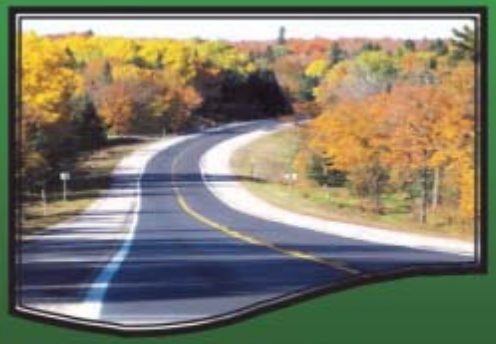
57th Annual Asphalt Paving Conference

Managing Density For Asphalt Pavement



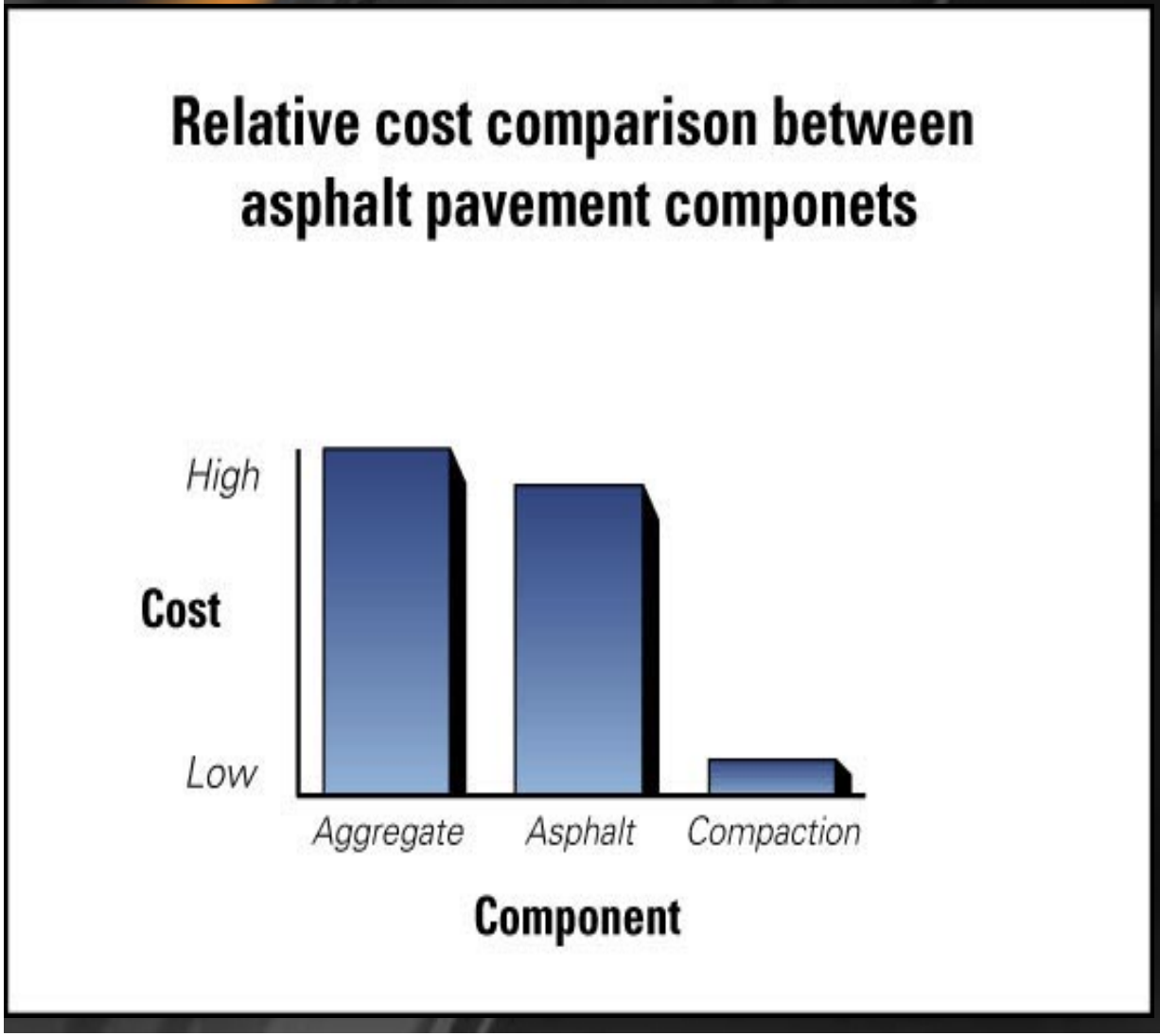
March 26-27, 2013
Soaring Eagle Casino & Resort
Mt. Pleasant, Michigan

Asphalt Pavement Association of Michigan

www.apa-mi.org

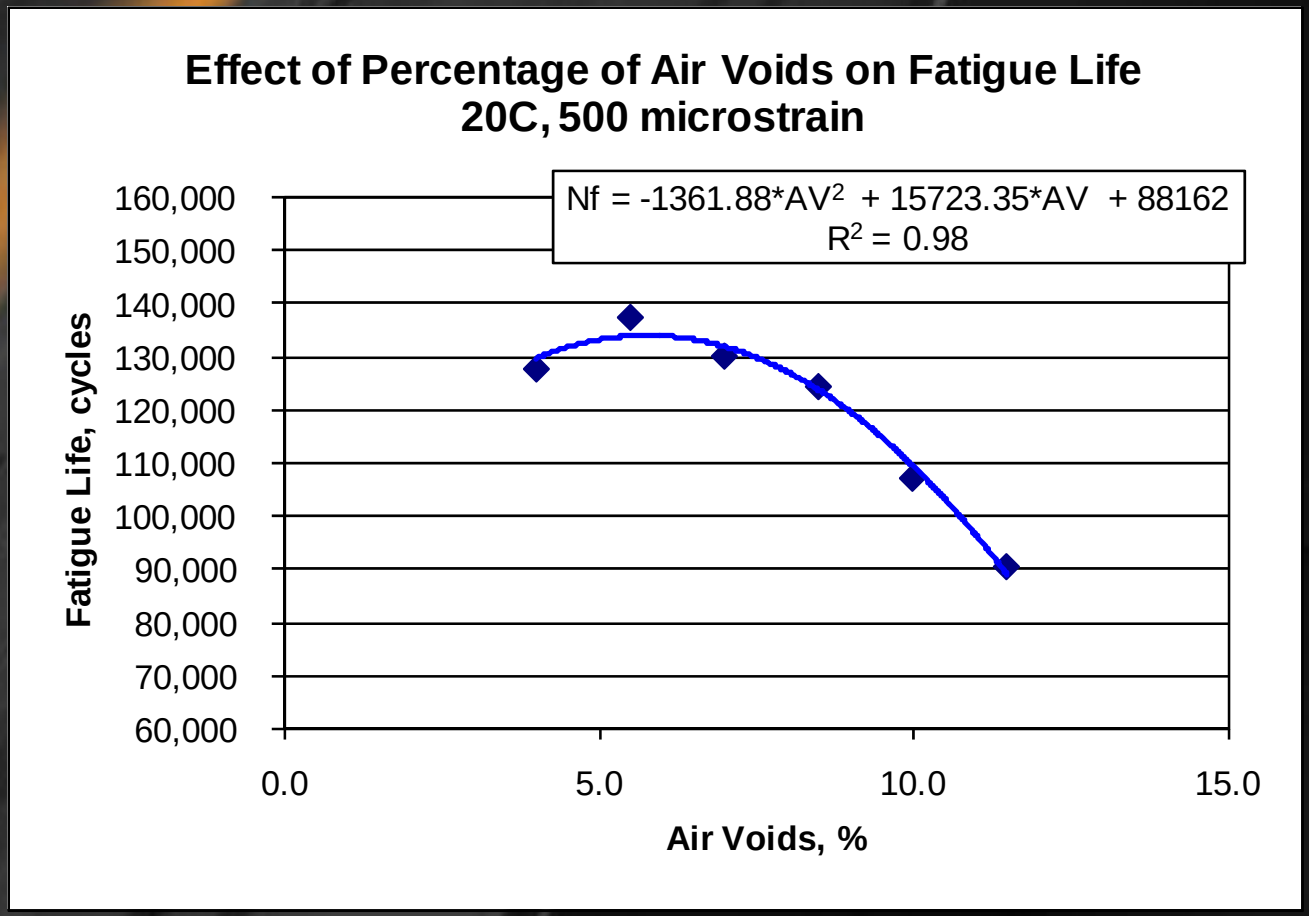

Density
vs.
Pavement Performance

Cost of Compaction



- Least expensive part of the process
- Compaction adds little to the cost of a ton of asphalt

Importance of Compaction



UK-AI Study

1.5% increase in density leads to 10% increase in fatigue life.

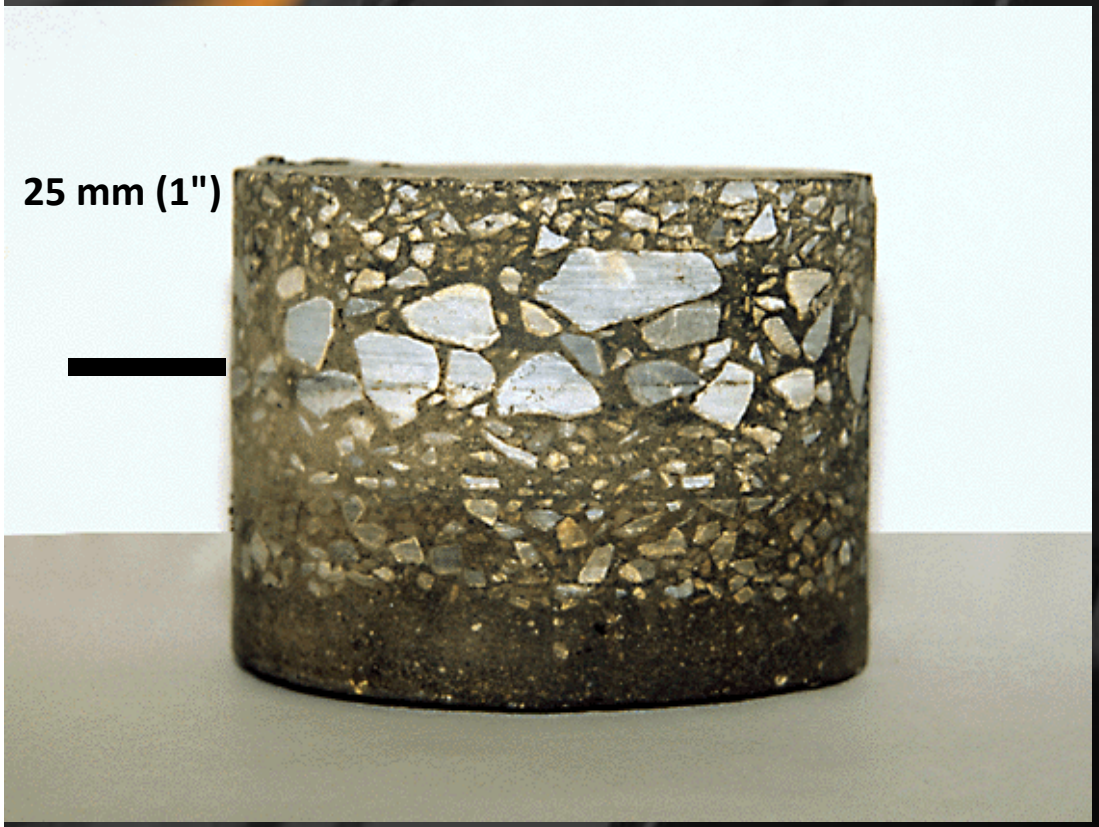
Field Density Testing

Quality Control & Acceptance of Joint Density

Density Gauge

6-inch Core

Compaction of HMA Pavements



Cores determine density

- Quality control
- Payment
- Different from nuclear
- Correlate readings

Compaction of HMA Pavements

Nuclear gauges

- Set up rolling pattern
- Used for quality control
- Adjust rolling when
  - Mix
  - Conditions change

