Balancing the Paving Operation

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Any golfers or golf fans here?

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Any idea on location?

What is the significance with the number 54?

- 54 is the score a player would achieve if a birdie was recorded on every hole on a par-72 course
- Would you consider this a perfect round?

Has 54 ever been scored in professional round?

Best recorded round: Jim Furyk, 58, August 7, 2016

Travelers Championship, Final Round

Jim Furyk celebrates becoming the first-ever PGA Tour golfer to shoot 58 in a tournament round. Steven Ryan/Getty Images

Baseball fans: Remember him?

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Diamondbacks pitcher Randy Johnson killed a bird with a pitch on March 24, 2001. *Michael Chow/azcentral Sports*

- What feat did Randy accomplish on May 18, 2004?
- Threw a perfect game against the Atlanta Braves.

	1	2	3	4	5	6	7	8	9	R	H	E
Arizona Diamondbacks	0	1	0	0	0	0	1	0	0	2	8	0
Atlanta Braves	0	0	0	0	0	0	0	0	0	0	0	3

WP: Randy Johnson (4-4) • LP: Mike Hampton (0-5)

- 27 batters, 27 outs, no hits, no walks, no baserunners, no runs
- Aspirational goal for a pitcher and team
  - Objective that challenges the limits of what's possible

What does “perfect” paving day look like?

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- Thoughts?
  - Production Targets
  - Efficiency
  - Quality Control Requirements
  - Smoothness
  - Density
  - Safety
- Aspirational goal for paving?
  - Paver runs at a constant speed throughout the shift
  - 100% efficiency

Aspirational Goals

- How many contribute to Jim's near-perfect 58 score?
  - 1? (Jim), maybe his caddy/ coach
- How many contribute to Randy's perfect game?
  - 9, Randy plus his 8 fielders on defense
- How many are involved in your perfect paving day?

Balancing the Paving Operation

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BALANCING THE PAVING OPERATION

The synchronized balance of the four phases of asphalt paving to provide continuous paving operations.

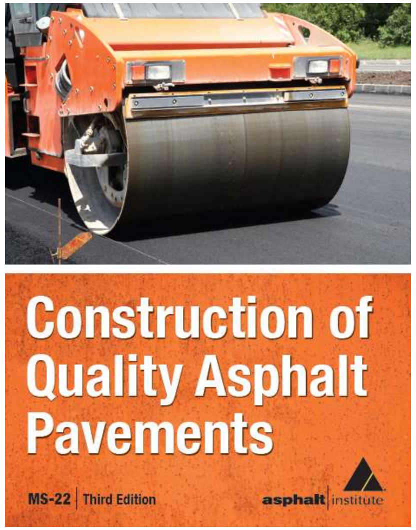
Foreword

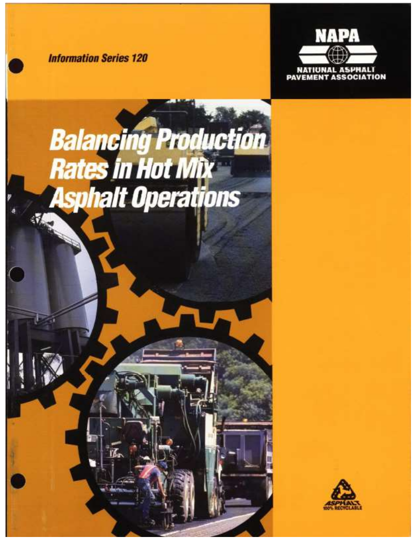
- We will discuss some fundamental concepts around the balanced paving operation
- More detail and examples are provided in MS-22
- Classes available provide a deeper dive into balanced operations and best practices
  - Asphalt Institute – CQAP
  - Asphalt Institute – PIC (online)

- **Course Outline**
  - Module 1: Inspector's Authority and Responsibility
  - Module 2: Materials
  - Module 3: Mixtures and Mix Design
  - Module 4: Plants & Production
  - Module 5: Transportation, Delivery, & Preparation
  - Module 6: Placement
  - Module 7: Compaction
  - Module 8: Acceptance and Testing
- **Each module roughly 90-120 mins**
- **Modules consist of ppt slides with audio, exam**

http://www.asphaltinstitute.org/training/seminars/paving-inspector-certification-pic/

The Asphalt Institute Paving Inspector Certification Series





Production

The basic operations of the HMA plant:

1. Proper storage and handling of the component materials
2. Accurate proportioning and feeding of the cold aggregate into the dryer
3. Effective drying and heating of the aggregate to the proper temperature
4. Efficient control and collection of the dust from the dryer
5. Proper proportioning and mixing of binder with aggregate
6. Proper storing, dispensing, and weighing of finished mix

Factors Impacting Production Rates

- Overall Plant Capacity and Size
- Silo Storage
  - Fully Heated & Insulated
  - Several Hundred Ton Capacity
- Daily Demand
  - How many mixes produced?
- Aggregate Moisture Content
  - Bigger Issue for Smaller Plants
- Discharge Temperature
  - WVDOT Maximum mixing temperature is 338°F
  - Why?

Impact of Production Rate: Example

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Jim's Crew

- Jim's crew is set up to pave
- Rained the night before
- Plant needs to produce multiple mixes
- Plant operator says 190 tons/ hour doable
- How many tons can Jim expect today on his 8-hour shift?
- 190 tph * 8 hours = 1,520 tons

Randy's Crew

- Randy's crew is set to pave
- Plant is up and running and normal capacity
- Plant started early and place some mix in silo
- Plant operator says 290 tons/ hour is doable
- How many tons can Randy get today?
- 290 tph * 8 hours = 2,320 tons

Balancing the Paving Operation

The synchronized balance of the four phases of asphalt paving to provide continuous paving operations.

