Roller Operations 101: A Basic Overview...

Dale Starr
Volvo Construction Equipment

Definitions

Consolidation

Compression

Compaction

Consolidation

Material volume change achieved naturally through passage of time
**Compression**

Material volume change produced by applying external static load

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**Compaction**

Material volume change produced by momentary application of force

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Compaction – Primary Forces
Manipulation and Oscillation
Impact and Vibration

Manipulation and Oscillation

Impact and Vibration
Three Roller Train

Project Specifications
Prescriptive or Performance Specifications?

WV Department of Transportation, Division of Highways, 2017 Edition Standard Specifications Roads and Bridges

"401.7.3-Compaction: Acceptance testing for compaction shall be performed in accordance with either the Lot-by-Lot method described in Section 401.7.3.1 or the rollerpass procedure described in MP 401.05.20."

"401.9.10-Compaction Equipment: Compaction may be performed by self-propelled steel-wheeled, pneumatic-tired and/or vibratory rollers."

"Compaction of patching and leveling shall be performed with three-wheel (steel) or pneumatic-tire rollers."

"Compaction of a scratch course shall be performed with a three-wheel (steel) or pneumatic-tire roller."

"During rolling, roller wheels shall be kept moist with only enough water to avoid picking up material. Fuel oil on roller wheels or pneumatic tires is not allowed. Rollers shall move at a slow but uniform speed with the drive roll or wheels nearest the paver."

Prescriptive or Performance?
TABLE 401.13.3A
Adjustment of Contract Price for Pavement Density not Within Tolerance of Density

<table>
<thead>
<tr>
<th>Percent of Density</th>
<th>Percent of Contract Price to be Paid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greater than 96%</td>
<td>Note 1</td>
</tr>
<tr>
<td>95% to 96%</td>
<td>102</td>
</tr>
<tr>
<td>92% to 94%</td>
<td>100</td>
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<tr>
<td>91%</td>
<td>98</td>
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<td>90%</td>
<td>96</td>
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<tr>
<td>89%</td>
<td>92</td>
</tr>
<tr>
<td>88%</td>
<td>88</td>
</tr>
</tbody>
</table>

Notes:
1. Mat density slightly above 96% is normally only a problem if it leads to asphalt flushing on the surface of the mat or rutting due to an unstable mixture. The Division will make a special evaluation of the material and determine the appropriate action.
2. When the density is less than 92%, the mat will be more susceptible to accelerated deterioration and a decrease in the expected service life of the pavement. For price adjustments on mat densities less than 88%, the percent of Contract Bid Price will be decreased by 1% per percentage of mat density less than 88%, unless a special evaluation performed by the Division determines an even greater price was appropriate.

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Commonwealth of Pennsylvania, Department of Transportation, Publication 408/2016

“(f) Rollers. Use a minimum of three steel-wheeled rollers, each weighing a minimum of 10 tons and as specified in Section 108.05(c). Operate rollers according to manufacturer’s recommendations. Use rollers equipped with a watering or soapy watering system that prevents material from sticking to the rollers. Do not use pneumatic wheel rollers. Do not use rollers in vibratory mode unless it can be demonstrated during the trial demonstration specified in Section 419.3(g) and to the satisfaction of the Representative that no breaking of aggregate or flushing of asphalt binder results from the vibration. Monitor pavement cores for aggregate breakage on every lot. Discontinue vibration if aggregate breakage or flushing of asphalt binder occurs.”

“(j) Compaction. Begin rolling material immediately after placement. Compact the SMA mixture to achieve the density acceptance requirements and to eliminate all roller marks while not producing flushing of the asphalt binder. Compact the mixture while it is in proper condition and adjust roller speed, pattern, and roller size (and/or amplitude and frequency if vibratory rolling is approved by the Representative) to eliminate displacement, shoving, cracking, and aggregate breakage as specified in Section 419.3(f). Satisfactorily correct displacement resulting from reversing roller direction and other causes.”

Ohio Department of Transportation, ODOT 2016 Construction and Material Specifications

“B. Compaction. Start compaction immediately after the SMA has been placed. Use only steel wheel rollers. Vibratory rollers in vibratory mode, set at a high frequency and low amplitude, can be used as the breakdown roller only. Always operate the breakdown roller immediately behind the paver. If isolated, small fat spots develop, apply sand immediately during compaction. If continuous and/or larger fat spots develop, cease production until resolved. Do not compact SMA that is below 230°F (110°C).”

