Compaction Theory and Best Practices

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Understanding the Importance of Density

Importance of Compaction

"More emphasis must be placed on obtaining adequate density." – NCHRP Report 531 (2004)

Carl Monismith – "…we could improve the life of our pavements in California a very substantial amount with the existing materials that we have if we just changed the compaction specification for the asphalt concrete. Right now we build pavements that have shorter lives than they should." (AAPT 1997)

Importance of Compaction

"**Compaction is the single most important factor that affects pavement performance** in terms of durability, fatigue life, resistance to deformation, strength and moisture damage." – C. S. Hughes, NCHRP Synthesis 152, *Compaction of Asphalt Pavement*, (1989)

"The **amount of air voids in an asphalt mixture is probably the single most important factor that affects performance** throughout the life of an asphalt pavement. The voids are primarily controlled by asphalt content, compactive effort during construction, and additional compaction under traffic." – E. R. Brown, NCAT Report No. 90-03, *Density of Asphalt Concrete—How Much is Needed?* (1990)

Link Density to Pavement Durability

Improved Compaction = Improved Performance

A BAD mix with GOOD density out-performed a GOOD mix with POOR density for ride and rutting.

WesTrack Experiment

Density vs. Loss of Pavement Service Life

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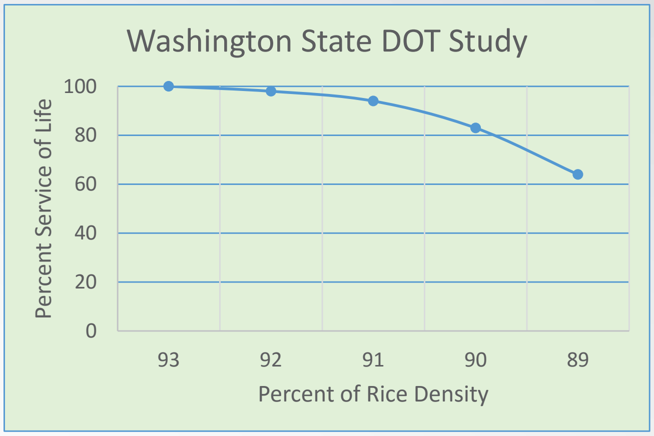
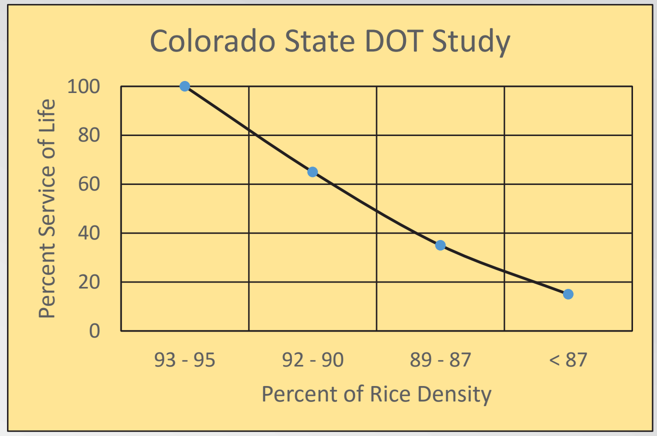


Thicker Pavements TRR 1217, 1989



Typical Pavements CDOT 2013-4, 2013

For both thicker and thinner, reduced in-place density at the time of construction results in significant loss of Service Life!

Tensile Strength & Moisture Susceptibility vs. Air Voids AASHTO T 283

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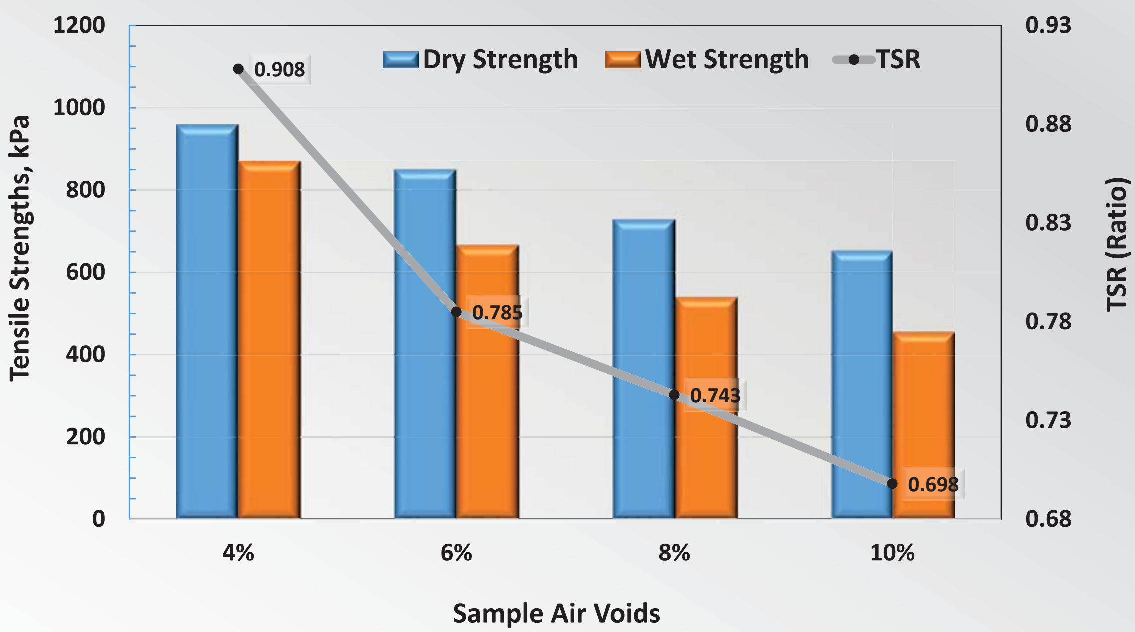

