Equipment 104

Roller Operation 101 -

Today’s Advanced Equipment
State of the Industry - early 1800s

Teamwork
State of the Industry - early 2000s
State of the Industry - early 2100s?
The A, B, Cs

• Asphaltic concrete mix is like eggs, meat and milk...it has a ‘shelf life’ and must be compacted before it cools (spoils)
• Binder content makes it more difficult or easier to compact HMA or WMA mixes
• CO DOT specification for compaction states the process must be “continuous and uniform”
• Compaction is a means-to-an-end...to reduce air voids and increase density
• Density is a pay factor in 17 states including AK, CO, ID, MI, MN, MT, OR, WA and WY  Air void content is a pay factor in 1 state - WI
The A, B, Cs

- Emulsion (tack coat) is essential to proper bonding between asphalt pavement layers and to prevent mix movement (creep) during rolling procedures
- Fine-graded mixes are typically easier-to-compact
- Gap-graded mixes are typically more difficult-to-compact
- Hot Mixed Asphaltic Concrete (asphalt) is America’s most recycled material
- Incentives and disincentives often result from failure to achieve density/air void content during compaction process
- Intermediate rolling adds up to 2-3% density following breakdown rolling
The A, B, Cs

• JMF (Job Mix Formula) is the CO DOT guidance to gradation, AC content and admixture dosage.
• Joint density is critical to pavement life; many states now have joint density specifications
• Kneading action (using the rubber-tired roller) provides superior compaction on leveling courses (vs steel drum)
• Leveling courses placed over irregular bases will contribute to final pavement smoothness
• Longitudinal joint density is critical to pavement life; NAPA produced TAS-33A, a publication outlining recommended Longitudinal Joint Construction procedure
The A, B, Cs

- Marshall mix designs are typically easier-to-compact than Superpave mixes
- Modified binders provide benefits which enhance pavement life but also can make compaction more difficult
- Neat asphalt binders have become less common in Superpave mix designs
- Oscillatory rollers can be effective for both intermediate and finish rolling applications
- Oxidation of asphalt binders is more rapid if high density was not achieved during the compaction process (AVC too high)
- Potholes result from weakness in bases or subgrades... rather than from improper rolling/compaction of flexible pavements
The A, B, Cs

- QA and QC are utilized to measure/evaluate the effectiveness of the laydown and compaction process
- RAP and RAS content is increasing in some mixes and can make the compaction process more difficult
- Smoothness is a pay factor impacted by rolling procedures
- Superpave mixes sometimes exhibit a ‘tender zone’ which complicates the compaction process and affects TAC
- Temperature is one of the most important considerations during laydown and compaction
- Test strips (CTS specification for CO DOT) are specified for jobs of 2000 tons or greater laydown volume
- Time Available for Compaction TAC is critical for all mixes
The A, B, Cs

- Understanding the compaction process helps roller operators be more effective and efficient
- Vibratory rollers are typically the best choice for breakdown rolling applications
- Warm Mix Asphalt is a rapidly growing mix type which is easier-to-compact on most applications
- Xenon lighting (on rollers) provides superior job site visibility, thereby enabling safer night-time operations
- Yellow is a preferred color for visibility on work sites
- Zebras are rarely used for compaction of flexible pavement mixes (except on the plains of central Africa)
Things I Have Learned... the silver bullets

- Keeping up with paver keeps ‘the man’ happy
- Not creating marks beats rolling them out
- Over-rolling can damage soft aggregates
- Rolling speed with vibration is critical
- Smooth starts and stops prevent marks
- Technology makes everyone's jobs easier
- Wetting systems need to be turned on
The Science and Technology of HMA Compaction
Compaction of HMA

• Decreases permanent deformation
• Decreases moisture damage
• Decreases low temperature cracking
• Increases fatigue resistance and life
• Increases strength and stability
• Reduces aging and/or oxidation
AVC / Density is paramount
Traditional 3 roller train
“Modern” 3-wheel rollers
Traditional 3 roller train
“Modern” pneumatic rollers
Traditional 3 roller train
“Modern” finish rollers
Why roller train changes?