The Hauling Operation

The hauling operation must provide a steady and consistent flow of asphalt mixture from the plant to the paver.

This is accomplished by:

- *Timely and proper loading of trucks at plant*
- *Adequate number of trucks to support continuous paver speed throughout production*
- *Consistent use of proper techniques for loading and unloading trucks*
- *Consistent spacing of trucks*
- *Making sure delivered mix meets temperature and segregation requirements*

The Contractor must anticipate the trucker's activities to properly estimate cycle time.

Types of Trucks

Truck Type	Capacity	Features	Example
End Dump	13 – 15 Tons	Lower capacity More maneuverable Good in tight spaces Overhead obstructions	
Semi-Trailer High Dump	20 - 22 Tons	Larger Capacity Easier to segregate Overhead obstructions	
Flow Boy Semi “Live Bottom”	20 – 22 Tons	Large Capacity No issues with overhead obstructions Regulated flow dump into hopper	

Verifying the Number of Required Trucks

- Critical to have adequate number of trucks to support plant production and established paving/ rolling speed
  - Not enough trucks
    - Paving interruptions – stop and wait
  - Too many trucks
    - Waiting at the plant or paver
- Inputs needed
  - Plant Production (tons/ hour)
  - Average Load (tons/ truck)
  - Cycle time (minutes)
    - Includes spraying, loading, ticket, haul time, time to unload, clean-out, return time to plant

$$\boldsymbol{Haul\ Units\ (Trucks)} = \frac{\boldsymbol{Plant\ Production\ \left(^{T}/_{hr}\right)}}{\boldsymbol{Average\ Load\ \left(^{T}/_{Truck}\right)}} \times \boldsymbol{Cycle\ Time\ (min)} \times \frac{\boldsymbol{hr}}{\boldsymbol{60\ min}}$$

Example Calculation

- Contractor will be producing at 340 tons/hour. They will be using semi trucks with high dump trailers hauling 22 tons of mix in each truck. Estimated cycle time is 30 minutes.
- Do we think ten trucks would be enough?

- **What is the minimum acceptable number of trucks?**

- $$\boldsymbol{Trucks = \frac{340\left({tons}/{hour}\right)}{22\left({tons}/{truck}\right)} \times 30\ (min) \times \frac{hour}{60\ min}}$$

$$\boldsymbol{Trucks = 7.7 \rightarrow 8\ minimum}$$

Comparing Hauling Requirements: Example

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Parameter	Jim's Crew	Randy's Crew
Plant Production Rate	190 tons per hour	290 tons per hour
Average Truck Capacity	20 tons	20 tons
Cycle Time (Case 1)	45 Minutes	30 Minutes
Trucks Required (Case 1)	**8 (Round up from 7.15)**	**8 (Round up from 7.25)**
Cycle Time (Case 2)	60 minutes	45 minutes
Trucks Required (Case 2)	10 (Round up from 9.5)	11 (Round up from 10.8)

- Who will need more trucks in Case 1?
- How many more trucks will be needed if cycle time increases 15 minutes (Case 2)?
- What should we do if we cannot get more trucks?

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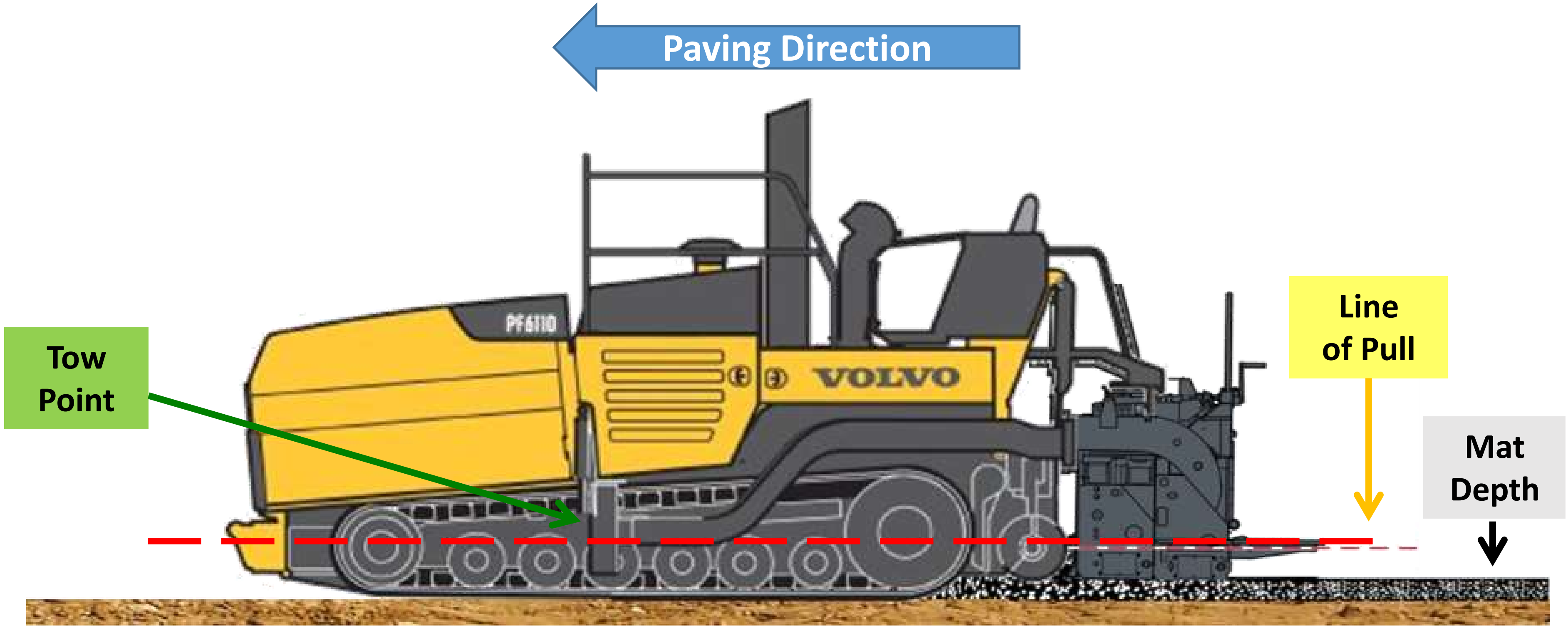
Paving

- What was our paving aspirational goal?
  - Paver runs at a constant speed throughout the shift
  - 100% efficiency
- What happens when we slow down or speed up?
- Or when we stop and start the paver?