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NCAT Report 16-02 (2016)

Literature Review on connecting in-place density to performance

- 5 studies cited for fatigue life
- 7 studies cited for rutting
- "A **1% decrease in air voids** was estimated to improve the fatigue performance of asphalt pavements between 8.2 and 43.8%, to improve the rutting resistance by 7.3 to 66.3%, and to **extend the service life by conservatively 10%**."

Research on Critical Air Void Level for Impermeability

"…to ensure that permeability is not a problem, the in-place air voids should be between 6 and 7 percent or lower. This appears to be true for a wide range of mixtures regardless of NMAS and grading." – NCHRP 531

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Forces of Compaction and Roller Types

Vibratory Screed Should Always be "ON"

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Forces of Compaction

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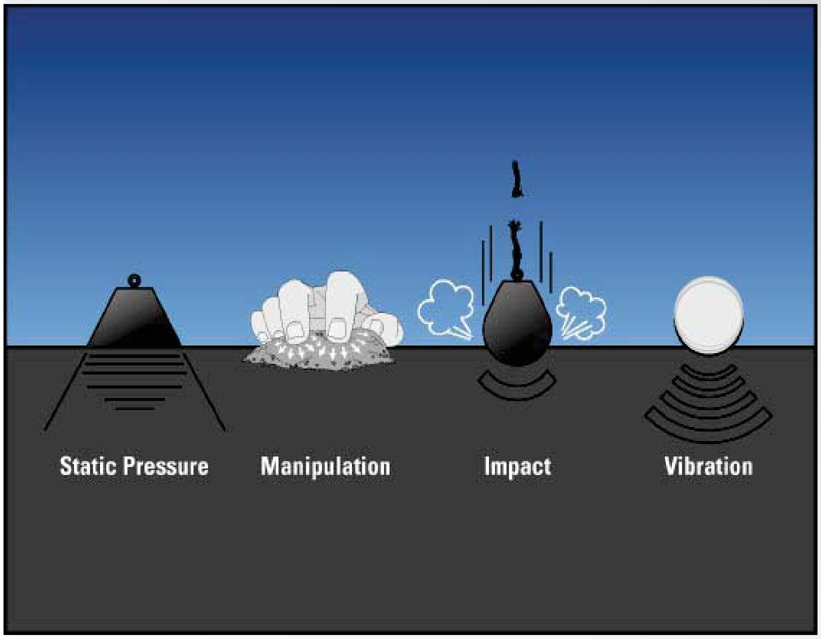

Compaction forces

- Low force
  - Static pressure
  - Manipulation
- Higher forces
  - Impact
  - Vibration

Effect of Roller Type, Size, Passes

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Roller type and size affects:

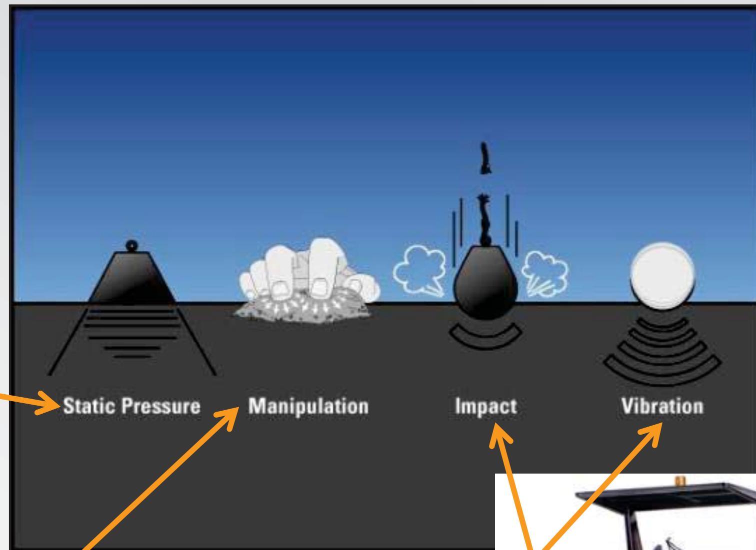
- Magnitude of the load
- Manner the load is imparted to the pavement