Factors Affecting Compaction

Factors Affecting Compaction

- Mix Properties
  - Aggregate
  - Asphalt
  - Air (Volumetrics)
  - Mix Temperature
- Lift Thickness
- Subgrade & Base Support
- Environmental Factors
- Type and Size of Roller, # of Passes

Effect of Aggregate

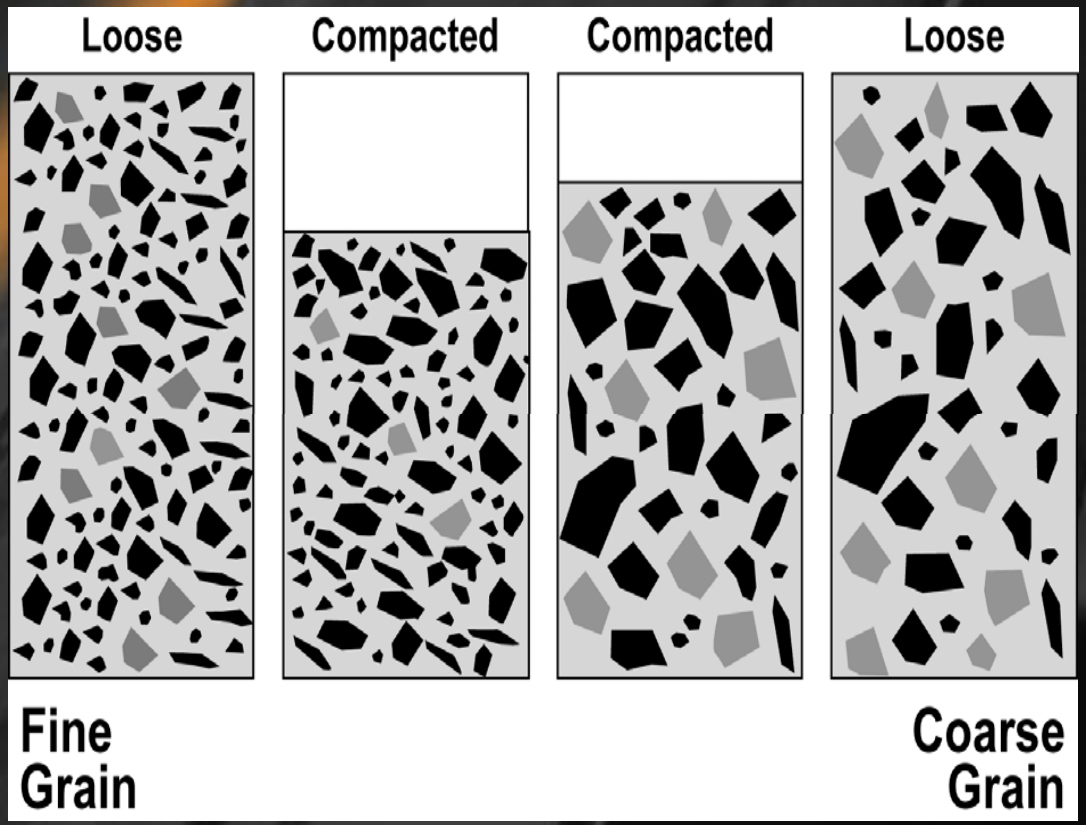
- Gradation
  - Continuously-graded, gap-graded, etc.
- Shape
  - Flat & elongated, cubical, round
- Surface Texture
  - Smooth, rough
- Strength
  - Resistance to breaking
  - Abrasion

Aggregate Types

- Natural
- Processed
- Synthetic

- Round (uncrushed)
- Single Crushed Face
- Multiple Crushed Faces

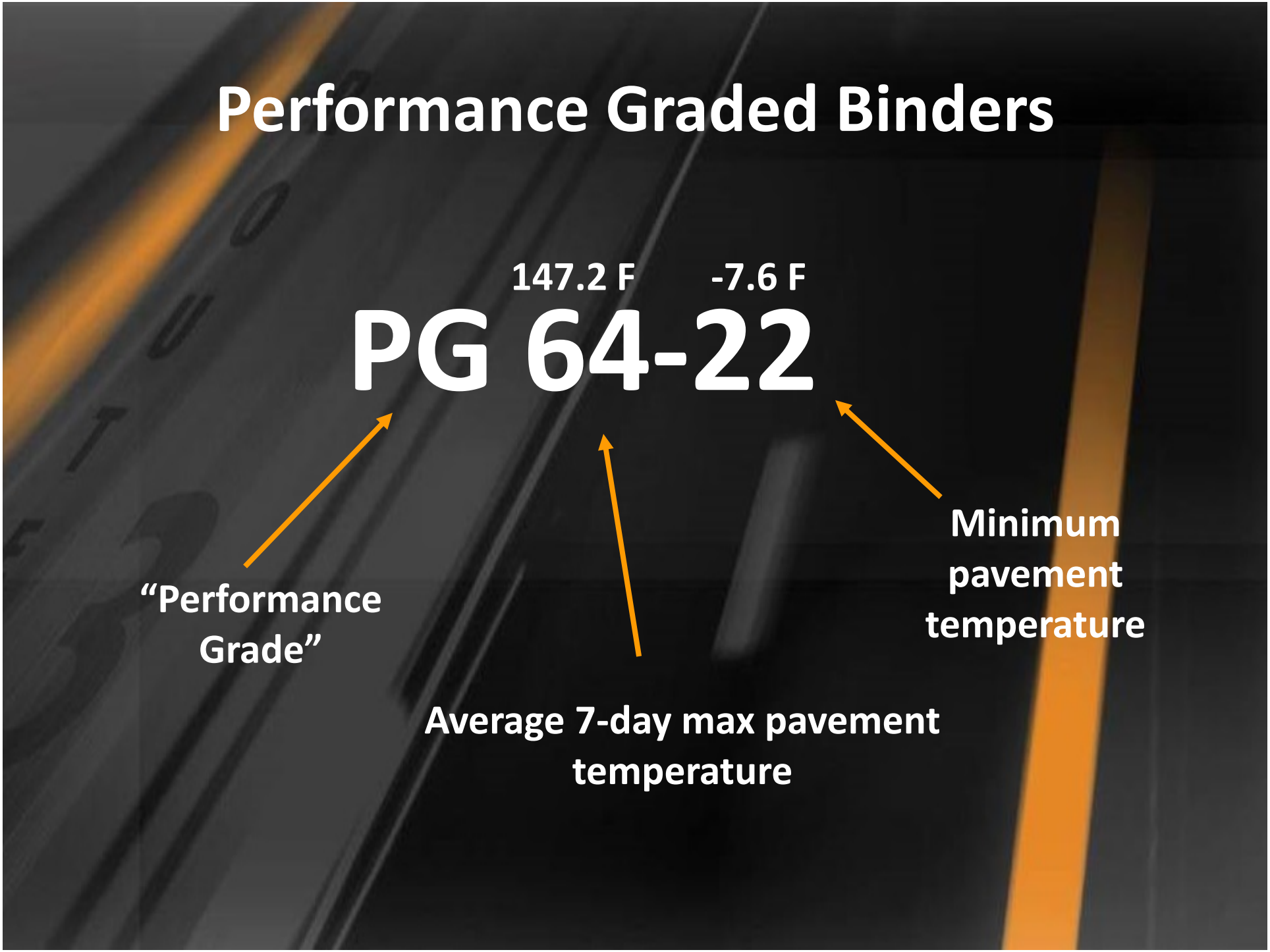
Asphalt Mixtures



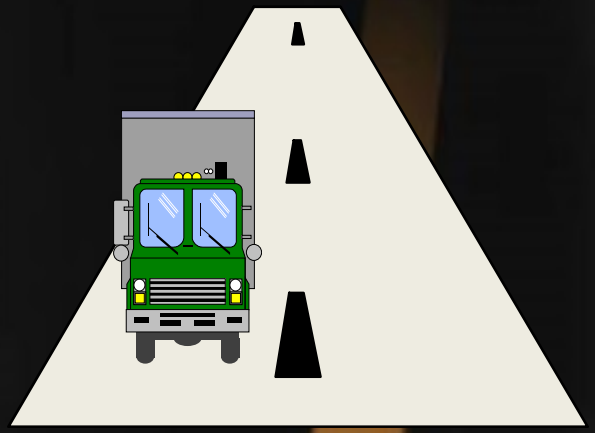
Mixtures

- **Compaction varies**
- **Adjust thickness for rolldown**
- **Match mat thickness**

Performance Graded Binders



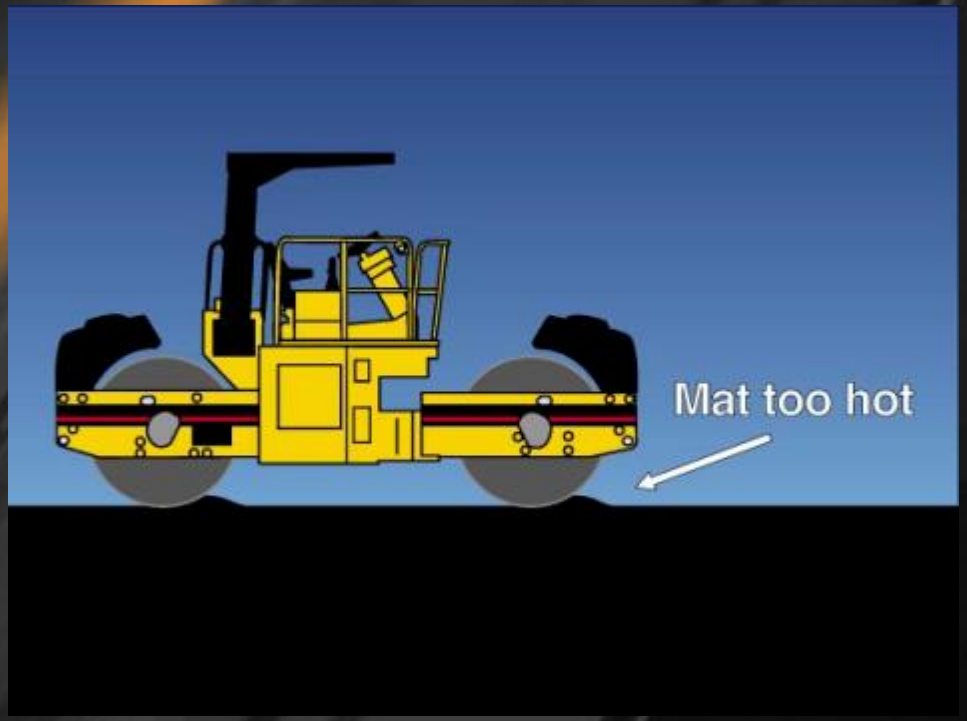
Loading Rate of Loading



Example

- Mainline pavement
  PG 64-22 ← *70 mph*
- Toll booth
  PG 70-22 ← Slow
- Weigh Stations
  PG 76-22 ← <u>Stopping</u>