“Free Floating” Screed

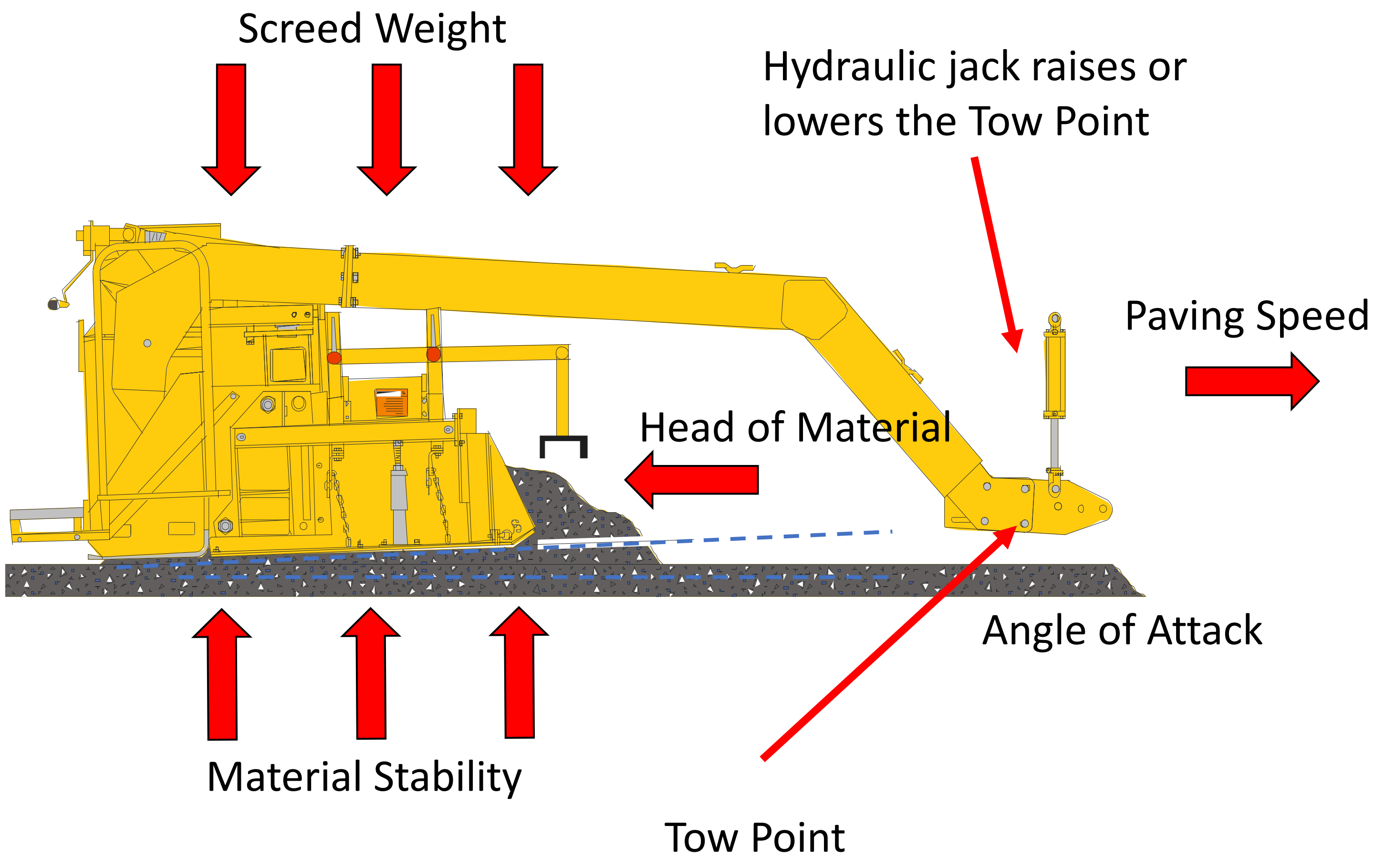


- The free floating screed finds equilibrium to run parallel to an imaginary line through the tow points known as the “Line of Pull”

Factors Affecting the Screed

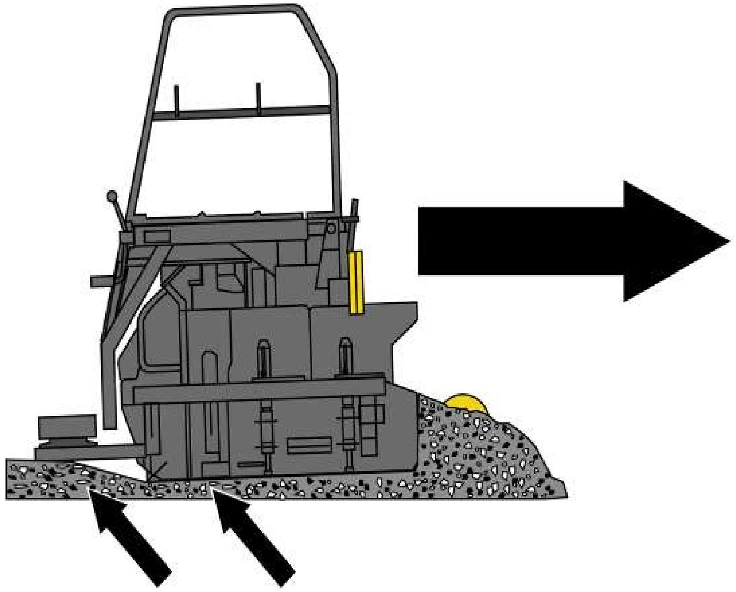
- Five factors affecting the screed

1. Screed weight (Downward force)
2. Mix Stability (Upward force)
3. Forward Motion (Horizontal Force)
4. Head of Material (Opposite horizontal force)
5. Angle of attack of the screed (Upward force)