- Need for higher pavement bearing capacity / rutting resistance
- Need for higher density at joints
- Need for more uniform density across pavement
Modern 3 roller train
Vibratory breakdown...
Pneumatic intermediate...
Application of technology

• Pneumatic plus vibration
• Manipulation plus particle motion for increased air void reduction
Application of technology
Compactor Operating Techniques

- Reduce operator fatigue
- Increase rolling productivity
- Increase compaction density
- Reduce number of passes
- Reduce operating (fuel) costs
- Reduce machine maintenance
Safe and Efficient Operation
Keep Back From Paver
Too Close for Safety?
Operating is More Than Driving

• Compaction is final process in paving
• Roller ‘train’ typically consists of 3 machines:
  – Breakdown roller
  – Intermediate roller
  – Finish roller
• Each make multiple passes
Uniform Rolling Patterns

5 pass pattern
Work Smart
Match Amplitude to Application

Lower force for thinner lifts

Higher force for thicker lifts
Frequency vs Amplitude

- Frequency change from high to low
- Manual control of amplitude
Dual Importance of Rolling Speed

- Smoothness (drum impact spacing)
- Production (keeping up with paver)
End of Pass ‘hump’
End of Pass Arc
Staggered Ends of Passes
Pneumatic Tire Roller Marks
Uniform Pressure plus Overlap
Ground Contact Pressure

- Ballasted weight
- Number of tires
- Tire size, ply rating, inflation pressure
Stopping or Standing
Rolling Joints
Adjacent Passes
Protecting the Unsupported Edge
Science in compaction

- Nijboer factor - tendency to displace or shove hot mix
- Drum energy – rotary or tangential motion
- Vibration frequency relationship to rolling speed with vibration
Nijboer value

- Static drum load ideally ~15 kg/cm² to avoid excessive mix displacement due to plastic deformation

<table>
<thead>
<tr>
<th>Model</th>
<th>Nijboer Value</th>
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<tbody>
<tr>
<td>BW161AD-4</td>
<td>19.4</td>
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<tr>
<td>CB-534D</td>
<td>17.1</td>
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<tr>
<td>CC 422</td>
<td>18.1</td>
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<tr>
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<td>SW850</td>
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</table>
Drum energy

- Product of amplitude, centrifugal force and vibration frequency
- Compactor drum energy reorients coarse and fine aggregate particles to remove voids and achieve higher HMA density in-place
Vibration frequency

- First vibratory rollers for HMA had frequency limited to 40 Hz
- Newest vibratory rollers for HMA have frequency as high as 70 Hz
Technology in compaction

• Automation of roller control functions
• Pavement surface temperature measurement from roller
• Intelligent compaction systems - IC
Roller automation

• Automatic start/stop of vibration
Roller automation

Adjustable engagement

• Four speed selections
• On/off speeds:
  • ½ mph
  • 1 mph
  • 1½ mph
  • 2 mph
Roller automation

• Automatic start/stop of vibration
• Automatic speed control/limit
Roller automation

- Automatic start/stop of vibration
- Automatic speed control/limit
- Automatic start/stop of water spray system
Automatic drum wetting

- Auto water on/off
- Automatic flow rate tied to speed
- Manual flow rate with rheostat or timer to vary flow
Automatic drum wetting

- Drum wetting system must function for HMA compaction
- Drums must be kept wet or pick-up will occur
Excessive water cools mat

As much as 60° F loss in surface temperature recorded by thermal imaging
Roller automation today

• Manual selection of amplitude based on laydown thickness
Roller automation today

• Manual selection of amplitude based on laydown thickness

• Manual discontinuance of vibration when target density achieved
Emerging roller automation

• Automatic control of dynamic forces of compaction to minimize pavement damage
• Automatic control of rollers to optimize compaction productivity
Temperature measurement

- Roller-mounted sensors
  - infrared

![Image of a temperature sensor displaying 290°](image1)
![Image of a control panel with digital display showing 270](image2)
![Image of a sensor mounted on equipment](image3)
Effect of temperature
Time available...
Vibrating drum technology

Faster vibration frequency + higher forces
Rolling speed with vibration
Rolling speed with vibration