Effect of Temperature - Mat Too Hot

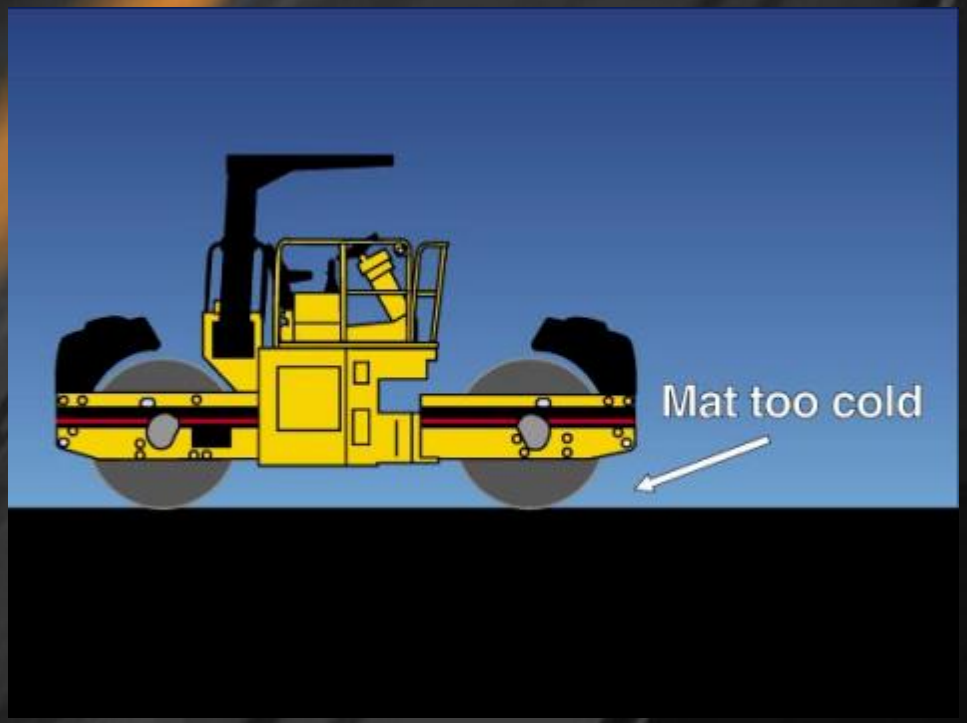


- Bulges in front of drums
- Mix moves & will not compact
- Roller leaves deep marks

Solution

- Stay back from paver
- Allow mat to cool (stiffen)

Effect of Temperature - Mat Too Cold



- Lower limit 180º F
  - No additional compaction
- No aggregate movement
  - Crushing aggregate
- Solutions
  - Closer to paver
    - Slow paver
    - Add rollers
  - Increase mix temp

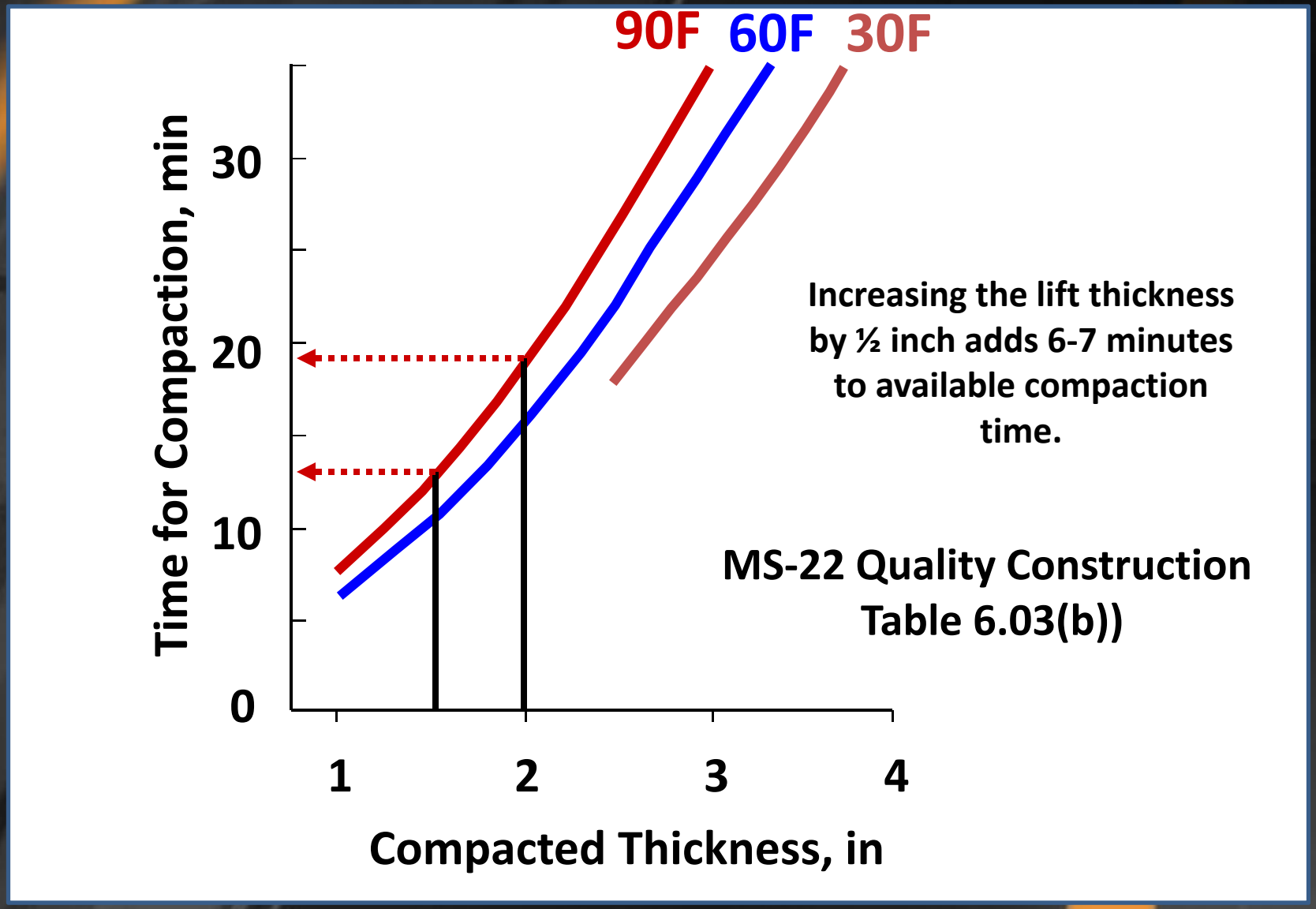
Effect of Lift Thickness

- Optimum lift thickness
  - 4x Nominal Maximum Aggregate Size (NMAS)
- Acceptable lift thickness = 3x to 5x NMAS
- Problems Compacting
  - 2x NMAS or less
  - 6x NMAS or more
- Especially critical paving on uneven surfaces

Asphalt Mix Designation

Superpave Designation	Remember: Max Size, mm
37.5 mm	50.0
25.0 mm	37.5
19.0 mm	25.0
12.5 mm	19.0
9.5 mm	12.5
4.75 mm	9.5

Lift Thickness



Effect of Subgrade & Base Support

- Good support critical to obtain proper density
- Spongy or unstable support
  - Provides little resistance to the rollers
  - Mixture not confined, energy disipated
- Mixture moves & cracks rather than compacts.



Effect of Environmental Factors

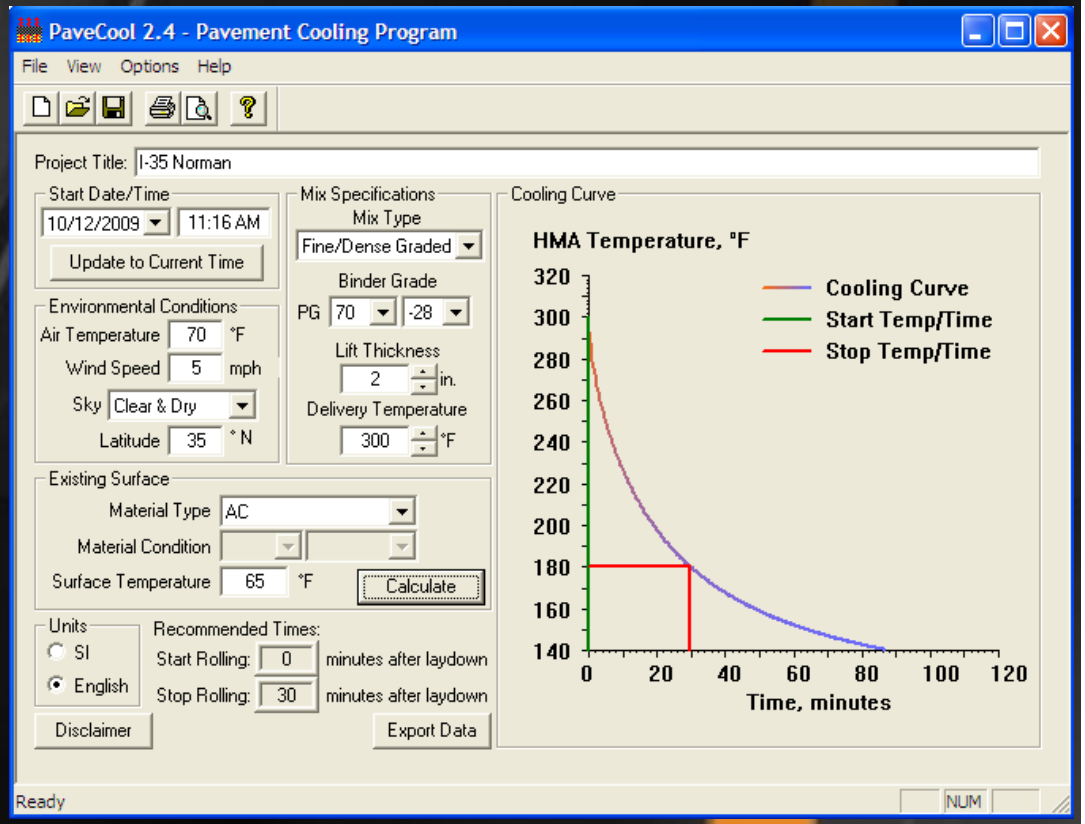
Factors affecting how fast the mix cools

- Affects time available for compaction
  - Ambient air temperature
  - Temperature of the existing surface
  - Wind speed
  - Lift thickness
  - As-delivered mix temperature
  - Overcast conditions

Effect of Environmental Factors

Minnesota DOT's *PaveCool*

- Excellent tool to determine compaction time
  - Based all factors
  - Free download