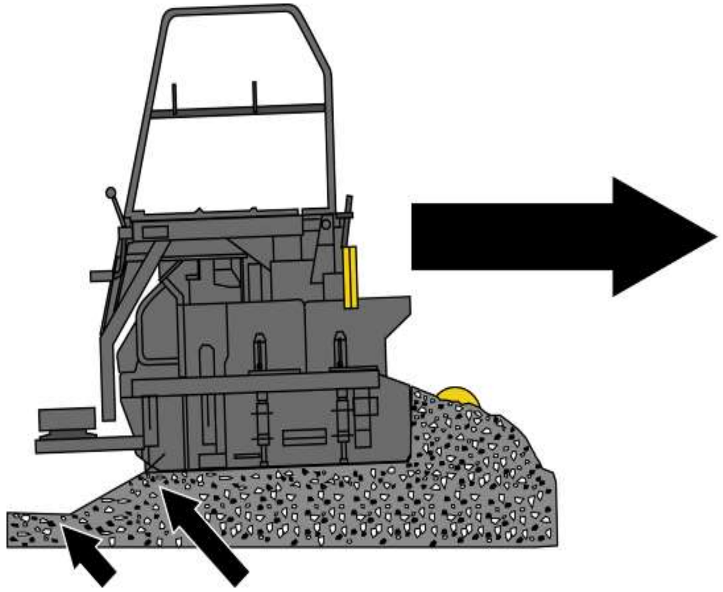
Paving Speed

Increasing Speed



- Shear force decreases
- Depth decreases

Decreasing Speed



- Shear force increases
- Depth increases

What happens when the paver stops for a while?

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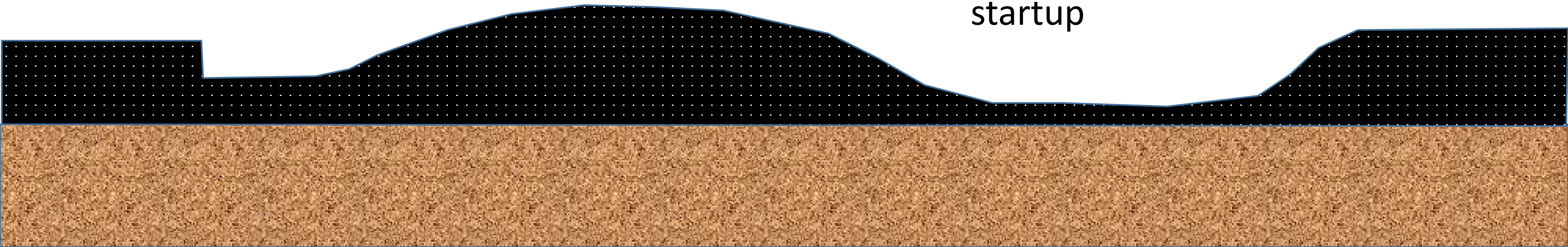
1. Screed sinks into hot asphalt

2. Asphalt under paver cools as paver sits idle, screed rides over cold asphalt

3. Screed sinks as paver moves onto hot asphalt at startup

about 24 feet

4. Screed eventually equlibrates to intended mat depth



Example: Paver Speed Based on Mix Delivery

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Input	Jim's Crew	Randy's Crew
Plant Production (tons per hour)	190	290
Unit Weight of Mix (lbs./ cu. ft)	150	150
Compacted Lift Thickness (in.)	2.0	1.5
Width of Pull (ft)	14	15
Spread Rate (lbs. / sq. yd – in)		

- Step 1: Determine the Spread Rate;
  - Expressed in pounds per square yard of HMA for every inch of compacted thickness
  - Based on the unit weight information provided by the QC lab.
- Who will have the greater spread rate?

$$Spread\ Rate\left(\frac{lbs.}{yd^2\ -in}\right) = Unit\ Weight\left(\frac{lbs}{ft^3}\right) \times \frac{ft}{12\ in} \times \frac{9\ ft^2}{yd^2}$$

$$Spread\ Rate\left(\frac{lbs.}{yd^2\ -in}\right) = 150\left(\frac{lbs}{ft^3}\right) \times \frac{ft}{12\ in} \times \frac{9\ ft^2}{yd^2} = 112.5$$

Example: Paver Speed Based on Mix Delivery

Input	Jim's Crew	Randy's Crew
Plant Production (tons per hour)	190	290
Unit Weight of Mix (lbs./ cu. ft)	150	150
Compacted Lift Thickness (in.)	2.0	1.5
Width of Pull (ft)	14	14
Spread Rate (lbs. / sq. yd – in)	112.5	112.5
Paver Distance Covered in 1 Hour		

- Step 2: Determine how far the paver will go in one hour at stated production rate

$$\frac{Production\ (\frac{ton}{hr})}{Width\ (ft) \times Thickness\ (in.) \times Spread\ Rate\ (\frac{lbs.}{sq.yd\ - in.})} \times (Units\ Conversion\ Factors) = \frac{feet}{hour}$$