• For optimum smoothness:
  – Drums to 35 inches in diameter select **14 impacts per foot**
  – Drums 35 to 50 inches in diameter select **12 impacts per foot**
  – Drums 50 to 55 inches in diameter select **10 impacts per foot**
  – Drums over 55 inches in diameter select **8 impacts per foot**
Rolling speed with vibration

\[
\begin{align*}
2500 \text{ vibrations/minute} & \quad (10 \text{ impacts/ft}) \quad = 250 \text{ fpm} \\
3000 \text{ vibrations/minute} & \quad (10 \text{ impacts/ft}) \quad = 300 \text{ fpm} \\
4000 \text{ vibrations/minute} & \quad (10 \text{ impacts/ft}) \quad = 400 \text{ fpm}
\end{align*}
\]
Pavement smoothness

- Rolling speed (maintaining correct drum impact spacing for smoothness) faster for higher rolling productivity
Drum impact spacing?
Rolling patterns
Rolling patterns
Keeping up with paver
Productivity balance

Plant output & transport

Laydown & rolling
History - US compactor manufacturers

- American Hoist and Derrick - Bros trademark 1975-1995; acquired in late 1980s by Caterpillar
- Buffalo-Springfield: merger of Buffalo-Pitts Co and Kelly-Springfield Roller Co; acquired by Koehring (1956) which acquired Bomag; acquired Hyster 1990 changed name to Compaction America, now owned by Fayat
- Galion Iron Works – founded 1907; acquired by Dresser Industries and absorbed by Komatsu Dresser joint venture
- Huber Manufacturing Co – 1874-1974, produced road rollers, both steam and diesel engine powered
- Hyster is HYPAC: acquired by Bomag 1990 changed name to Compaction America, absorbed into Bomag product line
History - US compactor manufacturers

- Ingersoll-Rand – organic development of product line in late 1960s; line acquired by Volvo 2006
- RayGo – founded 1964 by RAY Rettger GOrdon Gettis; number 1 in US market in late 1970s; acquired by Caterpillar in late 1980s
- Rexnord Inc – 1973-1998, name changed to Rexworks; compaction line dropped
- Tampo Manufacturing Company – trademarked 1946; compaction line split between Dynapac and I-R
- Vibroplus – trademark expired 1965, name changed to Dynapac; acquired by Atlas-Copco 2007
Rolling Speed with Vibration

• For optimum smoothness:
  – Drums to 35 inches in diameter select **14 impacts per foot**
  – Drums 35 to 50 inches in diameter select **12 impacts per foot**
  – Drums 50 to 55 inches in diameter select **10 impacts per foot**
  – Drums over 55 inches in diameter select **8 impacts per foot**
Rolling Speed with Vibration

\[
\text{2500 vibrations} \enspace \text{minute} \quad \text{(10 impacts/ft)} \\
\hspace{1cm} = 250 \enspace \text{fpm}
\]

\[
\text{3000 vibrations} \enspace \text{minute} \quad \text{(10 impacts/ft)} \\
\hspace{1cm} = 300 \enspace \text{fpm}
\]

\[
\text{4000 vibrations} \enspace \text{minute} \quad \text{(10 impacts/ft)} \\
\hspace{1cm} = 400 \enspace \text{fpm}
\]
Uniform Rolling Patterns

5 pass pattern
Paving Speed

- Compactor with 2500 VPM making five pass pattern at 250 fpm average rolling speed can keep up with paver moving at average speed of 50 fpm
Paving Speed

- Compactor with 3000 VPM making five pass pattern at 300 fpm average rolling speed can keep up with paver moving at average speed of 60 fpm
Paving Speed

- Compactor with 4000 VPM making five pass pattern at 400 fpm average rolling speed can keep up with paver moving at average speed of 80 fpm
Compactor Technology

- Automation of roller control functions
- On-board roller measurement of density
- Pavement surface temperature measurement from roller
- Intelligent compactor drums
Automatic Vibration

Adjustable engagement
• Four speed selections
• On/off speeds:
  • ½ mph
  • 1 mph
  • 1½ mph
  • 2 mph
Automatic Speed Control

- MSPI system
  - operator sets maximum working speed (and auto vibe speed)
Drum Impact Spacing