“Payment for compaction of the completed mainline pavement and ramps is by lot, based upon the degree to which density is attained. Payment for shoulders depends on the degree to which the density is obtained on the adjacent mainline pavement lane or ramp. However, when a cold longitudinal joint is made between a mainline pavement lane and an adjoining shoulder, payment for the shoulder will be based on the degree to which the density is obtained on the shoulder.”
Illinois Department of Transportation, Standard Specifications for Road and Bridge Construction, Adopted April 1, 2016

406.03 Equipment. Equipment shall be according to the following. Items

<table>
<thead>
<tr>
<th>Article/Section</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Self-Propelled Pneumatic-Tired Roller</td>
<td>1101.01</td>
</tr>
<tr>
<td>(b) Three-Wheel Rollers</td>
<td>1101.01</td>
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<tr>
<td>(c) Tandem Rollers</td>
<td>1101.01</td>
</tr>
<tr>
<td>(d) Vibratory Roller</td>
<td>1101.01</td>
</tr>
</tbody>
</table>

Rollers. Immediately after each lift of level binder, binder, or surface course mixture is placed, each lift shall be compacted with equipment meeting the requirements listed in the following Table 1.

1/ If the average delivery at the job site is 85 ton/hr (75 metric ton/hr) or less, any roller combination may be used provided it includes a steel wheeled roller and the required density and smoothness is obtained.

2/ One TB may be used for both breakdown and final rolling on bridge decks 300 ft (90 m) or less in length, except when the air temperature is less than 60 ºF (15 ºC).

3/ A vibratory roller (VD) may be used in lieu of the pneumatic-tired roller on mixtures containing polymer modified asphalt binder.

4/ Pneumatic-tired and vibratory rollers will not be allowed.

North Carolina Department of Transportation Raleigh, Standard Specifications for Roads and Structures, Jan 2014

610-14 DENSITY ACCEPTANCE

“The Department will evaluate the asphalt pavement for density acceptance after the asphalt mix has been placed and compacted using the Contractor’s QC test results, the Department’s QA test results (including verification samples) and by observation of the Contractor’s density QC process conducted in accordance with Section 610 of the Asphalt QMS Manual. Minimum density requirements for all mixes will be as specified in Table 610-7. Density acceptance will be as provided in Section 10 of the Asphalt QMS Manual.”

Indiana Department of Transportation, 2018 Standard Specifications, effective for Lettings on or after Sept 1, 2017

409.03 Compaction Equipment “Compaction equipment must be self-propelled, steel wheel or pneumatic tire types, in good condition, and capable of reversing direction without backslipping. All roller wheels shall be equipped with scrapers to keep the wheels clean, have water spraying devices on the wheels, and steering devices capable of accurately guiding the roller.” A tandem roller which has a drive wheel bearing of no less than 300 lb/in… A pneumatic tire roller shall have a minimum rolling width of 5.5 ft… shall be equipped with compaction tires, minimum size 7.50 by 15, exerting a uniform, average contact pressure from 50 to 90 psi… A vibratory roller that has both drums equipped for vertical impact forces, a variable amplitude system, and have a minimum vibration frequency of 2,000 vibrations per minute… An oscillatory roller… The rollers should be operated to avoid shoving and at speeds not to exceed 3 mph.”

Density acceptance will be based on lots and sublots… pay factor 100% for density 92.0-93.0% with pay factors adjusted up (maximum 96.9%) or down (minimum 98.0%).
Air Void Content or Density?
Which do agencies really need and want? What is the difference?

Prescriptive Specifications
How can paving contractors increase bonuses, maximize incentives, limit disincentives/penalties?

Performance Specifications
How can paving contractors increase bonuses, maximize incentives, limit disincentives/penalties?
‘Best Practices’ Laydown & Rolling

Balance paving speed with capability of roller train to keep up with optimum paving speed.

NCHRP Research Report 856 ©2017

Typical paver speed between 20 - 40 feet per minute; most respondents indicated that slower speed would be advantageous to optimize density.