Number of passes:

- Increases the density
- To break over point after a # of passes
  - Lowers compaction
  - If continued, damages mat

Roller Types

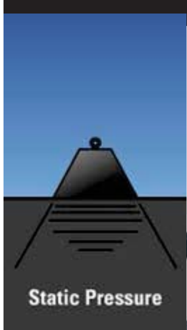
Static Steel-Wheeled



Pneumatic

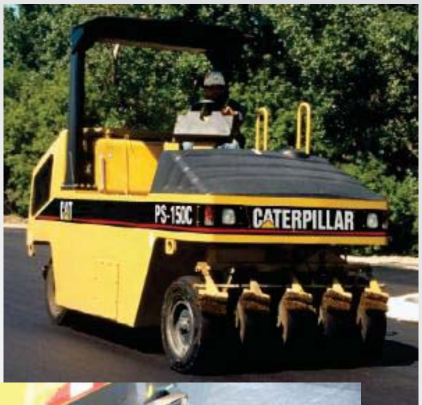
Vibratory

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 must face paver

Pneumatic Rollers

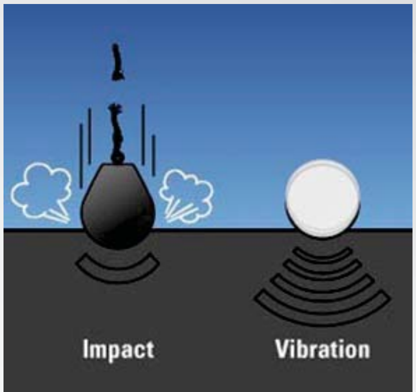


- Reorients particles through kneading action
- Tire pressures:
  - ~80 psi (cold) for compaction
  - ~50 psi (cold) for finish rolling
  - Range of tire pressures not to exceed 10 psi
- Used as Intermediate or as Breakdown Roller
- Tires must be hot to avoid pickup
- Tires must be smooth - no tread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

Pneumatic Rubber Tired Rollers

- Many experts believe kneading action helps in providing a tighter surface that is more dense and less permeable compared to drum rollers.
  - Research supports this
- But must keep these away from the unsupported edge to avoid excessive lateral movement of mat.
- Use during intermediate rolling of the supported edge.
  - Not finish rolling