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

Forces of Compaction & Roller Types

Effect of Roller Type, Size, Passes

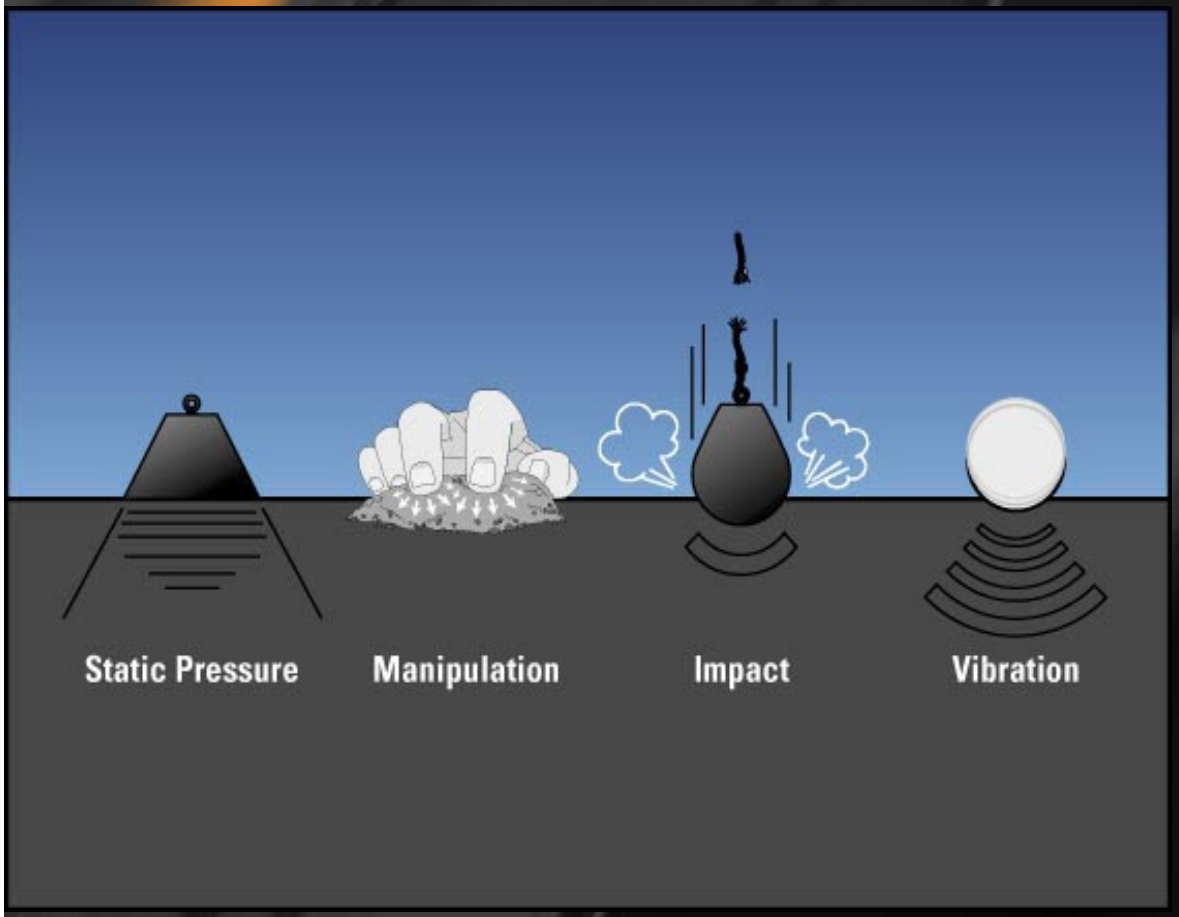
Roller type and size affects:

- Magnitude of the load
- How the load is applied

Number of passes:

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

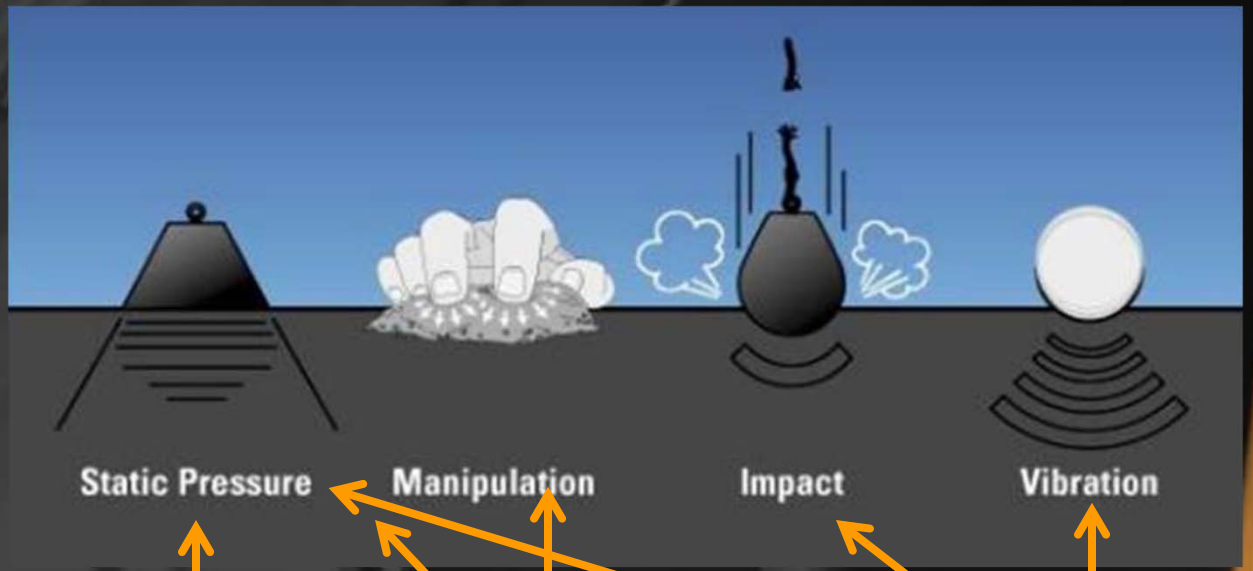
Forces of Compaction



Compaction forces

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

Roller Types



Steel-Wheeled

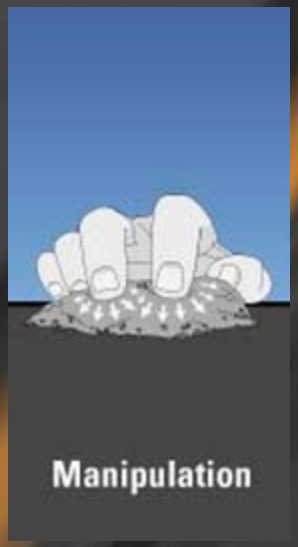
Pneumatic

Vibratory

Static Steel-Wheeled Rollers

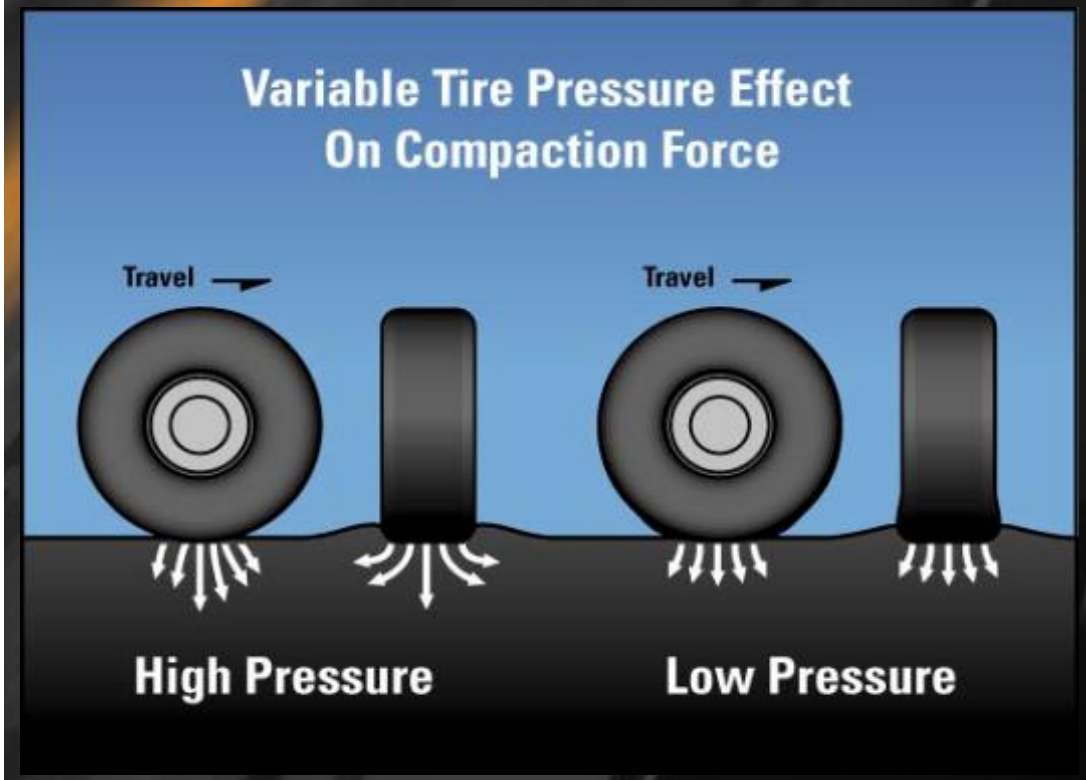
- 4 -14 ton rollers applies static force
  - 3-Wheel
  - Vibratory rollers in static mode
  - Lighter rollers for finish rolling
  - Drive wheel must face paver
    - “Climbs” uncompacted mix
    - Tiller wheel pushes mix
  - Drums must be smooth and clean
    - Water spray & scraper bars
    - Critical for polymer modifiers
    - Avoid rollers used on agg base

Pneumatic Rollers



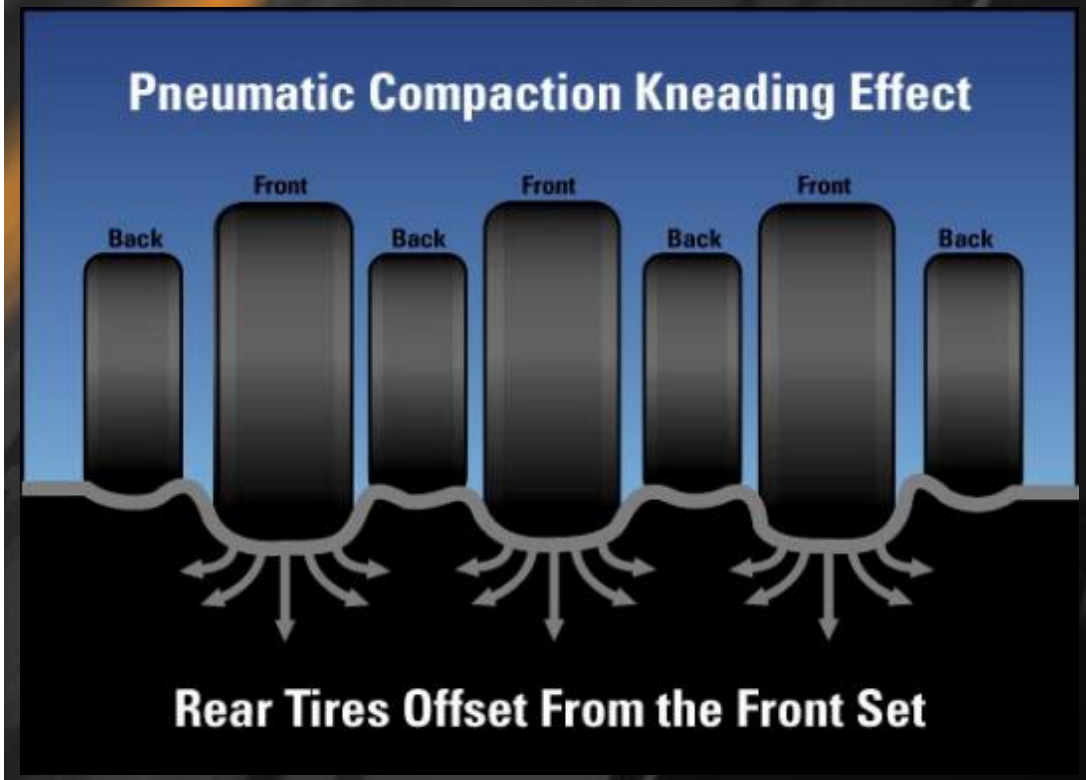
- Kneading action reorients aggregate
- Tire pressures:
  - ~80 psi (cold) for compaction
  - ~50 psi (cold) for finish rolling
  - Range not to exceed 10 psi
- Tires must be hot to avoid pickup
- Tires must be smooth - no tread
- Not used for
  - Porous friction
  - SMA
  - Polymer modified mixes

Pneumatic Rollers



- Force is:
  - Weight on tire divided contact area
    - Expressed as PSI
- Change PSI by changing:
  - Tire pressure
  - Ballast
- Low tire pressure
  - Low force
- High tire pressure
  - High force