Jim's Crew →

$$\frac{190\ (\frac{ton}{hr})}{14\ (ft) \times 2\ (in.) \times 112.5\ (\frac{lbs.}{sq.yd\ - in.})} \times \left(\frac{2000\ lbs.}{1\ ton} \times \frac{9\ sq\ ft}{1\ sq\ yd}\right) = \mathbf{1,085}\frac{feet}{hour}$$

Randy's Crew →

$$\frac{290\ (\frac{ton}{hr})}{15\ (ft) \times 1.5\ (in.) \times 112.5\ (\frac{lbs.}{sq.yd\ - in.})} \times \left(\frac{2000\ lbs.}{1\ ton} \times \frac{9\ sq\ ft}{1\ sq\ yd}\right) = \mathbf{2,062}\frac{feet}{hour}$$

Example: Paver Speed Based on Mix Delivery

Input	Jim's Crew	Randy's Crew
Plant Production (tons per hour)	190	290
Unit Weight of Mix (lbs./ cu. ft)	150	150
Compacted Lift Thickness (in.)	2.0	1.5
Width of Pull (ft)	14	15
Spread Rate (lbs. / sq. yd – in)	112.5	112.5
Paver Distance Covered in 1 Hour	1,085	2,062

- Step 3 : Determine Paver Speed in feet per minute

$$\frac{Distance\ Covered\ in\ an\ Hour}{60\ \frac{min}{hr}} = Paver\ Speed\ \frac{ft}{min}$$

Jim's Crew

$$\frac{1{,}085\ \frac{ft}{hr}}{60\ \frac{min}{hr}} = \mathbf{18.0}\frac{ft}{min}$$

Randy's Crew

$$\frac{2{,}062\ \frac{ft}{hr}}{60\ \frac{min}{hr}} = \mathbf{34.4}\frac{ft}{min}$$

- This results reflect a scenario where the paver is not stopping at all!
- 100% efficiency

Example: Paver Speed Based on Mix Delivery

Input	Jim's Crew	Randy's Crew
Plant Production (tons per hour)	190	290
Unit Weight of Mix (lbs./ cu. ft)	150	150
Compacted Lift Thickness (in.)	2.0	1.5
Width of Pull (ft)	14	15
Spread Rate (lbs. / sq. yd – in)	112.5	112.5
Paver Distance Overed in 1 Hour	1,085	2,209
Paver Speed (ft/min) at 100% Eff	18.0	34.4

- Step 4 : Apply Efficiency Factor (Assume what portion of the time the paving will be moving)

	Jim's Crew	Randy's Crew
Let's assume the paver is running 90% of the time	$\frac{18.0\frac{ft}{hr}}{0.90} = \mathbf{20.0}\frac{ft}{min}$	$\frac{34.4\frac{ft}{hr}}{0.90} = \mathbf{38.2}\frac{ft}{min}$
What if the paver is running 80% of the time	$\frac{18.0\frac{ft}{hr}}{0.80} = \mathbf{22.5}\frac{ft}{min}$	$\frac{34.4\frac{ft}{hr}}{0.80} = \mathbf{43.0}\frac{ft}{min}$

Example: Paver Speed Based on Mix Delivery

Input	Jim's Crew	Randy's Crew
Plant Production (tons per hour)	190	290
Unit Weight of Mix (lbs./ cu. ft)	150	150
Compacted Lift Thickness (in.)	2.0	1.5
Width of Pull (ft)	14	15
Spread Rate (lbs. / sq. yd – in)	112.5	112.5
Paver Distance Overed in 1 Hour	1,085	2,209
Paver Speed (ft/min) at 100% Eff.	18.0	34.4
Paver Speed (ft/min) at 90% Eff.	20.0	38.2
Paver Speed (ft/min) at 80% Eff.	22.5	43.0

- What big takeaways do we have from this exercise?
- Are these the target paver speeds that Jim and Randy need for the project?

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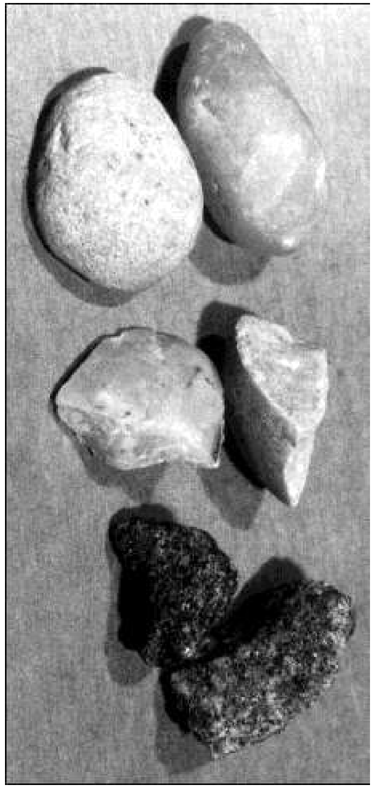
Compaction Operations

- **Achieving density is a quality indicator**
  - **If density is inadequate**
    - Increased voids and reduced pavement life
    - Reduction in pay
    - Remove and replace
- **This is accomplished by ensuring:**
  - Compaction is completed in the optimum temperature range
    - Impacted by
      - Mix type, binder grade and project conditions
  - Adequate number and type of rollers used to keep up with paver
    - Within individual roller's recommended speed range
  - Establishing project specific roller patterns
    - Determined by test strip density at beginning of project
  - Best practices for mat and joint compaction should be used consistently throughout project

