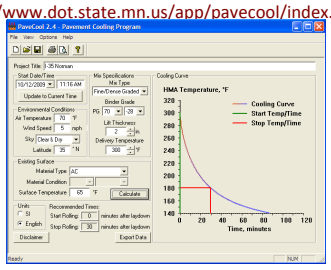
- **Ambient air temperature**
- **Temperature of the existing surface**
- **Wind speed**
- **Lift thickness**
- **As-delivered mix temperature**

12/9/14 17

Effect of Environmental Factors on Compaction

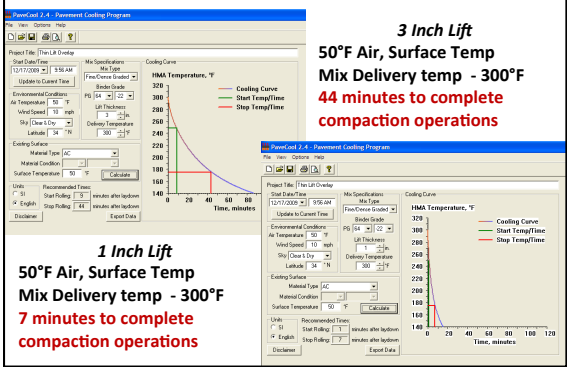
An excellent tool for determining time available for compaction based on these factors is Minnesota DOT's *PaveCool*, available for free download at:

http://www.dot.state.mn.us/app/pavecool/index.html



12/9/14

Mat temp, mix temp, lift thickness, and environment determine time available for compaction



3 Inch Lift
50°F Air, Surface Temp
Mix Delivery temp - 300°F
44 minutes to complete compaction operations

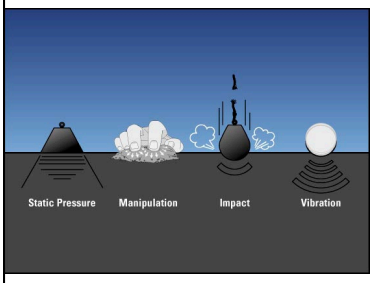
1 Inch Lift
50°F Air, Surface Temp
Mix Delivery temp - 300°F
7 minutes to complete compaction operations

Temperature and Weather Limitations

Many agencies specify minimum surface temperatures on which to lay, as shown in the example below:

Lift Thickness, in	Min. Surface Temp., °F
> 3	40
2 - 3	45
< 2	50

Forces of Compaction



- Four forces are used for compaction
- Static pressure and manipulation are low force
- Impact and vibration generate higher forces

12/9/14

Effect of Roller Type, Size and # of Passes on Compaction

Obviously, the roller type and size affects:

1) **the magnitude of the load**
2) **the manner in which the load is imparted to the pavement**

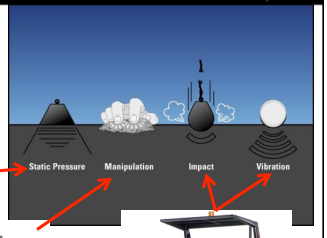
The number of passes:

- **increases the density with each pass**
- **density increase will diminish or possible break over after a certain # of passes**

12/9/14 22

Forces of Compaction - Roller Types

Static Steel-Wheeled



Pneumatic

Vibratory

12/9/14

Static Steel-Wheeled Rollers

- 8 -14 ton rollers normally used for HMA compaction
  - Commonly use vibratory rollers operated in static mode
- Lighter rollers used for finish rolling
- Drums must be smooth and clean
  - Water spray & scraper bars
- For initial compaction, drive wheel must face paver

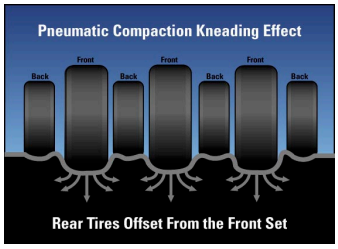
Static Steel-Wheeled Rollers

Pneumatic Rollers

- Reorients particles through kneading action
- Tire pressures:
  - ~80 psi (cold) for compaction
  - ~50 psi (cold) for finish rolling
  - Range of tire pressures not to exceed 10 psi
- Tires must be hot to avoid pickup
- Tires must be smooth - no tread
- Not used for PFC mixes or SMA

12/9/14

Pneumatic Rollers



- Overlap manipulates mat under and between tire
- Tight finish resists moisture penetration
- Manipulation increased by lowering tire pressure
- Static force increased by high tire pressure

12/9/14

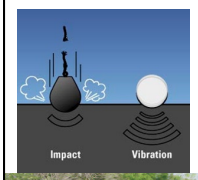
Pneumatic Rollers

Keeping tires hot and clean:

- Have operator drive back & forth for about 30 minutes to heat up tires before getting on mat
- Skirts may be used to retain heat
- Scrubbers may be used on each tire to knock off any accumulation
- Can use release agent spray
- Pick-up marks may not come out, so keep tires hot & clean!