Pneumatic Rollers



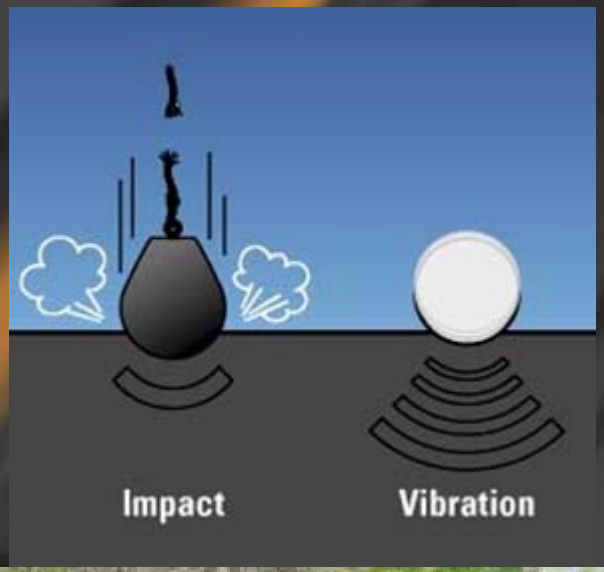
- Front-rear axles offset
  - Manipulates mix
  - Under & between tires
- Tighten finish
  - To resist moisture
- Lowering pressure
  - Increases manipulation
- Increasing pressure
  - Increases static force

Pneumatic Rollers

Keep tires hot and clean:

- Drive back & forth on cold mat
  - Up to 30 minutes
  - Internally heat tires
- Keep moving to keep tires hot
- Skirts may be needed to retain heat
- Scrubbers must be used
  - Knock off any accumulation
  - Only use release agent
- Once pick-up starts
  - Marks will not come out
  - Tires difficult to clean

Vibratory Rollers



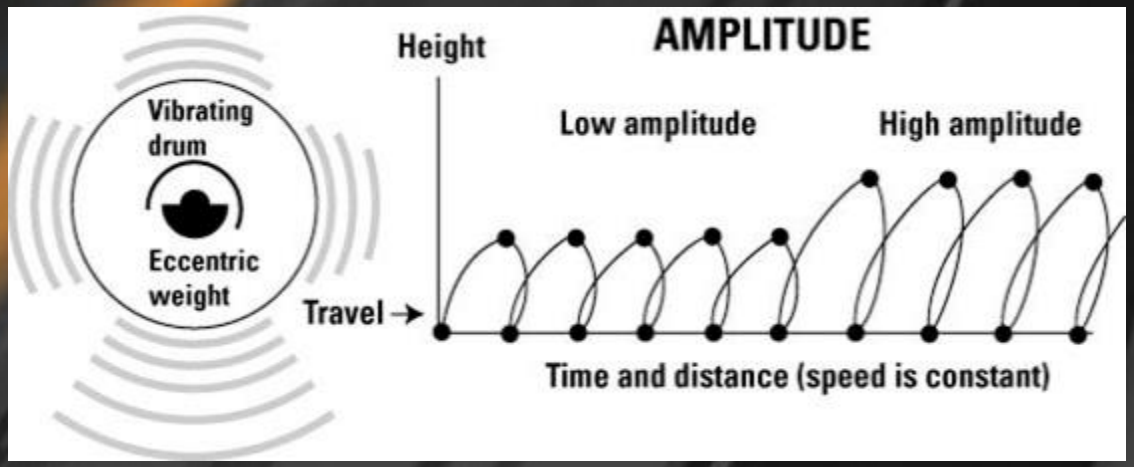
- Commonly used for initial rolling
  - Breakdown
  - Largest compaction increase
- "Heavy" rollers
  - Heavy duty components & frames
  - 8-18.5 tons, 57-84 in wide
  - 50-200 lbs/linear inch (PLI)
- Frequency: 2700-4200 impacts/min
- Amplitude: 0.016-0.032 in
  - Thin overlays (≤ 2 in)
  - Low amplitude or static mode
- Operate at least 10 impacts/foot
  - 2-4 mph

Vibratory Rollers

Effectiveness

- 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

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

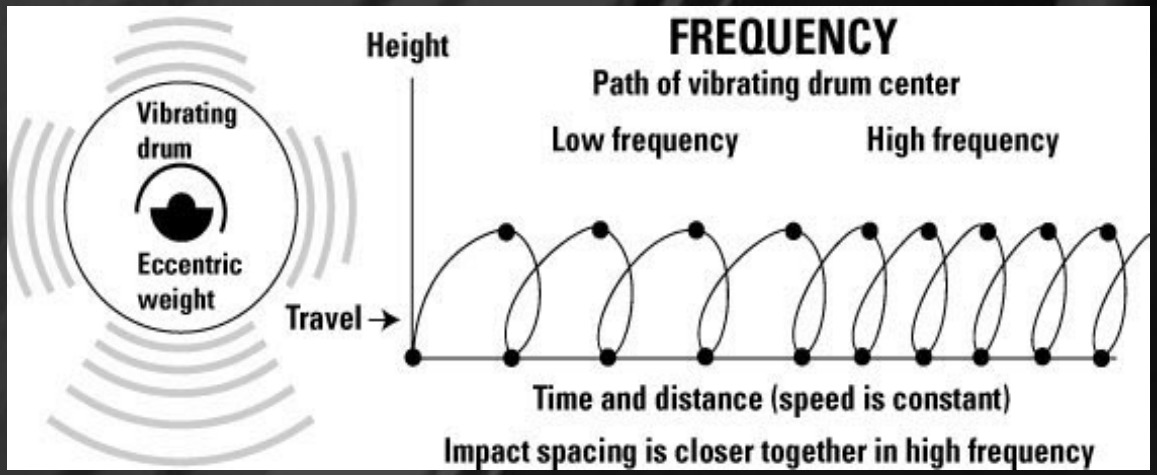
High Amplitude

Vibratory Rollers - 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

Vibratory Rollers - Frequency

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

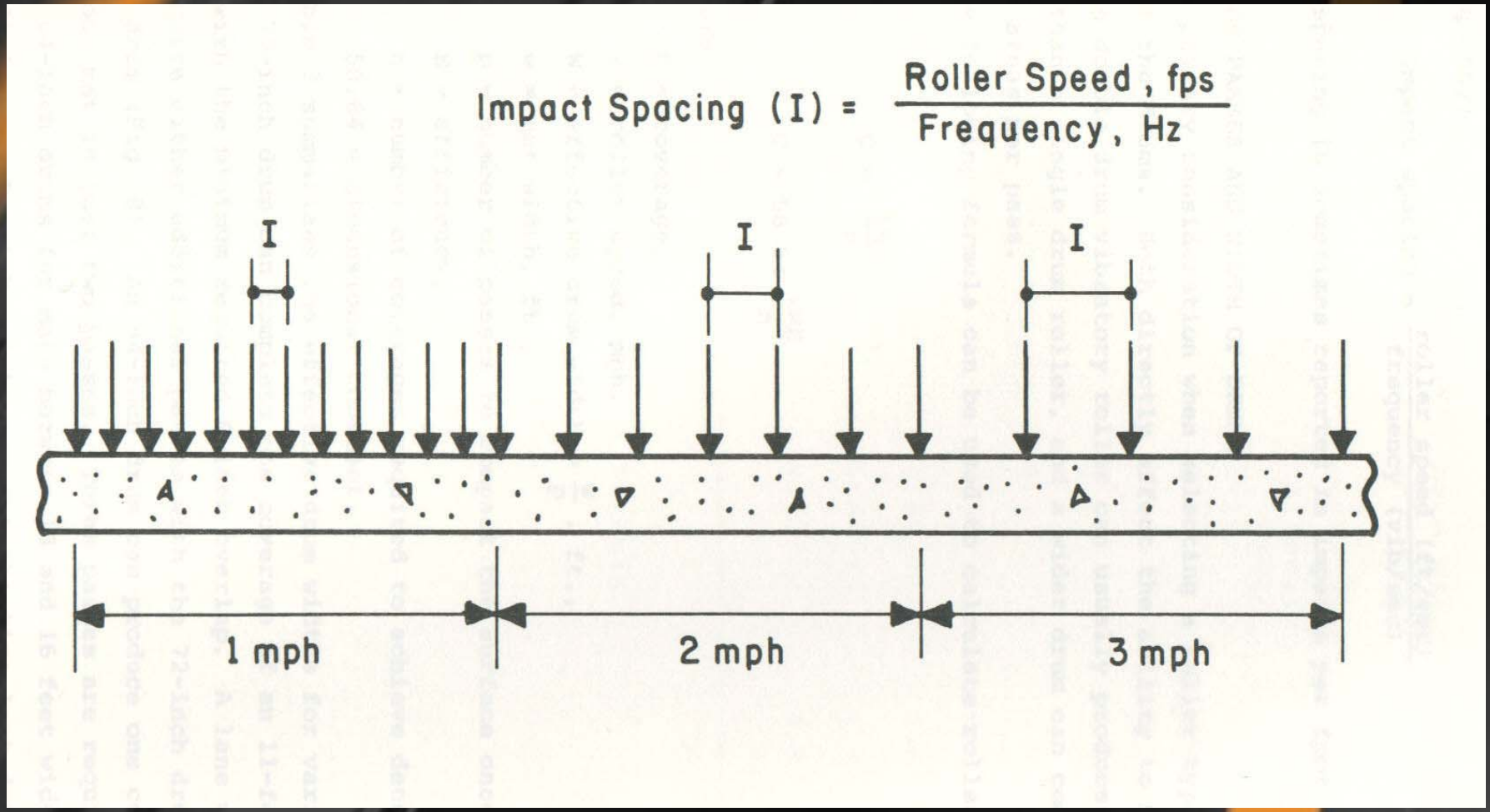


Vibratory Rollers - Frequency

Vibrating Reed Tachometer

- Checks the accuracy of the roller's frequency reading
- Contains a group of reeds with a specific natural frequency
- As a single vibrating drum passes VRT
    - Observe which reed is vibrating
    - Check value off the machine tachometer

Vibratory Rollers - Frequency



Drum Impacts per Foot

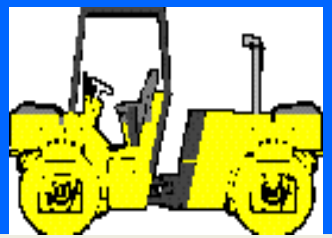
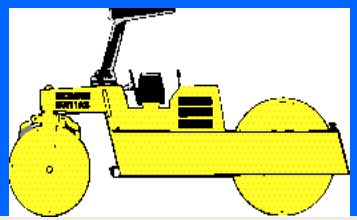
Frequency	2 MPH	3 MPH	4 MPH	5 MPH
2000 vpm	11.36	7.58	5.68	4.55
2200 vpm	12.50	8.33	6.25	5.00
2400 vpm	13.64	9.09	6.82	5.45
2600 vpm	14.77	9.84	7.39	5.91
2800 vpm	15.91	10.61	7.95	6.36
3000 vpm	17.05	11.36	8.52	6.82
3200 vpm	18.18	12.12	9.09	7.27
3400 vpm	19.32	12.88	9.66	7.72
3600 vpm	20.45	13.64	10.22	8.18
3800 vpm	21.59	14.39	10.80	8.63
4000 vpm	22.72	15.16	11.36	9.10

Sequence of Roller Operations
&
Roller Procedures

Sequence of Roller Operations

- Breakdown Rolling
- Intermediate Rolling
- Finish Rolling

Roller Operations - Temperature Zones

Compactive Force	Pressure Impact Vibration	Pressure Manipulation	Pressure
			
Temperature Ranges	300° - 260°F	250° - 220° F	200 - 180° F

Breakdown Rolling

- Initial compaction operation
- Gets most of the density
- Begin at highest temp without mat distortion
- Work closely to paver
- Dual drum vibratory works best
  - Both drums powered
  - Pressure
  - Impact
  - Vibration