Vibratory Rollers

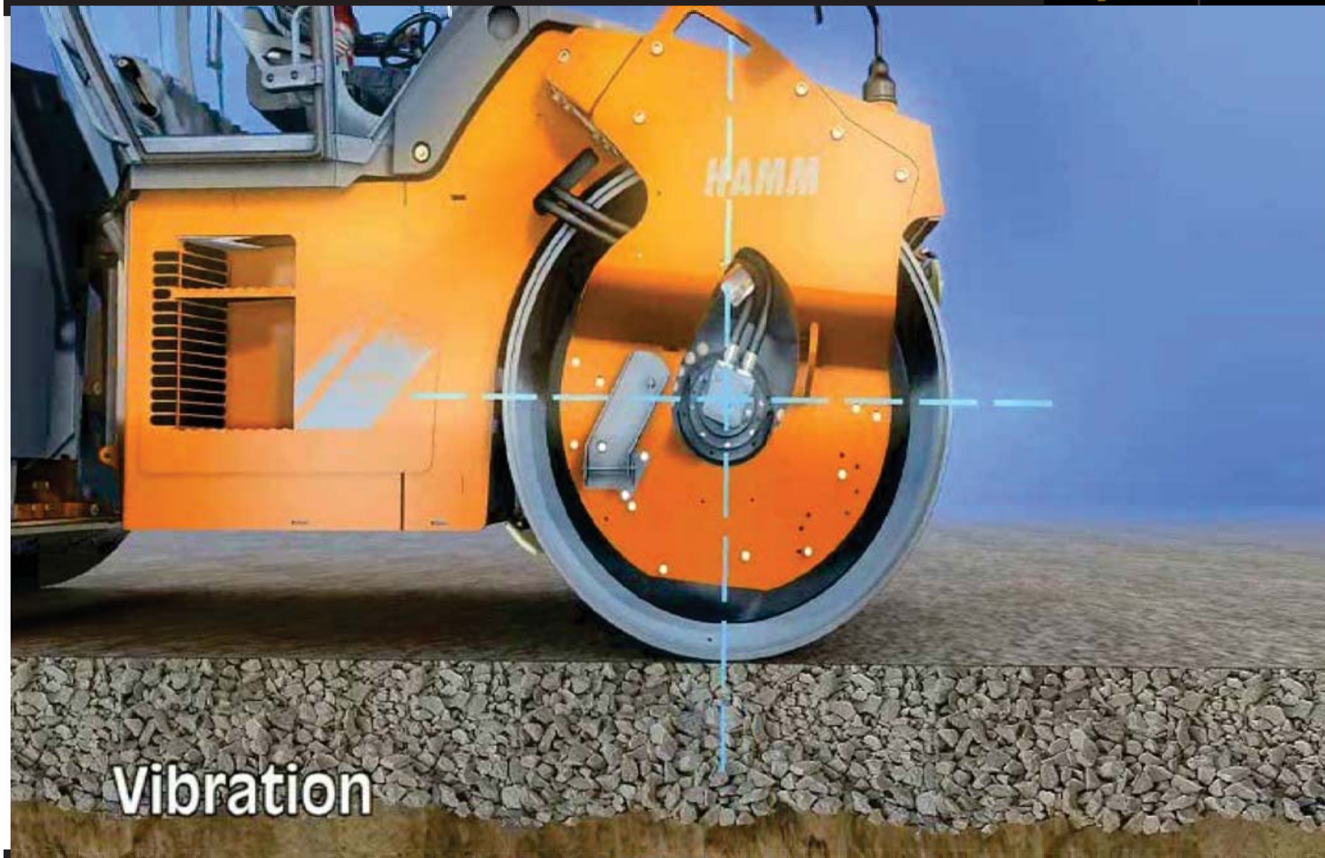


- Commonly used for initial (breakdown) rolling
- 8-18.5 tons, 57-84 in wide ("heavy" rollers)
  - 50-200 lbs/linear inch (PLI)
- Frequency: 2700-4200 impacts/min.
- Amplitude: 0.016-0.032 in.
  - For thin overlays (≤ 2 in.) use low amplitude or static mode
- Operate to attain at least 10 impacts/ft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

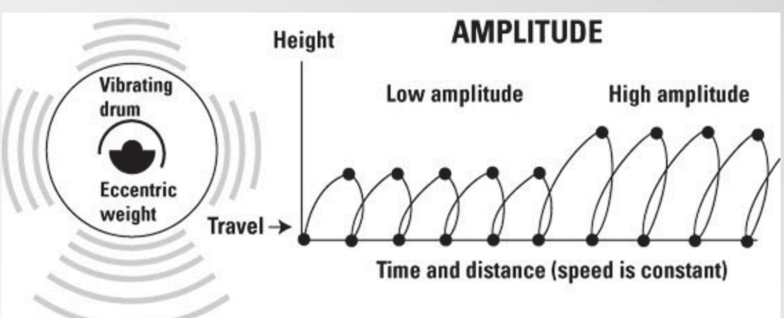
What Makes Vibratory Rollers More Effective?

- Movement of drum initiates particle motion
- When particles are moving
  - Resistance to deformation is reduced
- Force applied by weight of drum plus inertia
  - Produces a greater compactive effect
  - Achieving more compaction per pass than static rollers

How Does a Vibratory Roller Work?



Vibratory Rollers - Amplitude

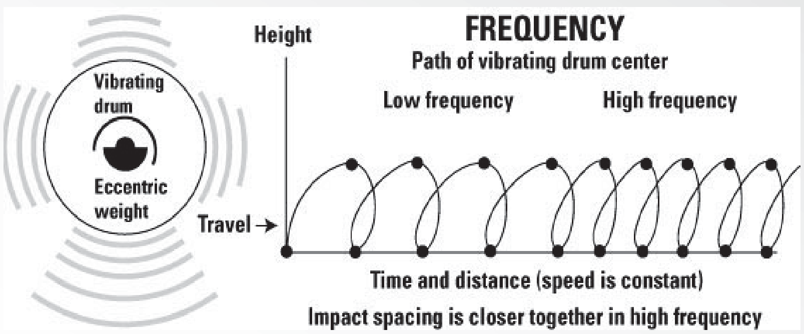


- Spinning eccentric weight causes drum movement
- Falling drum adds to compactive force
- Distance drum moves is called amplitude
- Amplitude determines impact force

Low Amplitude

High Amplitude

Vibratory Rollers - Frequency



- Frequency
  - Drum impacts per minute
- Match travel speed to frequency
- Best results when impact spacing is 10-14 per foot

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
4000 vpm	22.72	15.16	11.36	9.10

Vibratory Rollers - Amplitude

- Amplitude too high
- Travel speed too fast
- Vibrating cool mat
  - Roll closer to paver
- Finish rolling too cool
  - Roll closer to intermediate roller
- Finish roller too light

Newer Roller Technology

- Technology
  - Intelligent Compaction
  - Vibratory Pneumatic
  - Oscillatory Rollers

Vibratory Pneumatic Roller

Intelligent Compaction Benefits

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- Color-coded display in cab – real-time feedback
- Optimum # passes are achieved more consistently
- Analysis of data provides insight into critical factors of the compaction process
- Proof rolling of base or mapping of existing materials