12/9/14

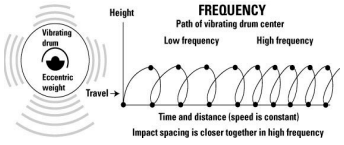
Vibratory Rollers



- Commonly used for initial (breakdown) rolling
- 8-18.5 tons, 57-84 in wide ("heavy" rollers)
  - 50-200 lbs/linear inch (PLI)
- Frequency: 2700-4200 impacts/min.
- Amplitude: 0.016-0.032 in.
  - For thin overlays (≤ 2 in.) use low amplitude or static mode
- Operate to attain at least 10 impacts/ft
  - 2-4 mph

12/9/14

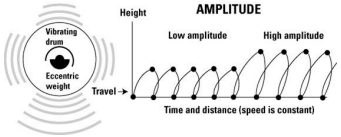
Vibratory Rollers - Frequency



- Frequency is drum impacts per minute
- Working speed must match frequency
- Best results when impact spacing is 10-14 per foot

12/9/14

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

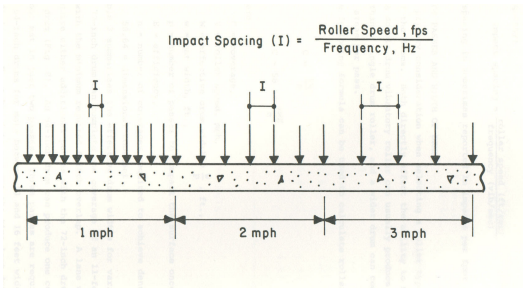
12/9/14

What Makes Vibratory Rollers More Effective?

- Movement of drum initiates particle motion
- Resistance to deformation is much less when particles are moving than when static (inertia)
- Force applied by weight of drum has greater effect, thus achieving more compaction per pass than other roller types

12/9/14

Vibratory Rollers - Frequency



12/9/14

Vibratory Drum Impacts per Foot

Frequency	2 MPH	3 MPH	4 MPH	5 MPH
2000 vpm	11.36	7.58	5.68	4.55
2200 vpm	12.50	8.33	6.25	5.00
2400 vpm	13.64	9.09	6.82	5.45
2600 vpm	14.77	9.84	7.39	5.91
2800 vpm	15.91	10.61	7.95	6.36
3000 vpm	17.05	11.36	8.52	6.82
3200 vpm	18.18	12.12	9.09	7.27
3400 vpm	19.32	12.88	9.66	7.72
3600 vpm	20.45	13.64	10.22	8.18
3800 vpm	21.59	14.39	10.80	8.63

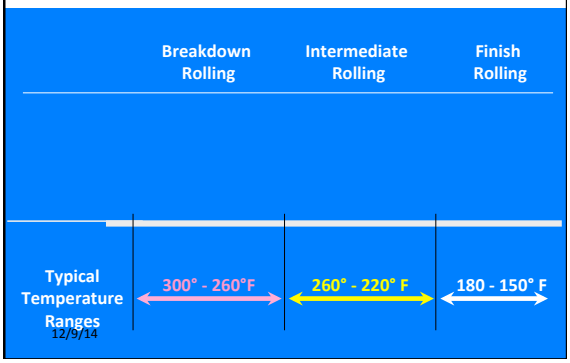
12/9/14

Sequence of Roller Operations

- Breakdown Rolling
- Intermediate Rolling
- Finish Rolling

12/9/14

Roller Operations - Temperature Zones



12/9/14

Breakdown Rolling

- First roller behind paver
- Gets most of density
- Begin at highest temperature without huge mat distortion
- May have to work very close to paver for some mixes

12/9/14

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: pneumatic or vibratory at low amplitude or static

12/9/14

Finish Rolling

- Main purpose is smoothness and removal of any roller marks
- Not intended to increase compaction
- Once smooth, stop rolling
- Typical roller types: steel-wheel (static mode)

12/9/14

What is "Good Practice"?

- Compact mat when it is hot!
- Conduct a density control strip at the beginning of the project
  - Determine optimum roller pattern
  - Stick with roller pattern throughout project
- Reverse directions properly
- Don't stop roller on hot mat
- Use proper technique when compacting longitudinal joints

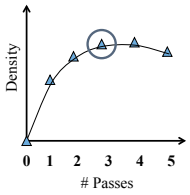
Density Control Strip

Perform a test strip at the beginning of the job to determine optimum number of passes for breakdown, intermediate and finish rollers

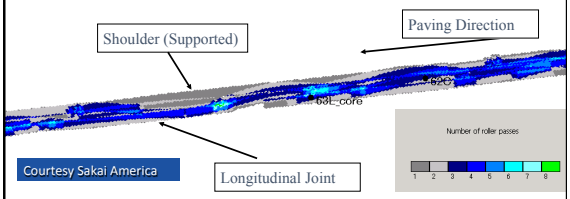
Pattern Decisions

- How many passes?
- How many repeat passes
- How to be sure mix is rolled at correct temperature?
- How fast to roll?