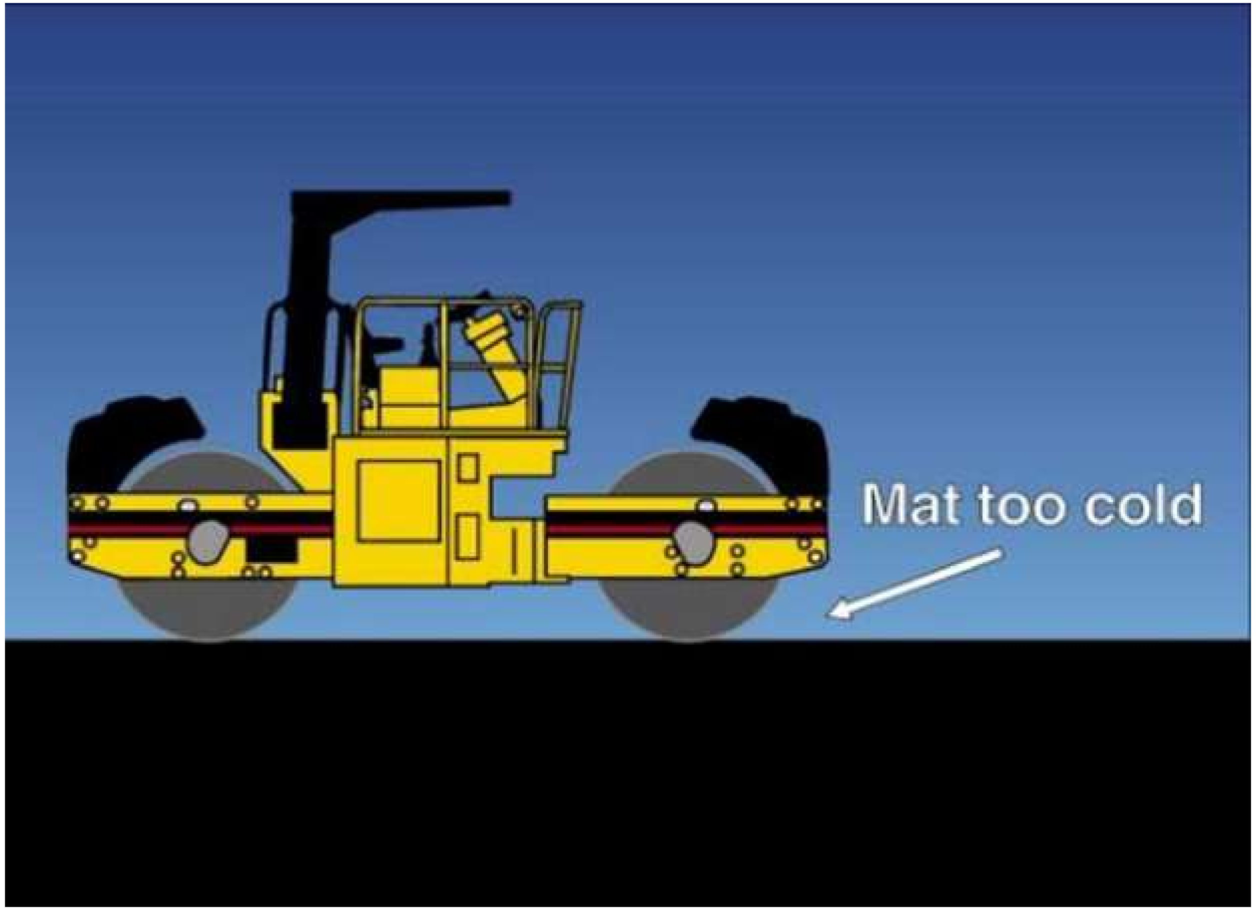
Factors Affecting Compaction

- There are five major factors that impact compaction:
  - Mat temperature
  - Mixture properties and characteristics
  - Layer Thickness
  - Environmental Conditions
  - Subgrade and Base