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
  - Leave deep marks -- hard 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

Finish Rolling

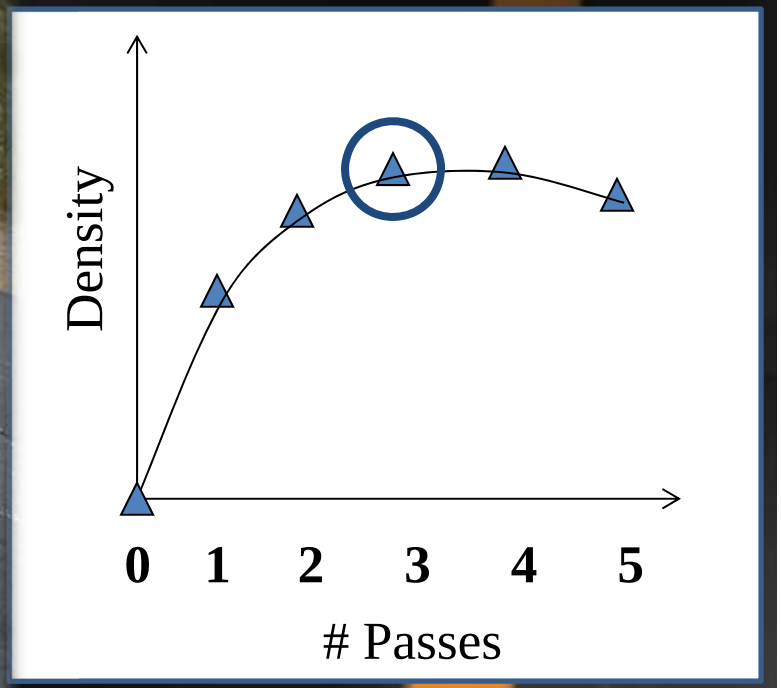
Main purpose

- 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

Establishing Rolling Pattern



Rolling Pattern

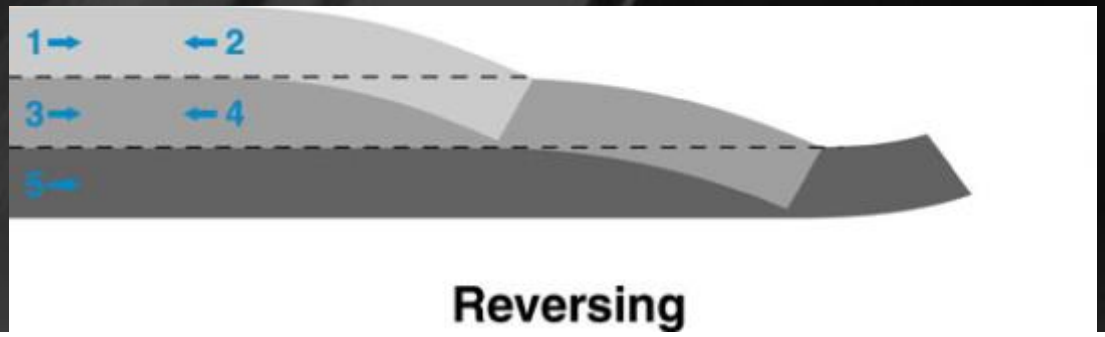
- Speed & lap pattern for each roller
- Number of passes for each roller
  - One trip across a point on the mat
- Set minimum temperature each roller finishes pattern

- ***IMPORTANT:***
- Paver speed must not exceed compaction operation!!!
  - Paver makes single pass
  - Roller pattern requires 3-7 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**



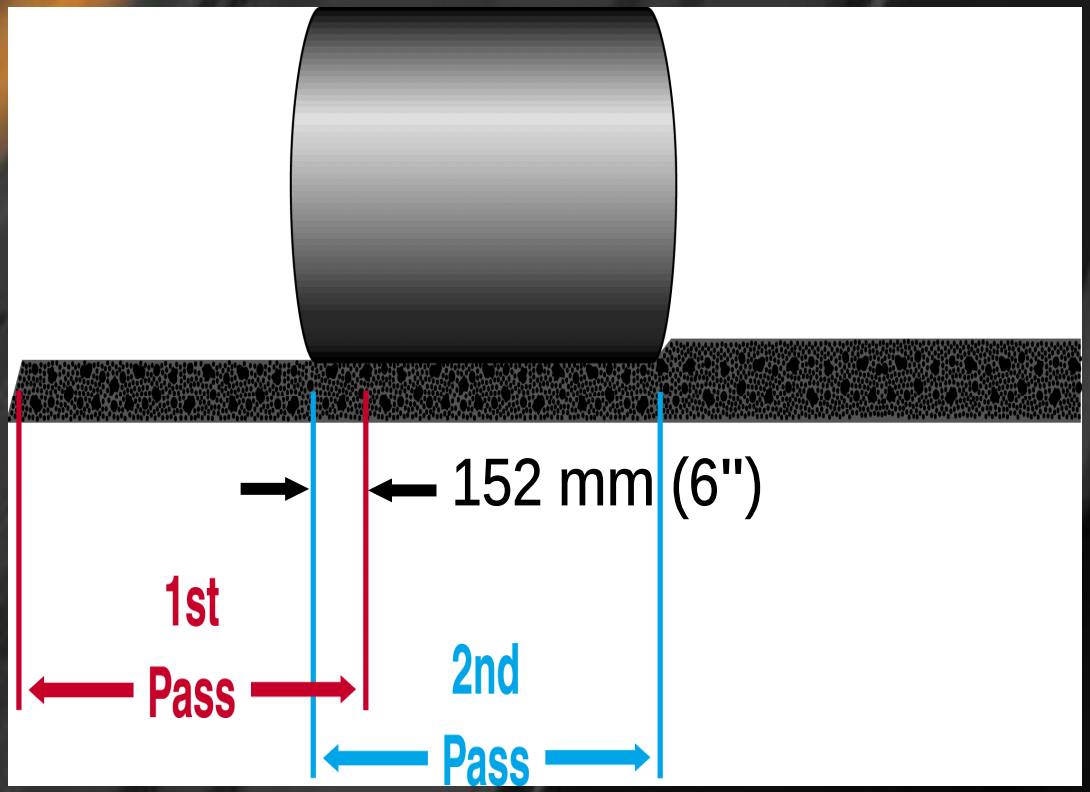
Reversing

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
  - Adj paver speed

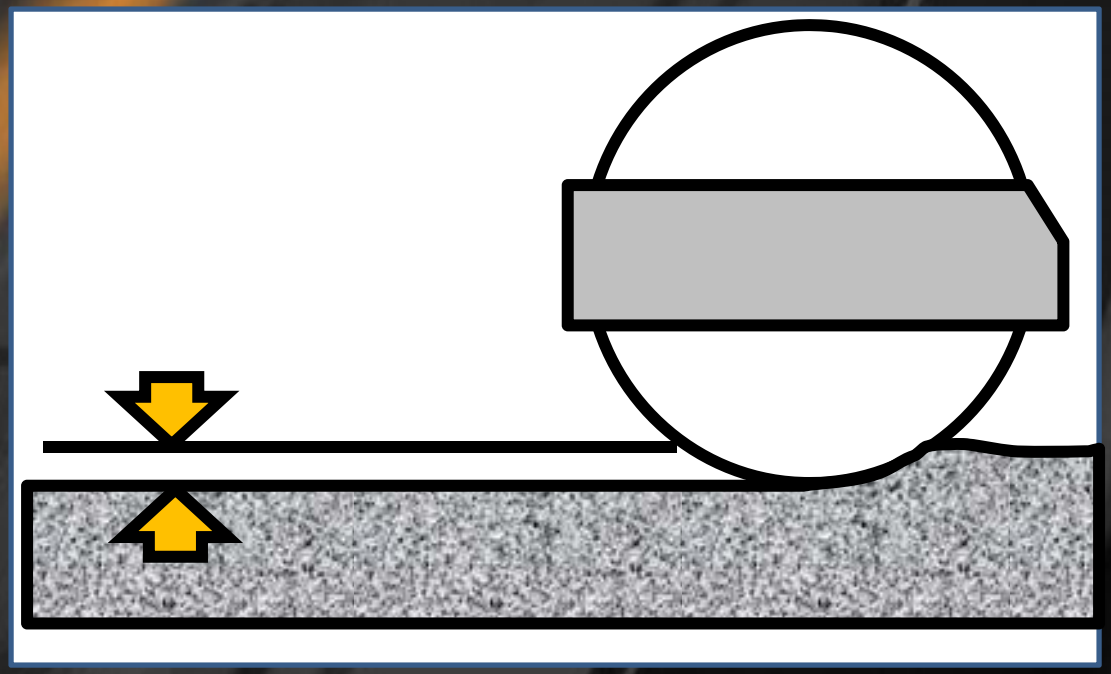
General Rolling Procedures



Overlaps

- 6” overlap assures uniform compaction
- Include overlap when selecting drum width
- Roller should cover mat in 3 overlapping passes

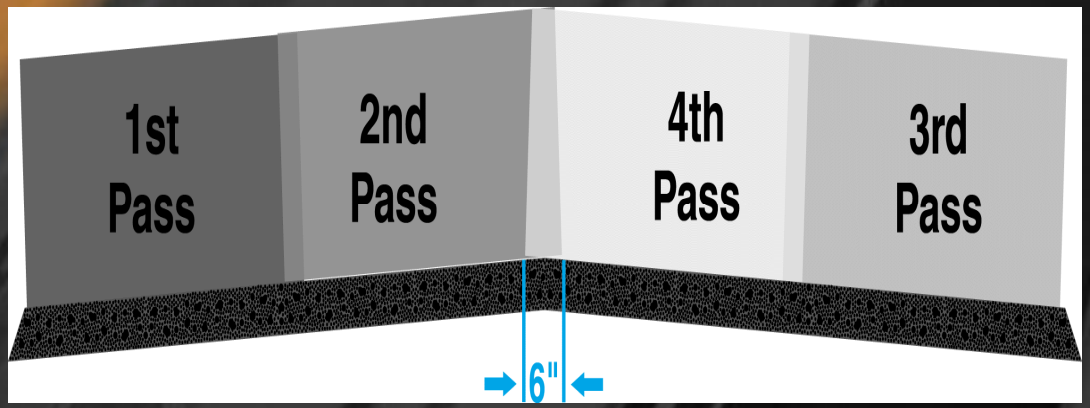
General Rolling Procedures



Rolldown

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

General Rolling Procedures



Rolling a Crown

- Never straddle crown
- Work from bottom toward crown both sides
- Strengthens mat to support roller on slope
- Overlap crown 6” on last pass