Establishing Rolling Pattern



Spot check the roller operator for number of passes



Courtesy Sakai America

In this case when tracked by GPS, the actual roller pattern and number of passes did not match up with what was intended.

12/9/14

General Rolling Procedures

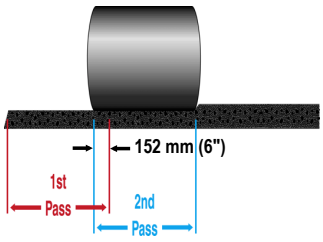
Stay close to the Screed !

- Roll when the temperature is high for the best density
- Keep up with the paver, but not too fast
- May have to roll shorter runs to keep up at slow speeds

12/9/14

General Rolling Procedures

Overlaps



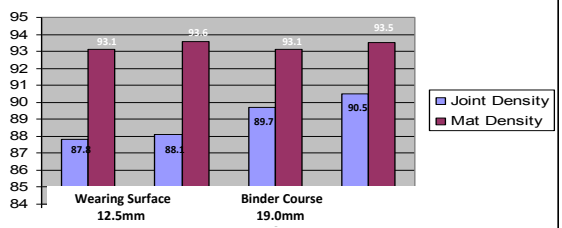
- 6" overlap assures uniform compaction
- Include overlap when selecting drum width
- Roller should cover mat width in no more than 3 overlapping passes

12/9/14

Longitudinal Joint Compaction

Poor Compaction of Long. Joints

Typical Joint vs. Mat Density

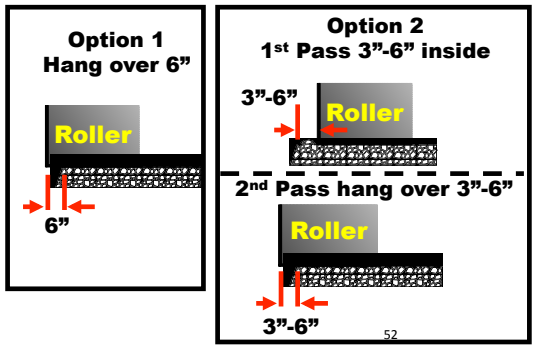


Longitudinal Joint Compaction

- "Confined" joints are placed against an existing structure
  - Previously placed lane, curb & gutter, etc.
- Unconfined joints more difficult to compact than confined joints
- Various joint compaction methods can be successful
  - Success means target density/high air voids at joints

Two Types of Long. Joints

Rolling Unsupported Edge: 50/50



52

Rolling the Supported Edge Our Recommendation:

1st pass off the joint approx 6-8 inches

2nd pass overlap onto the cold mat

With Recommended Method, Still Must Watch for Stress Cracks

During Site Visit to CO, Staying off 6" on 1st Pass

Stress cracks evident at edge of the drum

(while more likely from rolling unsupported edge, can also occur from rolling supported edge)

Density Acceptance/Quality Control

Measuring Density

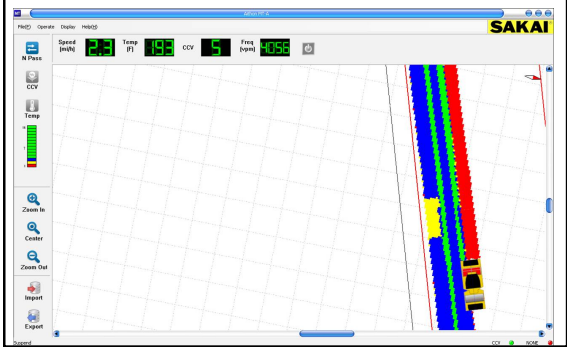
Using cores…… ***or a nuclear density gauge***

Simply Put…..

Intelligent Compaction is a Smarter Way to Get Things Done!

Sakai IC Onboard Display Unit

Color-Coded On Board Display



Conclusions

- Compaction is the final step in construction of a quality HMA pavement
- Good compaction is critical for pavement performance
- It is good practice to:
  - Have a density specification
  - Test for density regularly
  - Make density part of the pay factor

QUESTIONS?

Good Reference Materials on the Topic:

MS-4: The Asphalt Handbook

MS-22: HMA Construction

http://www.asphaltinstitute.org