Oscillatory Rollers

Bomag

Hamm

Sakai

CAT

Newer Roller Benefits

- Aid in compacting difficult mixes
- Lower cessation temperature
- Contact suppliers for additional information

Roller Operations & Roller Procedures

Compaction Variables at the Roller

- Roller Patters
  - Sequencing
  - Passes—A roller passing over one point in the may one time
  - Roller Speed
- Rolling Zone
- General Rolling Operations
- Dealing With Challenging Mixes

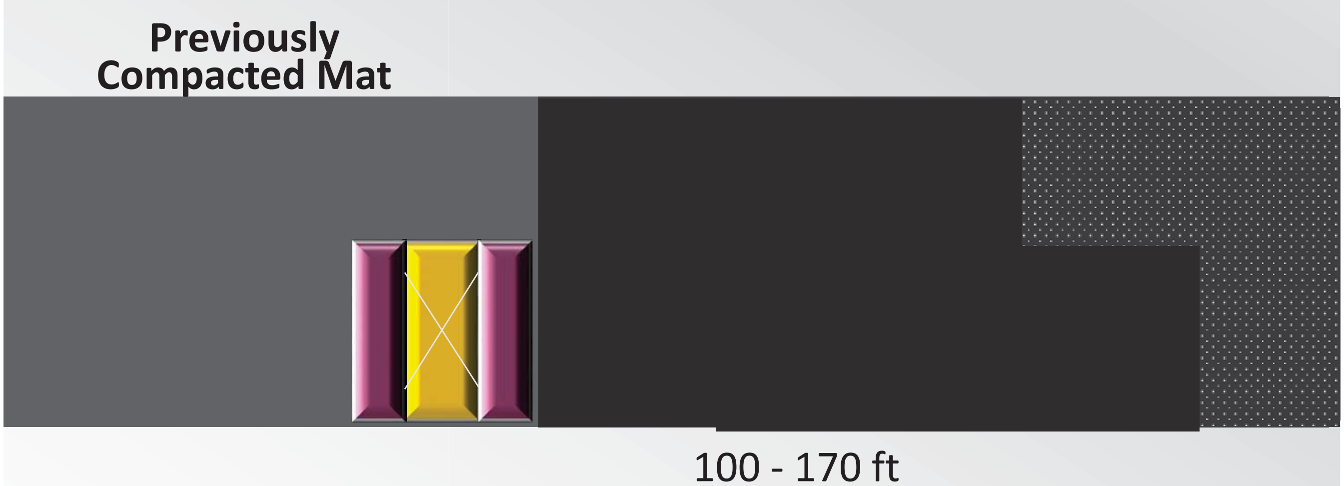
Traditional Roller Operations Sequencing

- Breakdown Rolling
- Intermediate Rolling
- Finish Rolling

Pattern Decisions

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

Rolling Pattern



- Roller width should overlap 6 inches
- Odd number of passes to advance
- Repeat uniformly

Establishing Breakdown Rolling Pattern

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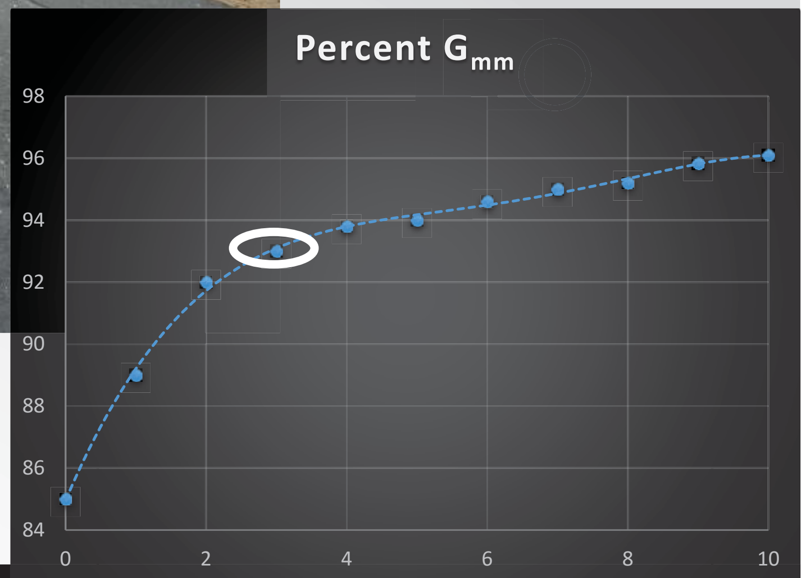
Goal: 93.5% G_{mm}



Select: 3 Passes (Intermediate will get the rest of the density)

Rolling Pattern

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- Speed and lap pattern for each roller
- Number of passes for each roller
  - One trip across a point on the mat
  - Set minimum temperature each roller finishes

IMPORTANT:

- Paver speed must not exceed compaction!!!
- Paver makes single pass
- Roller pattern requires 3-7 passes