NCHRP Research Report 856 ©2017

Tonnage placed per day most commonly < 3,000 tons.
Laydown Thickness - Paver Output

3000 tons per day during 8 hours actual paving = 375 tons per hour
Pavement 12 ft (~3.66 m) wide; laydown thickness 3 in (~76 mm)
Paver travels 1,724 ft to lay 375 tons

Modern 3 Roller Train

Compaction equipment in roller train selected to keep up with paver at optimum paving speed for productivity

Follow ‘Best Practices’ in rolling

Most common breakdown roller - DDV
Intermediate rolling relatively even distribution between DDV and PTR
Most common finish roller – DDS
Decision about roller(s) is contractor responsibility, driven by ability to achieve proper percent density
Breakdown Rolling Phase

Breakdown rolling achieves initial density (reduction in air void content); typically done using double drum vibratory compactors.

Intermediate Rolling Phase

Intermediate rolling adds density (reduces air voids) plus reduces permeability of layer; usually done using pneumatic compactors.

Intermediate Rolling Technology

Alternative to pneumatics to add density (reduce air voids) plus reduce permeability of layer accomplished using oscillatory compactors.
Finish Rolling Phase

- Drive with compression roll toward paver
- Gradual steering & turns
- Remove roller marks already in pavement
- Reverse direction smoothly
- Smooth starts and stops
- Rolls moist, not wet

Finish Rolling Technology

Oscillatory compactors are alternative to steel wheel tandems to remove surface marks plus increase final density

Why Roller Train is Changing

- Need for higher pavement bearing capacity & rutting resistance
- Need for higher density at joints & unsupported edges
- Need for more uniform density across pavement
‘Best Practices’ in rolling

Temperature: one of the most important considerations during laydown and during compaction

Time Allowed for Compaction – TAC critical for all paving mixes

Operating Techniques

Reduce operator fatigue to increase productivity
Reduce rolling passes to increase productivity
Increase density, especially at joints
Reduce maintenance and operating costs

Breakdown - Work safe, be Efficient
Keep Safely Back From Paver

Don’t Roll up too Close for Safety

Operating is More Than Driving

Roller ‘train’ can consist of multiple compactors in breakdown mode
Each compactor can make multiple passes based on panel width
Uniform density results can provide incentive or disincentive to contractor
Breakdown Rolling Patterns

5 pass pattern

How Many Passes Side-by-Side?

<table>
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<tr>
<th>Paved Panel Width (feet)</th>
<th>3 inches</th>
<th>4 inches</th>
<th>4.5 inches</th>
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</table>

Add compaction equipment to match optimum paving speed

‘Best Practices’ in rolling

Vibratory compactor: 3000 VPM frequency for pass pattern. 300 feet per minute. Average rolling speed...cannot keep pace with paver moving at average speed 60 feet per minute.
Match Amplitude to Application

Adjust Amplitude for Each Lift
Lower amplitude selections used for thinner lifts, or materials easier to compact, like WMA
Higher amplitude selections used for thicker lifts, or materials more difficult to compact, like SMA

Match Amplitude to Application

Higher force for base courses
Lower force for thin overlays
Match Amplitude to Application

Higher force for base courses
Static roll or reduced force for thin overlays

Adjust Frequency (Amplitude)

Frequency change – high or low with dual amplitudes
Higher frequency in low amplitude
Lower frequency in high amplitude
Vibration Frequency Trend

First vibratory rollers for HMA – frequency limited to 2000 vpm (~33 Hz)

Newest vibratory rollers for HMA – frequency up to 4200 vpm (70 Hz)

Influences of Vibration Frequency

Smoothness based on drum impact spacing (directly tied to vibration frequency and rolling speed with vibration)

Production based on rolling speed with vibration (ability to keep up with paving train)

What About Smoothness?

Smoothness directly tied to vibratory drum impact spacing and rolling speed with vibration
Uniform Rolling Speed... How Fast?

For optimum smoothness:
- Drums less than 35 inches in diameter: 14 impacts per foot
- Drums 35 to 50 inches in diameter: 12 impacts per foot
- Drums 50 to 55 inches in diameter: 10 impacts per foot
- Drums 55 to 60 inches in diameter: 8 impacts per foot

Uniform Rolling Speed... How Fast?

- 2500 vibrations / minute
  - 10 impacts/foot 250 feet / minute = 2.84 mph
- 3000 vibrations / minute
  - 10 impacts/foot 300 feet / minute = 3.41 mph
- 4000 vibrations / minute
  - 10 impacts/foot 400 feet / minute = 4.54 mph

Maintain Consistent Rolling Speed

Vibratory compactor: 3000 VPM, 300 feet per minute average rolling speed, five pass rolling pattern can keep pace with paver moving at average speed of 60 feet per minute.
Rolling Speed... Too Fast?