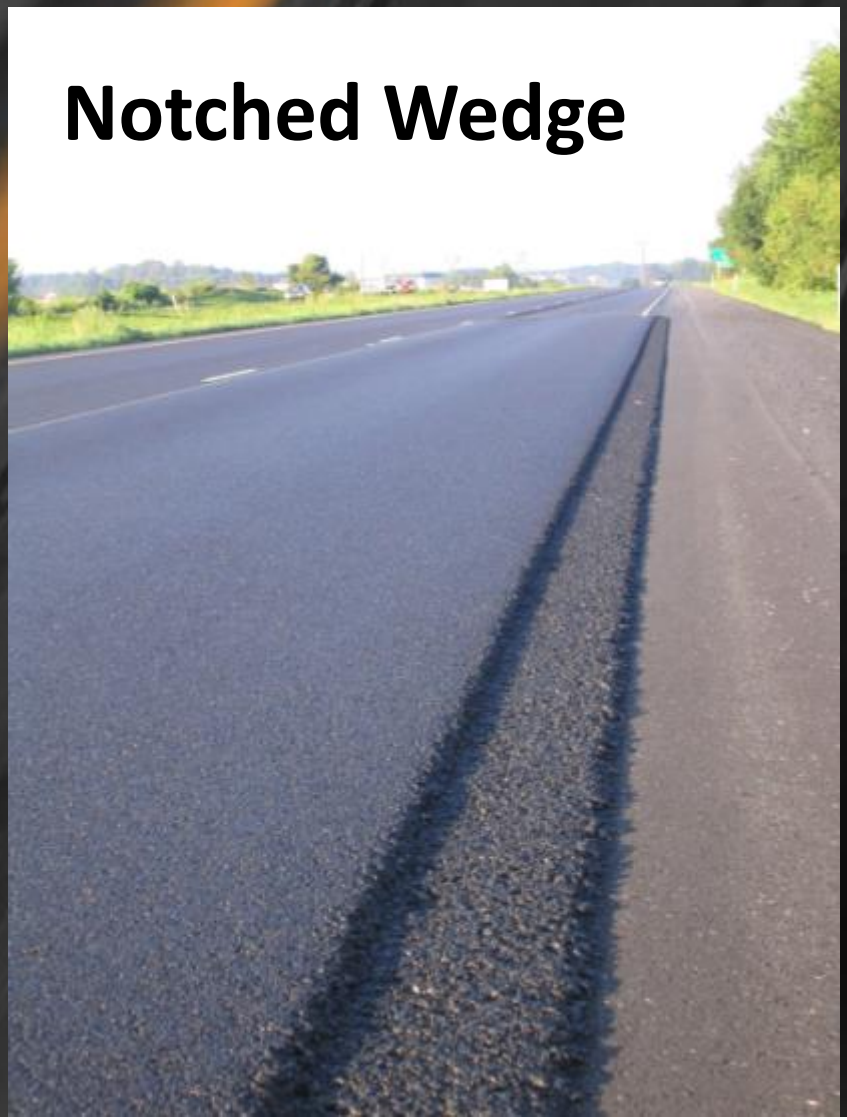
General Rolling Procedures

Parking

- Never park on a hot mat
- Leaves a transverse bump that cannot be rolled out
- When servicing:
  - Roll back to cooler mat
  - Service vehicles on mat < 175° F

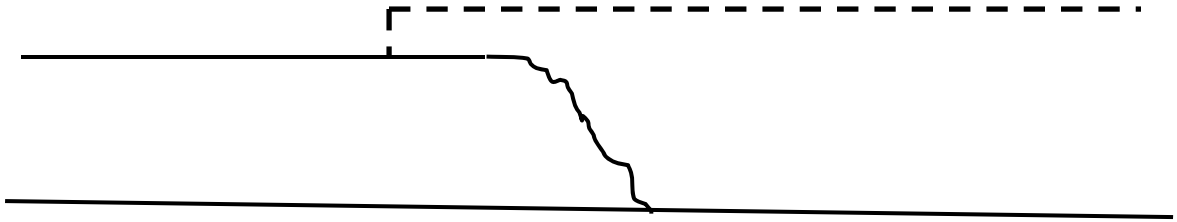
Achieving Density on HMA Joints

Longitudinal Joint Types

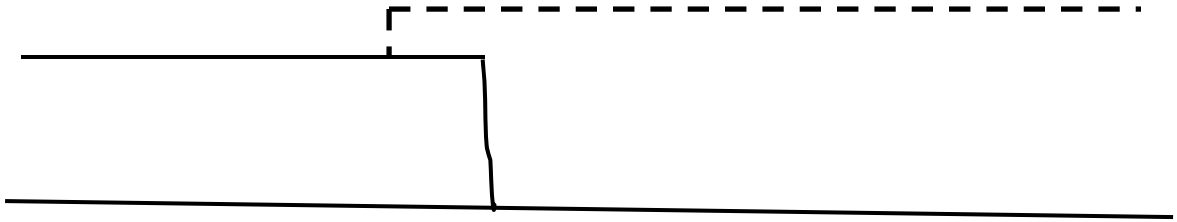


Longitudinal Joint Types

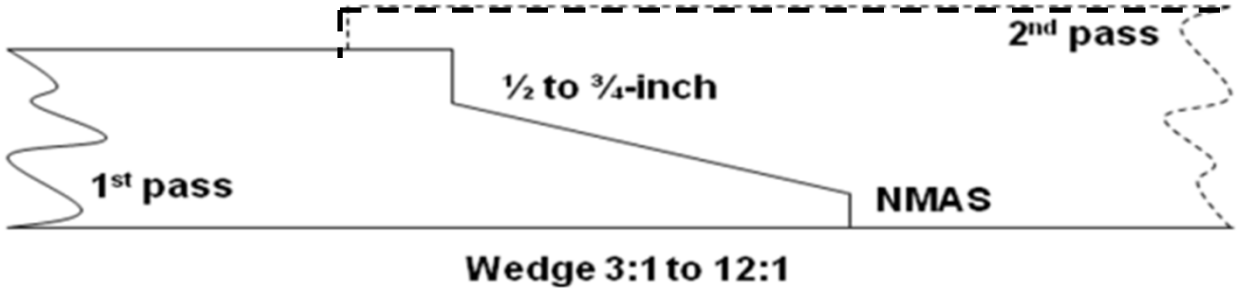
Butt Joint (paver construction)

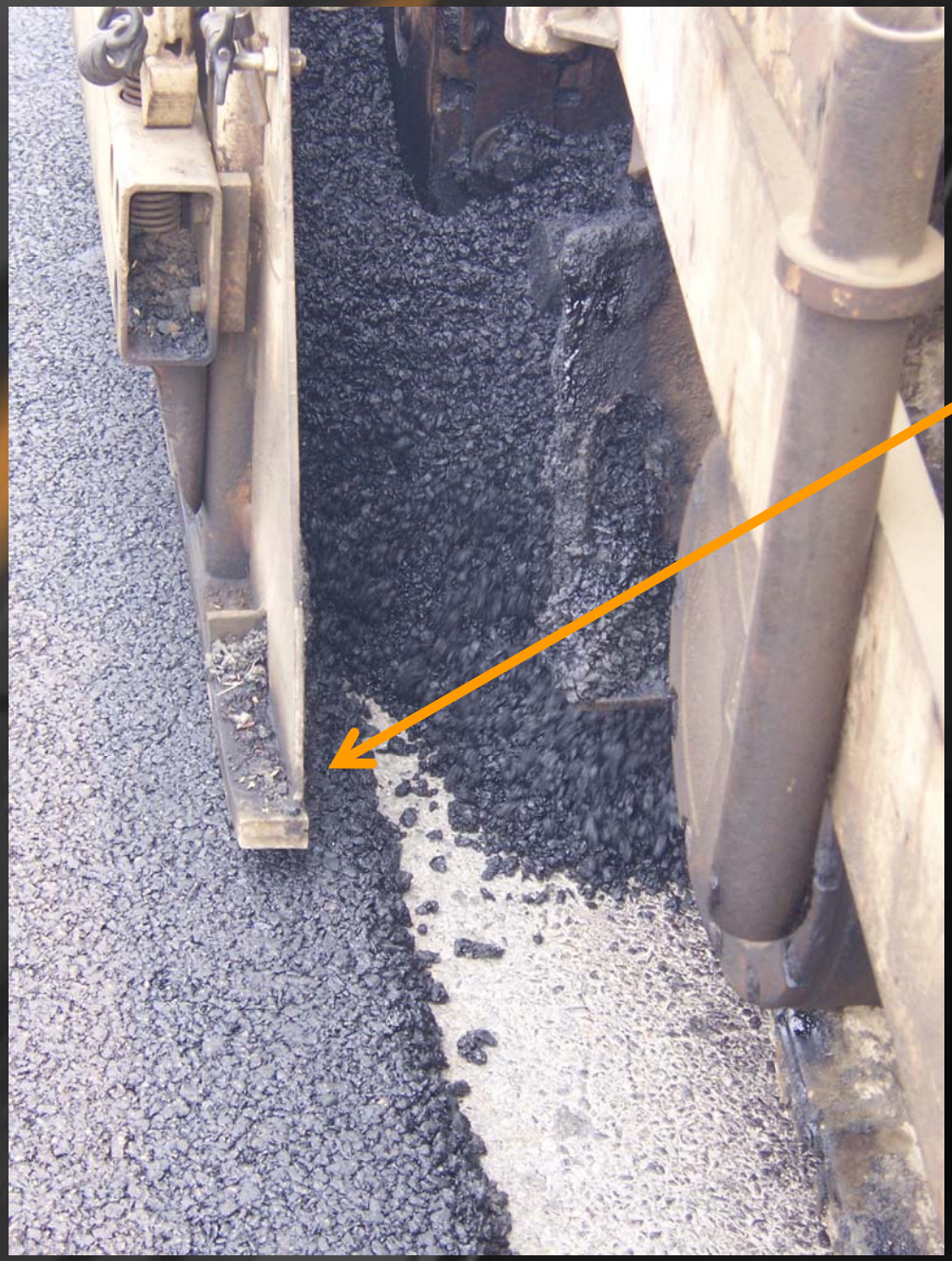


Butt Joint (milled or cutback)



Notched Wedge Joint





Proper Overlap:

- **1.0 ± 0.5 inches**
  - **Exception: Milled or sawed joint should be 0.5 inches**

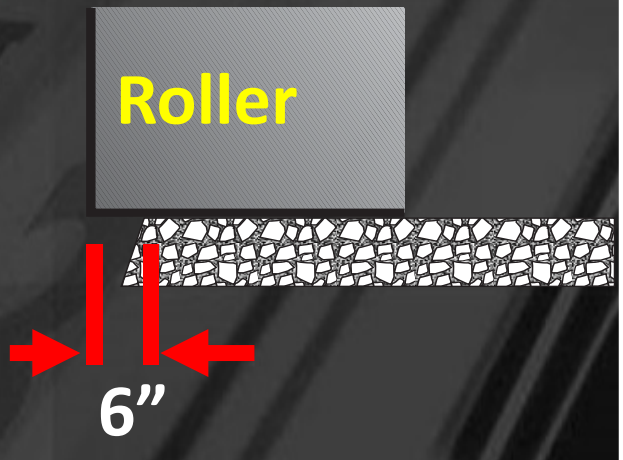
Rolldown

- **15-25% based on mix**

Rolling Unsupported Edge?