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
- May be performed with two coordinated rollers

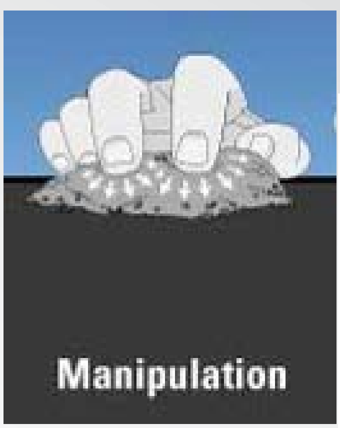
Breakdown Rolling

- Traditionally 3-wheel steel
- D/D vibratory most common
- Vibration most productive during breakdown
- Pneumatics
  - Used on base courses
  - Leveling courses
    - Forces mix into cracks
    - Compacts without bridging minor ruts
  - Can leave marks – may be harder to roll out

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:
  - Traditionally pneumatic
  - Vibratory at low amplitude and/or static mode

Pneumatic Roller



Finish Rolling

Main purpose

- Minimal compaction
- Smoothness
- Removal of any marks
- Once smooth, stop rolling

Typical roller types:

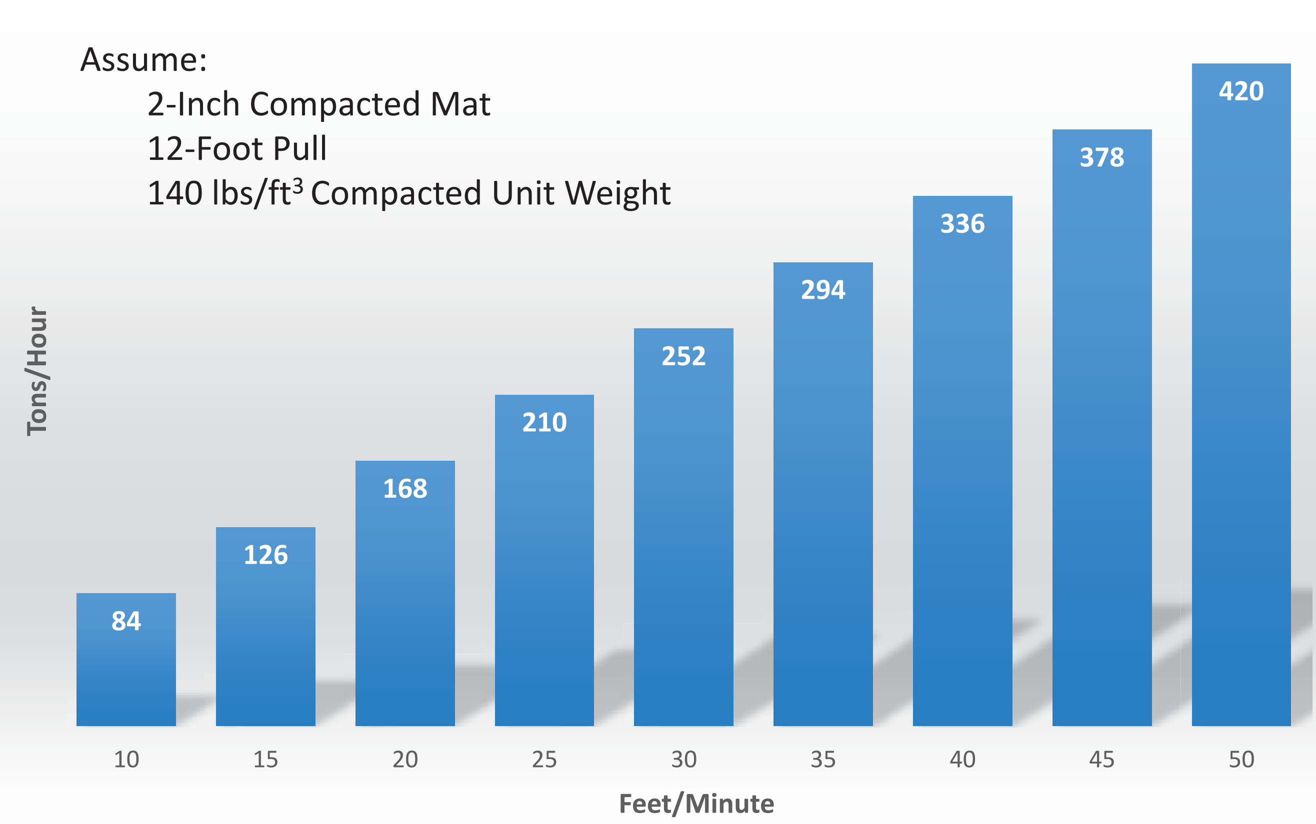
- Tandem steel-wheel
- Pneumatic w/lower pressure
- Vibratory static mode only