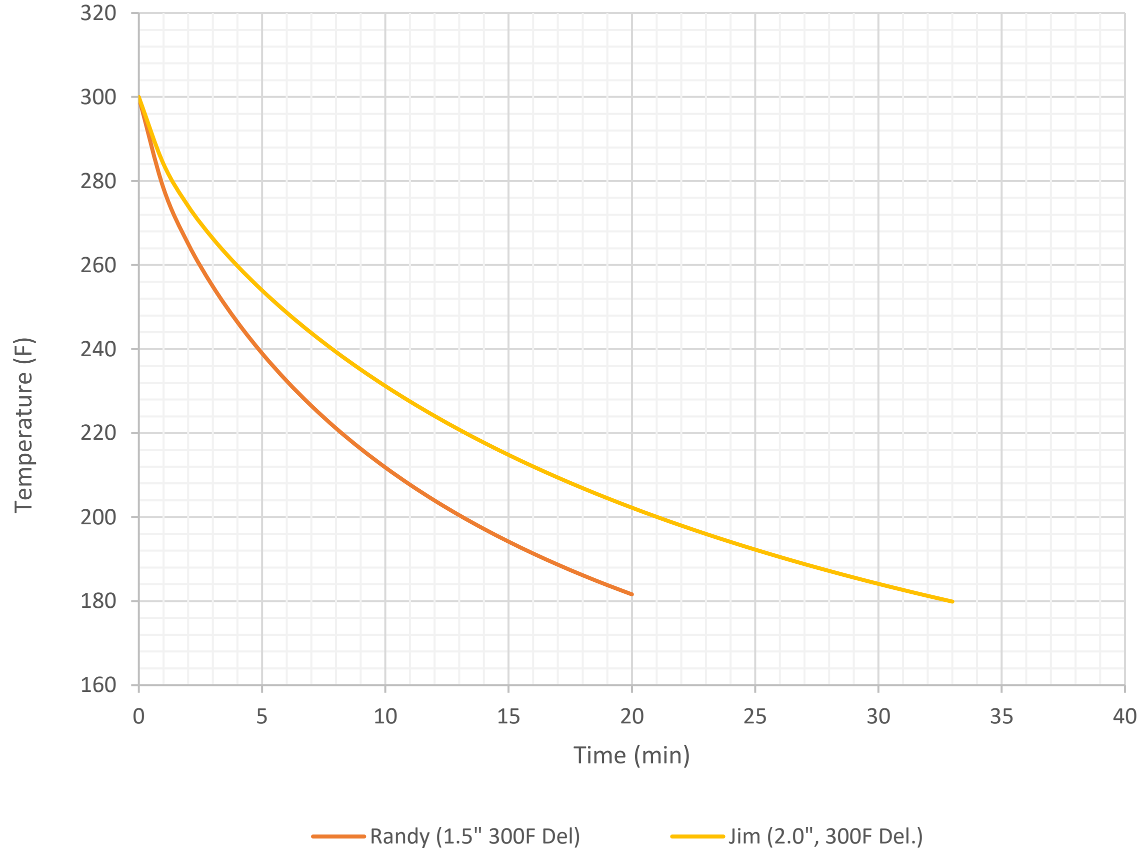
Effect of Temperature - Mat Too Cold

- Cessation temperature is
  - the minimum mat temperature where it can be reasonably expected that compactive effort will not substantially increase density
- Typically, 175-180°F
- Compacting below cessation temperature will result in:
  - No increase in mat density
  - Damage to the mat (breaking aggregate, etc.)
- Agencies commonly specify minimum mat temperature where compaction rolling must cease
  - WVDOT = 175 °F

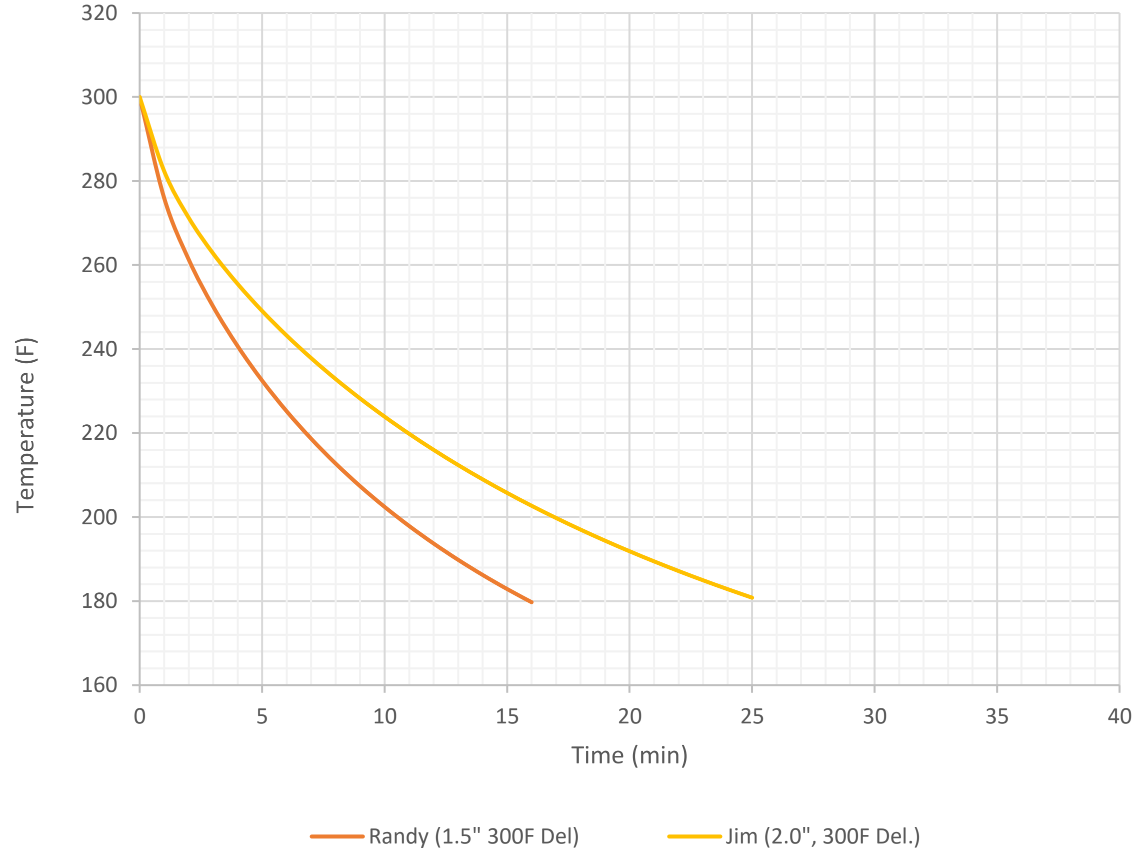


Impact of Project Conditions on Compaction Time

Let's Assume Ambient and Surface Conditions are 85°F



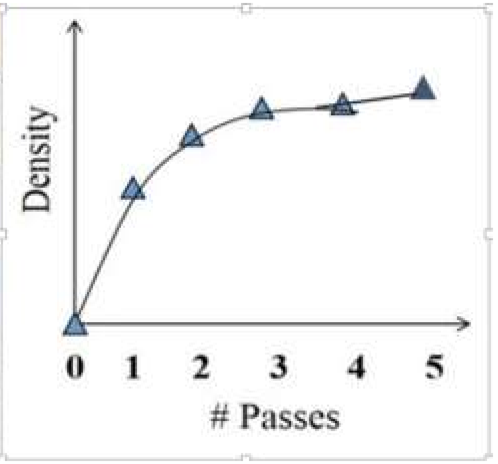
What if Ambient and Surface Temperature is 65°F?