Rideability Often a Pay Factor

International Roughness Index
Make First Pass with Vibration

Use Automatic Vibration Controls

Protect Unsupported Edges
End Passes in Staggered Arcs

Arc To Center or Supported Edge

Reverse Smoothly to Limit Shoving
How Many Coverages?

How Much Time is Available?

Pay Attention to TAC
Watch out for Segregation

Avoid Excessive Drum Wetting

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

Intermediate Roll - Manipulate
Pneumatic Compactors

“401.17 Compaction. The hot mix asphalt shall be compacted by rolling. Both steel wheel and pneumatic tire rollers will be required.”

“Factors to be considered include (3) Size, speed, and tire pressure of rubber tire rollers.”

Ground Contact Pressure

Dependent upon:
- Ballasted weight
- Number of tires
- Tire size, ply rating, inflation pressure

Uniform Pressure plus Overlap
Watch out for Roller Tire Marks

Intermediate Roll - Oscillation

Oscillation benefits:  
Drum never bounces  
No drum impact force  
Manipulation reduces voids  
Safe to use on bridges, near buildings, longitudinal joints  
Effective on cooler mixes, either HMA or WMA
Where to use Oscillation

“Make or Break” temperature zone

<table>
<thead>
<tr>
<th></th>
<th>High Temp</th>
<th>Low Temp</th>
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<tbody>
<tr>
<td>Breakdown</td>
<td>&lt; 90°</td>
<td>&lt; 95°</td>
</tr>
<tr>
<td>Intermediate</td>
<td>90° - 93°</td>
<td>95° - 97°</td>
</tr>
<tr>
<td>Finish</td>
<td>93° - 97°</td>
<td>97° - 100°</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Target density zone</th>
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<tbody>
<tr>
<td>77-80% behind paver</td>
<td>88-92%</td>
</tr>
<tr>
<td>92-97%</td>
<td></td>
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</tbody>
</table>

Intermediate Rolling - Oscillation

Oscillation limitations:
- Deep lifts hard to compact
- Drum wear can be rapid (early replacement not uncommon)
- Fixed frequency and fixed amplitude are typical (generally not adjustable)

Finish Roll to Remove Marks
Stop or Stand at an Angle

Uniformity Density? for PWL/PWT

Roll Joints for Maximum Density
Where is The Joint?

Use of an Edge Compactor

Overlap Adjacent Passes
Protect Unsupported Edges

Compaction of Supported Joint

Method allows material at joint to be confined prior to rolling. Both sides are confined, so full force and weight of roller compresses mix down into joint to achieve highest density.

Good Joint Performance

Important to fill the joint fully with mix to get high density for best joint performance. Sufficient material at joint results in tight joint, but with some crushing of aggregate at surface.
Good Joint Appearance

How do we Improvement?

Improve Talent – Step-by-Step

- Communicate regularly, with purpose
- Increase responsibility and independence
- Plan for success... and for succession
- Reduce distractions and interferences
- Reward initiative and high performance
- Train and cross-train to improve competence
Hold Regular Project Meetings

Toolbox Talks and Training Aids Series
- TAS-32 Truck Exchange
- TAS-33 Longitudinal Joint Construction
- TAS-34 Forces of Compaction
- TAS-35 Rolling Procedures
- TAS-36 MTV Exchange

Someone Needs to Read TAS-32!
Someone Needs to Read TAS-33!

Agency and Contractor Objectives

Common Objectives...the A-B-Cs...
- Always pay attention to ‘THE JOB AT HAND'; avoid distractions
- Be sure to work safe and work smart; watch out for one another
- Concentrate on density and smoothness
- Don’t forget the importance of production
- Educate the work force; never ignore the importance of training
- Follow the rules: ‘Slow and steady’ wins the bonus
- Guarantee incentives and avoid disincentives using ‘Best Practices’
Humanity Rules...

Never forget...At the end of each shift, everyone deserves to return home to family and friends...
Have a prosperous and safe paving season!

Thank You very much!

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CONEXPO – CON/AGG 2020
• March 10-14, 2020
• Las Vegas, NV
• 140+ education sessions

Roller Operations 101:
A Basic Overview...

Dale Starry
Volvo Construction Equipment
Thank You

Session Evaluations/PDH's
• Complete session feedback in mobile app, your comments appreciated.
• Professional Development Hours logged in session feedback.

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• World of Asphalt 2021
  • March 16-18, 2021
  • Atlanta, GA
  • 120+ education sessions