General Rolling Procedures

For best results

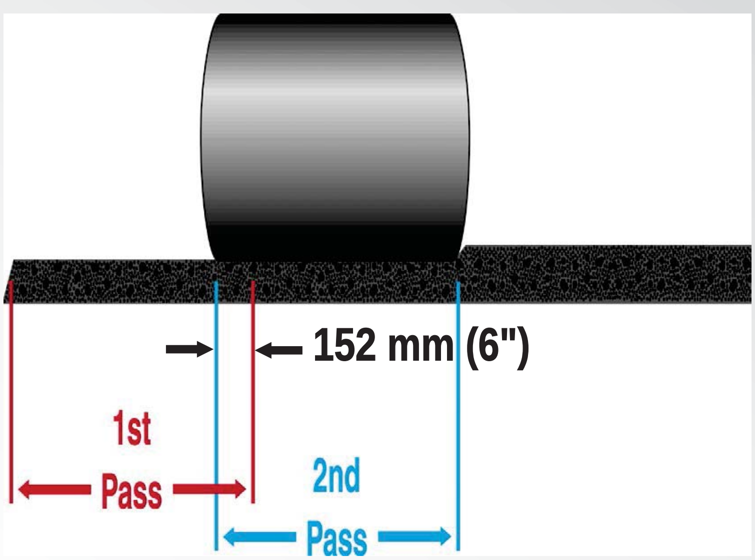
- Roll at highest temperature without excessive displacement
- Stay close to paver
- Monitor weather
- Keep up but not too fast
  - Slower paver speed
  - Not faster roller speed

Paver Speed and Output



General Rolling Procedures

Overlaps

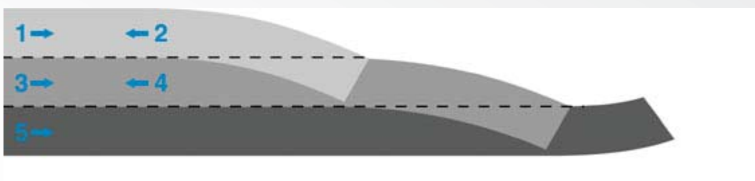


- 6” overlap assures uniform compaction
- Include overlap selecting drum width
- Roller should cover mat in no more than 3 passes

General Rolling Procedures

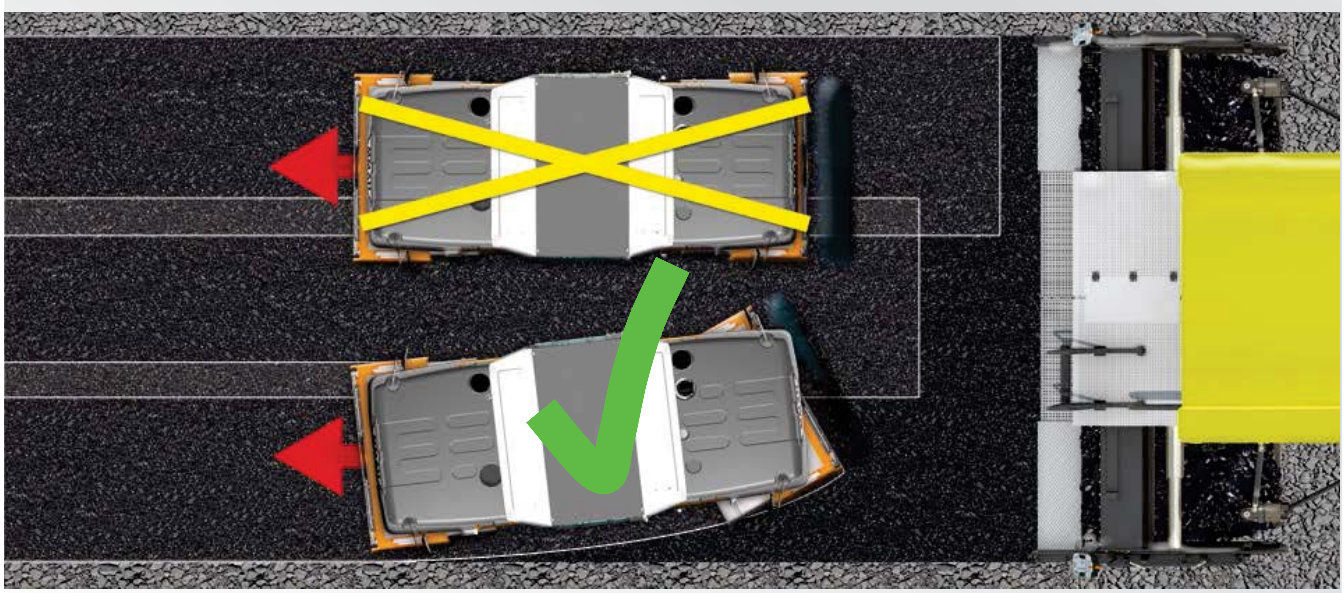
Reversing Directions

- Avoid straight stops
- Turn toward center of mat
- Don’t turn drum while stopped
- Next pass should roll out any marks created by reversing



Reversing

Compact the Mat While It Is Hot!