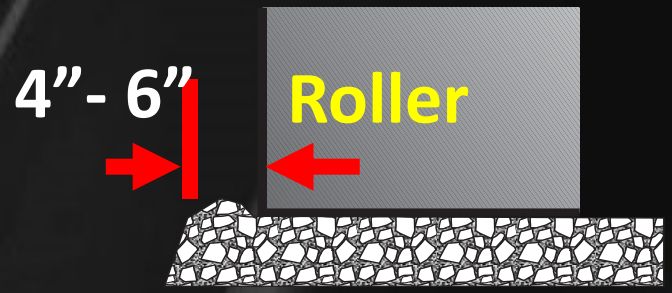
Option 1

Hang over 4-6”

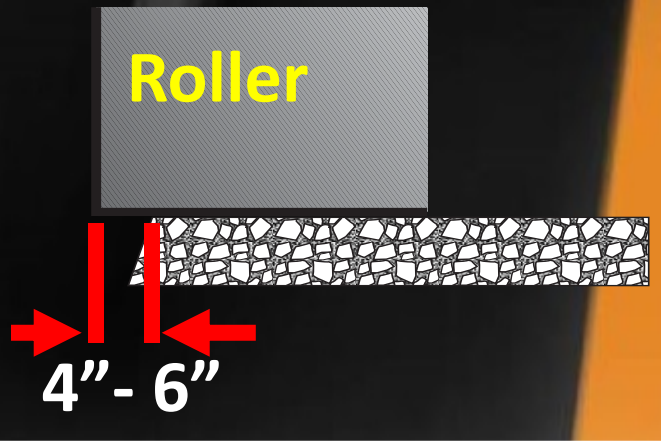


Option 2

1st Pass 4”-6” inside

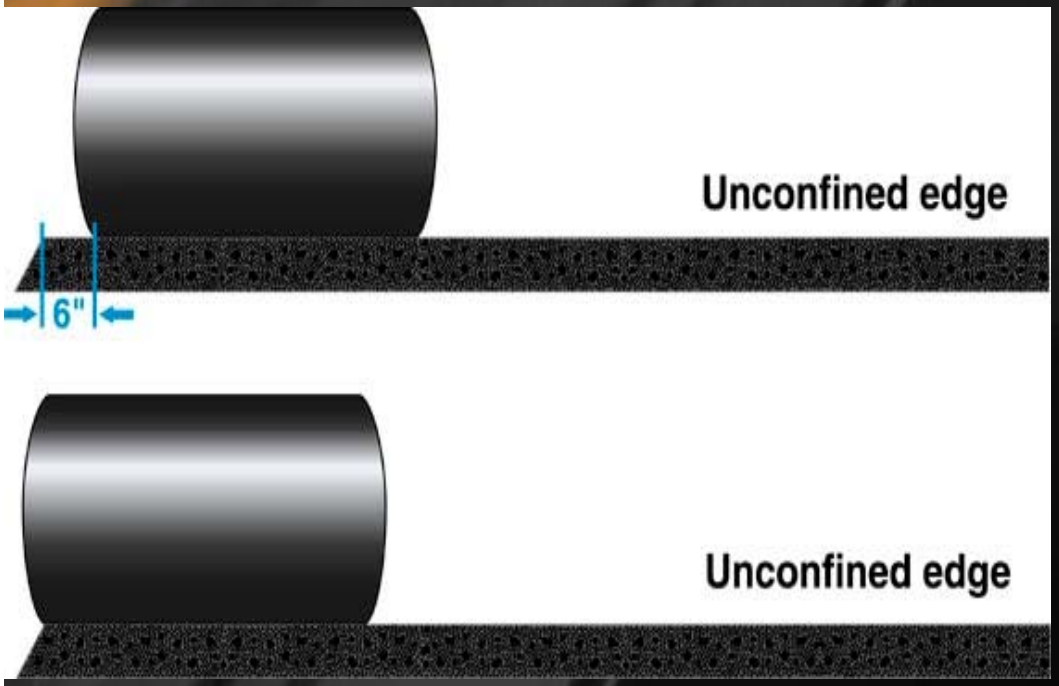


2nd Pass hang over 4”-6”



Option 1
1st Pass Hangs Over 4-6 inches

Option 2:
Stay Back 4-6 inches on 1st pass, then roll 2nd pass w/ slight overhang



- Concern:
  - Developing stress crack?
- Merit:
  - Min lateral movement?

Don’t Starve the Joint

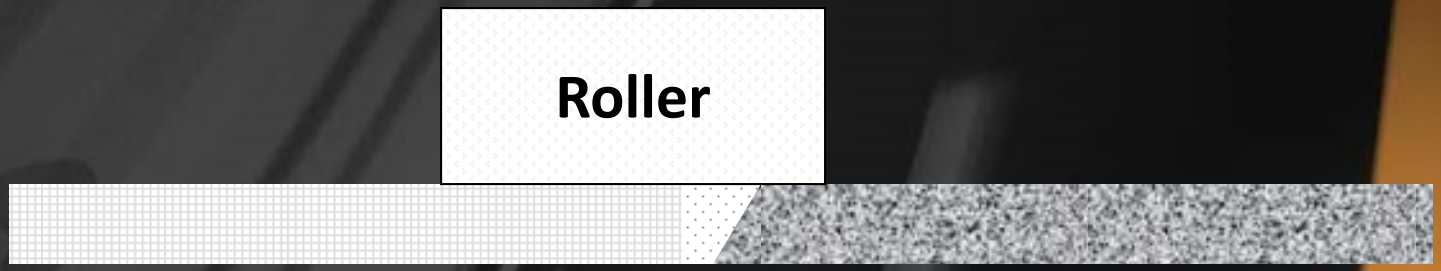
Rolling the Supported Edge

1st pass off the joint approx 6-8 inches

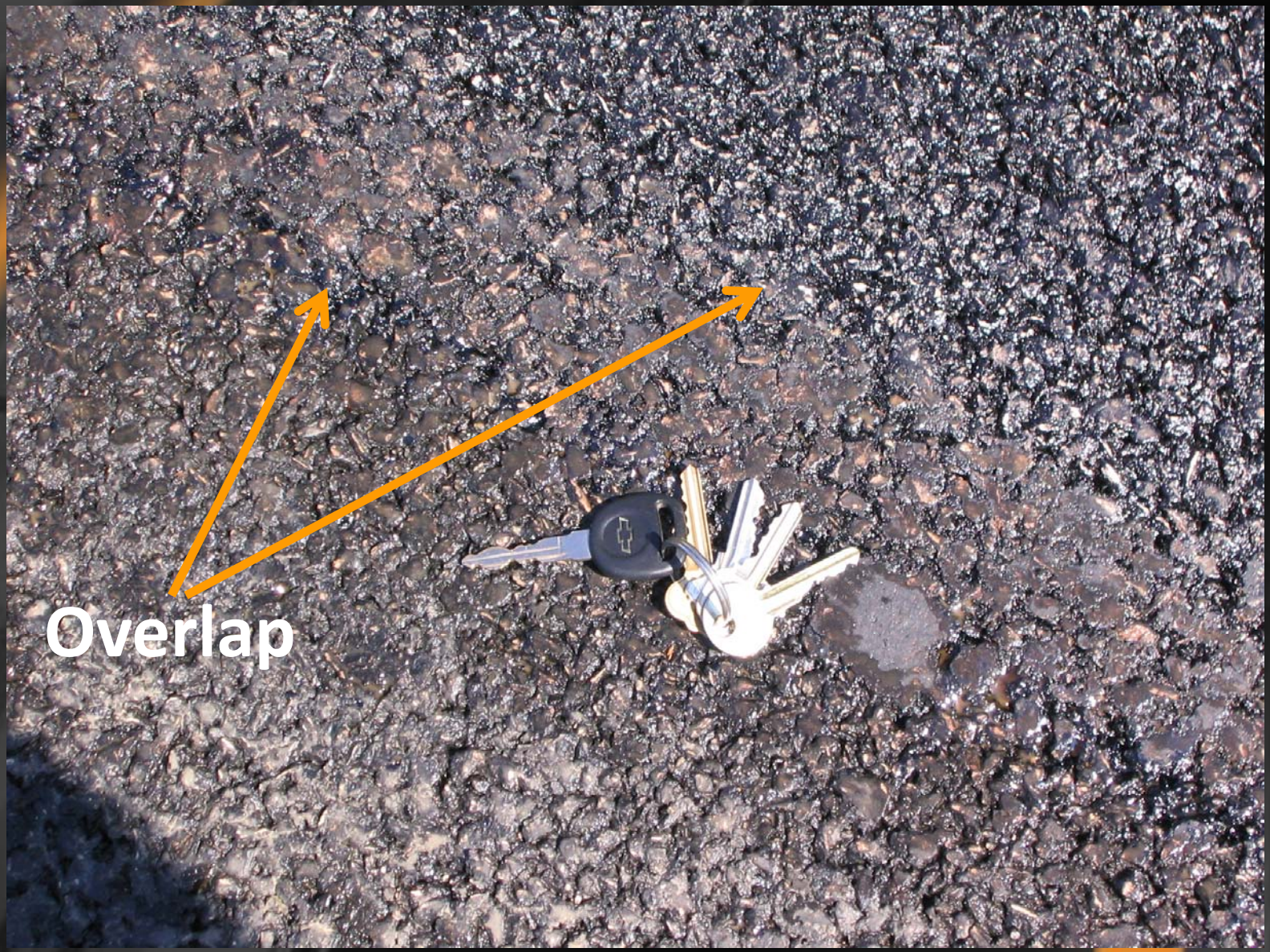
2nd pass overlaps on cold mat 3-6 inches

Alternate Method
1st Pass over the Supported Edge

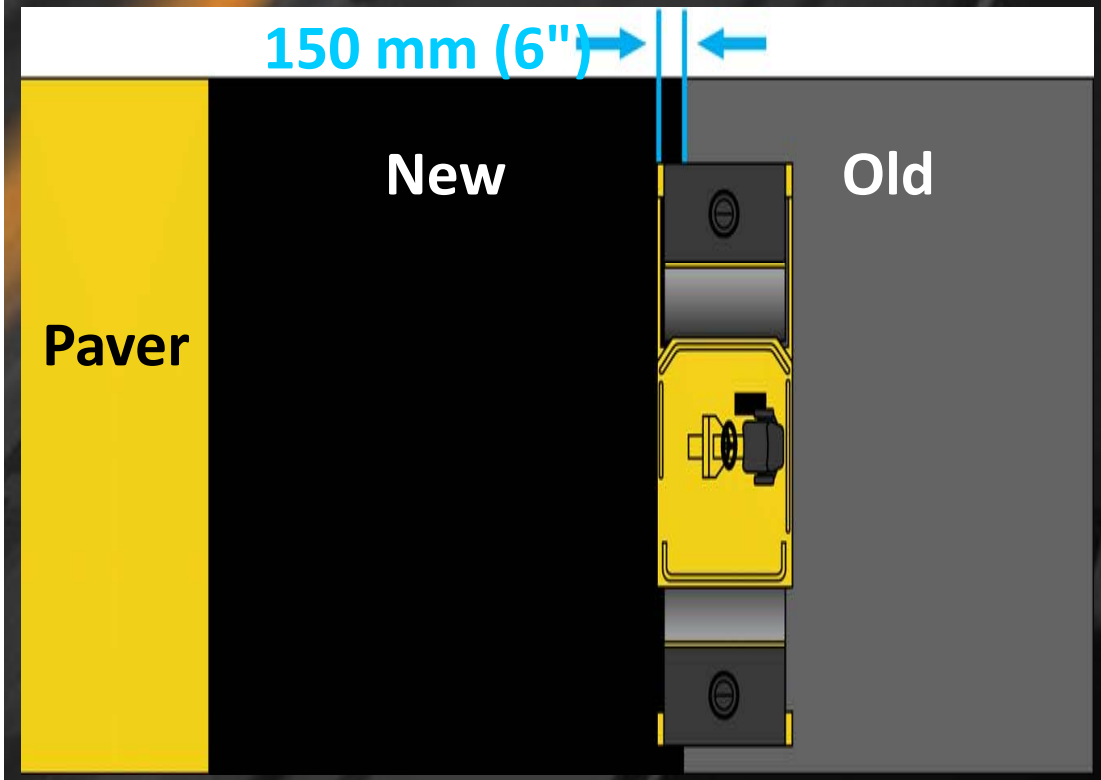
Roller in vibratory mode with edge of drum overhanging 2 to 4-inches on cold side.



Concern with this method is if insufficient HMA laid at joint, then bridging occurs (roller supported by cold mat)


Overlap

Transverse Joint
Starting a Lane



- Roll transverse
- Roll static
- Start drum on cold side
- Move over in 6” - 8” increments until drum is all on hot side

Transverse Joint
Starting a Lane

Rolling Transverse Joint

Checking Transverse Joint

Safety and Traffic Control Concerns

Reference Materials on the Topic:

MS-2: Mix Design Methods

SP-2: Superpave Mix Design

MS-4: The Asphalt Handbook

MS-22: HMA Construction

http://www.asphaltinstitute.org

Thank You

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