• ‘Cruise control’ that adjusts rolling speed to frequency
Drum Impact Spacing

• Operator control using impact spacing gauge
Drum Impact Spacing

- EXact Compact Meter
  - input required impacts per foot (from 10 to 16) into meter and set roller speed to operate within green lighting zone 3.4
Frequency Adjustment

• Frequency change with amplitude change from high to low
Frequency Adjustment

- Frequency change from high to low
- Manual control of amplitude
Frequency Adjustment

- Frequency change with manual adjustment of amplitude (with more than two selections)
Automatic Water Spray

- Timed mode for control of water flow
- Spray and no spray interval selected by operator
Automatic Water Spray

- Auto water on/off
- Automatic flow rate tied to speed
- Manual flow rate with rheostat or timer to vary flow
- US patent Dec04 No. 6,827,524
Critical Roller Function

- Drum wetting system must function for HMA compaction
- Drums must be kept wet or pick-up will occur
Excessive Water Cools...

As much as 60° F loss in surface temperature recorded by thermal imaging.
Smart Rollers for HMA

• Newest asphalt compactor technologies
  – Ammann ACEplus – compaction measurement and control with navigation
  – BOMAG Asphalt Manager 2 – IC system
  – Bomag TanGO – tangential oscillation drum
  – Caterpillar Compaction Control with GNSS – IC system measures ICMV, passes, temperature
  – Dynapac Dyn@lyzer – compaction control and documentation; DCM or DCM with GNSS
Smart Rollers for HMA

• Newest asphalt compactor technologies
  – Hamm HCQ Navigator – Hamm Compaction Quality IC system with GPS
  – Hamm Oscillation – rear drum with oscillation/vibration
  – Sakai CIS2 – IC with Topcon GPS positioning
  – Sakai ND – both drums with oscillation/vibration
  – Volvo Co-Pilot – Density Direct IC system with GPS
Ammann ACE

- Variable amplitude
- Variable frequency
- Variable rolling speed
- Automatic change in Compaction Energy of vibrating drum (front drum or rear drum only)
Ammann ACE

- Measures dynamic stiffness (FVDK) of material 30-50 times per second
- Automatically adjusts compaction energy based on stiffness of material
- Changes position of two eccentric weights to adjust compaction energy
- Optional infrared temperature meter
BOMAG Variomatic

Control unit

low dynamic energy

Compaction principle
static pressure and dynamic energy which is automatically adjusted to type of material, compactibility, layer thickness and base layer conditions.

Applications: asphalt layers, granular bases and subbases.

high dynamic energy
BOMAG ASPHALT-MANAGER
Caterpillar Versa Vibe™

“Four resultant amplitude selections and two frequencies”
Versa Vibe™ Adjustment

Amplitude wheel

Amplitude switch
NUTATING OR OSCILLATING DRUMS
Bomag TanGO Drum
Oscillatory Drum Internals
Horizontal Shear Forces

• Drum maintains constant contact with pavement surface; eliminates “bouncing” of the roller’s rear drum
Where to use Oscillation

‘Make’ or ‘Break’ zone

Paver screed

Target density zone

<table>
<thead>
<tr>
<th>Breakdown</th>
<th>Intermediate</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Temp</td>
<td>+/- 300°</td>
<td></td>
</tr>
<tr>
<td>Low Temp</td>
<td>+/- 175°</td>
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</table>

77 % relative density 88-90 % 92-94 %
Dual Drum Oscillation

- Capable of one or two vibratory drums
- Switchable to one or two oscillatory drums
- Only product able to “switch” same drum function
Sakai Vibratory Pneumatic
Sakai vibrating tires

• Four different amplitude settings
  – Allow more versatility and the ability to easily compact both stiff and tender mixtures.
  – Provide more uniform density throughout the pavement layer thickness

Vibrating tires have dynamic kneading effect on pavement
Emerging Automation

• Automatic control of dynamic forces of compaction to minimize pavement damage
• Automatic control of rollers to optimize compaction productivity
• Global Positioning Systems
Density Achievement

• Several systems exist to measure drum “bounce” or reflection of drum
• Few systems can adjust drum to match material requirements
Machine Monitoring Architecture
Temperature Measurement

• Roller-mounted sensors
  – infrared
Drum Edge Lighting
Instrument Panel Lighting