Stay Close to the Paver with Breakdown Rollers.

Always Stop and Reverse Directions at an Angle!

Why Rollers Need to Turn to Stop

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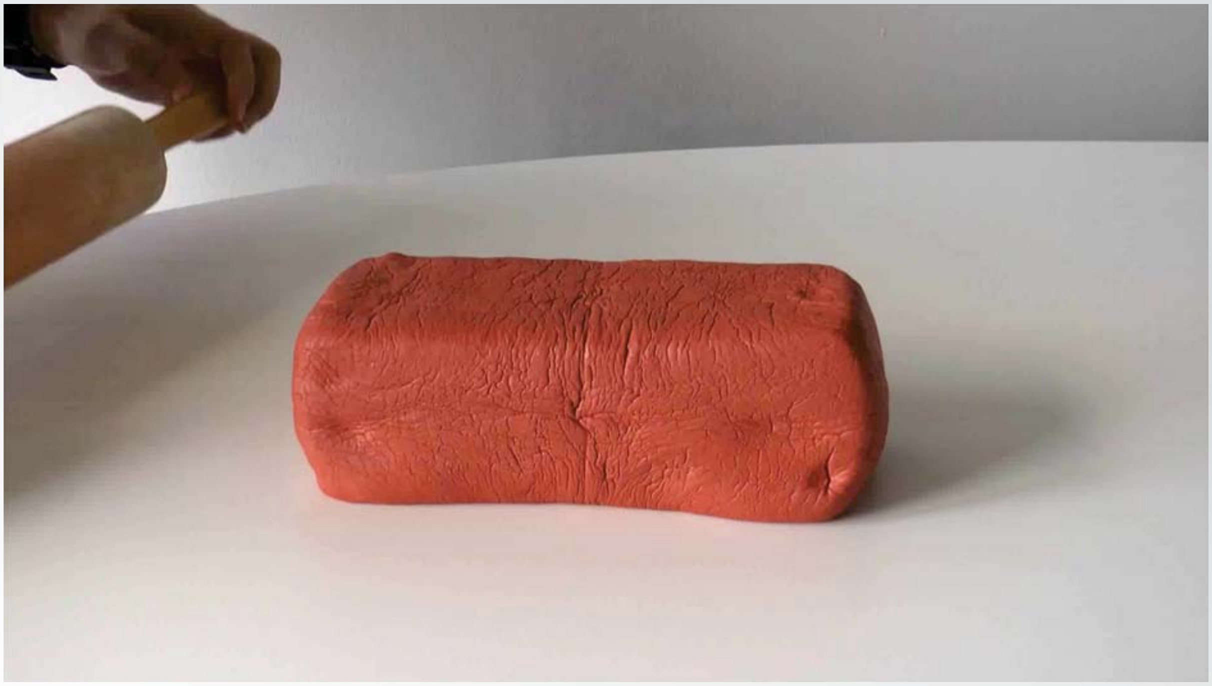

General Rolling Procedures

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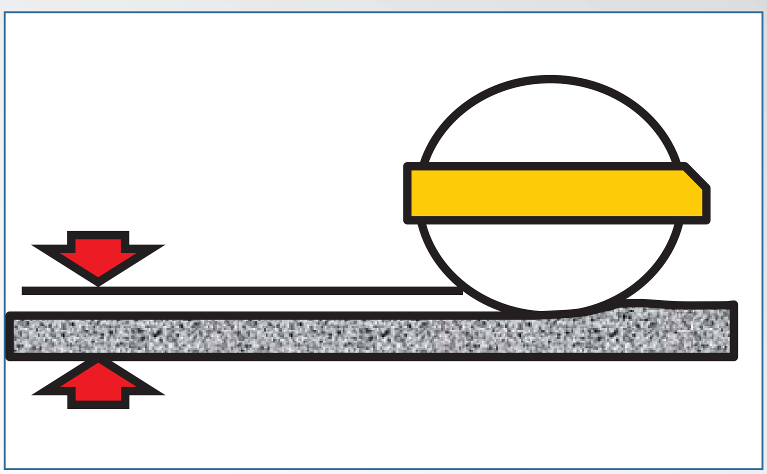

Rolldown

- Paver lays thicker lift
- Roller compacts to the design thickness
- Superpave mixes rolldown ~ 25%
- SMA, PFC & other open-graded mixes rolldown ~15%

Summary of "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 unless something changes in the conditions
- Reverse directions properly
  - Turn into stops
  - Do not turn while standing
- Do not stop roller on hot mat
- Use proper technique when compacting longitudinal joints

(See Asphalt Institute Webpage: asphaltinstitute.org)

Questions/Discussion

What is Achievable?