Today

Future
Instrument Panel Lighting
Future Developments

• Operator avoidance of objects on paved panel
• Operator-less control of roller position on panel and relative position to paver and other rollers
Optical Detection Systems
Object Avoidance
Rolling patterns
Rolling Unsupported Edges

Rolling Unsupported Edge
(First Paver Pass)

Edge of drum overhangs unsupported edge
Usually best for achieving maximum density at unsupported edge
Roll Unsupported Edges with 3 to 6” Drum Overhang

For a durable longitudinal joint, it is necessary to compact the unsupported edge of the mat correctly. The key to getting good density is applying loading while avoiding lateral movement of the mix at this edge. For this reason pneumatic tired rollers should never be operated close to this edge. Extend the drum of a tandem steel wheel roller over the unsupported edge of the lane by about 3 to 6”. If this is done, the mix will not move laterally and a crack will not form. Also, adequate tack/bond minimizes mix movement.
Roll Unsupported Edges with 3 to 6” Drum Overhang

Extend the drum of a tandem steel wheel roller over the unsupported edge of the lane by about 3 to 6”.

![Road roller extending the drum over the unsupported edge of a lane](image-url)
What We Don’t Want

Rolling Unsupported Edge
(First Paver Pass)

Edge of drum on unsupported edge
Can cause lateral movement at the unsupported edge
What We Don’t Want

Note the mix breaking over at the unsupported edge. This illustrates why rolling directly on the edge is not desirable.
What We Don’t Want

Rolling Unsupported Edge
(First Paver Pass)

Edge of drum inside unsupported edge
Can cause cracking near the edge and lateral mix movement at the unsupported edge
Rolling the Unsupported Edge
Close up - Unsupported Edge
Roll mat from unsupported edge toward joint

Mat Compaction

For most applications, mat should be rolled from the unsupported edge to the longitudinal joint (number of passes to cover the mat depends on roller & mat widths)

3-6” overhang

1st Pass

2nd Pass

152 mm (6”)

ROCKY MOUNTAIN DETAILERS CONFERENCE & EQUIPMENT SHOW
Compaction at the Joint

Confined Edge Compaction at the Joint

Next to last pass across the mat leaves 6” – 12” uncompacted at the joint (shown above). Last pass overlaps the joint by 2” – 6”.

6-12”
Compaction at the Joint

This method allows the material right at the joint to be confined on both sides prior to rolling. By confining both sides, the full weight of the roller will force the mix down into the joint to achieve the best density available.
Rolling at the Joint
Finished Joint Appearance

This method results in a crushed stone line that is mostly cosmetic and will wear off with weather, time, snow plows, etc.
Good Joint Performance

Filling the joint fully and getting good density is what’s important for good performance. Sufficient material results in a tight joint with some crushed surface aggregate.
Density and Smoothness
Follow Test Strip Rolling Patterns

2 inches following compaction

vibratory

vibratory

Tender Zone
220°F~190°F

static

°F 300 275 250 225 200 175 150 125 °F

Base temperature 40°F

PennDOT 19mm Superpave design
Match Rolling Pattern to Panel Width
Finish Roll for Appearance
QC/QA Safety
Best Practices Cross References


• Multiple positive examples throughout Canada and United States:
  – Caltrans: Reflectorized Suits for Nighttime Work
  – IADOT: High-visibility Worker Apparel
  – MNDOT: High Visibility Reflective Clothing Required for Night Work
  – NSTPW: Three Levels of Illumination in the Work Area
  – NJDOT: Nighttime Lighting Specification for Night Work
  – NYDOT: Nighttime Construction Operations
  – NCDOT: Portable Lighting Specified in Contracts Containing Critical Lane Closures and/or Merges
  – ODOT: Certified Worksite Traffic Control
  – PennDOT: Highly Visible Reflectorized Flagger Vest
  – Virginia: Flagger Certification Program
Save the world! Use technology to reduce environmental impact.
The Future

- Pass counting and mapping
- Density measurement real-time - IC
- Feedback systems for density/smoothness
- Equipment monitoring for uptime
Pass or temperature mapping
Roller technologies IC
Intelligent Compaction
Equipment monitoring