Compaction Process – Important Considerations

- Best practices for compaction operation should be followed in these areas:
  - Determining roller requirements
    - The construction of a test section prior to paving is recommended
      - Number and types of rollers to be used in each phase of compaction
      - Roller passes for each roller
      - Roller speed
      - Time available for compaction based on mat temperature


Using a nuclear device to determine pavement density



Calculate Paver Speed Based on Compaction

Input	Jim's Crew	Randy's Crew
Plant Production (tons per hour)	190	290
Unit Weight of Mix (lbs./ cu. ft)	150	150
Compacted Lift Thickness (in.)	2.0	1.5
Width of Pull (ft)	14	15
Paver Speed – Plant (ft/min) at 90% Eff.	20.0	38.2
Passes for Coverage		

- Step 1: Effective Roller Speed
- Assume effective roller speed of 225 ft./min (2.6 mph)
    - Select a roller speed that is with the range for impact spacing based on frequency
    - Also consider an efficiency factor (account for change in direction, water refills, etc)
- Need to account for roller passes to cover paving width (assume 84 in drum w/ 6 in. overlap)
- 14 (ft)/ (7- 0.5) ft = 2.15 Passes for Coverage
- 15 (ft)/ (7- 0.5) ft = 2.3 Passes for Coverage
- Need to Round Up → 3 passes for Coverage of Entire Paving Width

Calculate Paver Speed Based on Compaction

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Input	Jim's Crew	Randy's Crew
Plant Production (tons per hour)	190	290
Width of Pull (ft)	14	15
Paver Speed – Plant (ft/min) at 90% Eff.	20.0	38.2
Passes for Coverage	3	3
Passes Need for Density	3	4

- Based on the test strip, Jim's crew need 3 passes for density; Randy needs 4
- The compaction production rate is based on effective roller speed and total passes required

$$Total\ Passes = Passes\ for\ Coverage \times Passes\ for\ Density$$

$$Paver\ Speed = \frac{Effective\ Roller\ Speed\ \frac{ft}{min}}{Total\ Passes}$$

Jim's Crew

$$3 \times 3 = 9\ Total\ Passes$$

$$\frac{225\ \frac{ft}{min}}{9} = \mathbf{25}\ \frac{ft}{min}$$

Randy's Crew

$$3 \times 4 = 12\ Total\ Passes$$

$$12 + 1 = 13\ Total\ Passes$$

$$\frac{225\ \frac{ft}{min}}{13} = \mathbf{17.3}\ \frac{ft}{min}$$

Establishing Paver Speed

Input	Jim's Crew	Randy's Crew
Plant Production (tons per hour)	190	290
Width of Pull (ft)	14	15
Paver Speed – Plant (ft/min) at 90% Eff.	20.0	38.2
Passes for Coverage	3	3
Pass Need for Density	3	4
Paver Speed – Compaction (ft/min.)	25.0	17.3

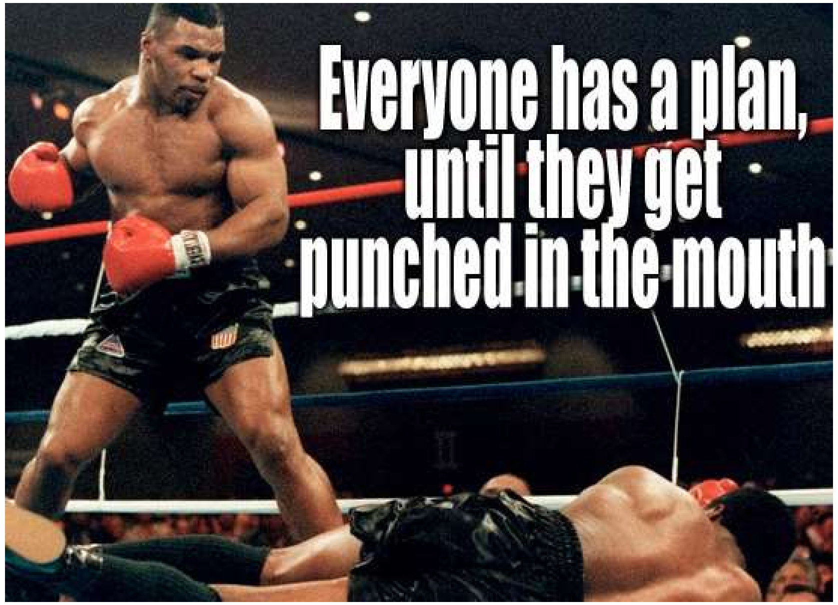
- Paver speed must be balanced with the rate of mixture delivery and the rate of densification by the rollers.
- The results that indicate the ***slower*** paver speed is what will control to create a proper balance in the paving operations.
- What speed should Jim's crew set for the paver?
- What speed should Randy's crew need to target?
- What other options exist for Randy's crew?

Options for Randy's Crew

- Option 1: Run paver at 17.3 ft/min
  - Slow everything else down
  - Plant and Trucking
- Option 2: add a breakdown roller
  - Extra roller provides added passes at same speed
  - Run paver at 37 – 38 ft./min
  - Minimize Paver Stops (Higher efficiency)
  - Adjust Plant Production Accordingly
- Option 3: Add second breakdown and another intermediate roller
- Option 4….

Final Thoughts

- Set your goals and develop a plan
- Remember: Everyone has a plan until:
  - Truck goes down
  - Rolling pattern needs adjusted
  - Plant is down
  - Cycle time increases
  - Any others?
- Communication and composure is critical!
- Remember the moving parts and balance
- Industry of Continuous Improvement



Dad, there's an app for that!

Caterpillar Paving Calculator 4+

Caterpillar Inc.

Designed for iPad

★★★★★ 2.0 • 25 Ratings

Free

Asphalt Pro 4+

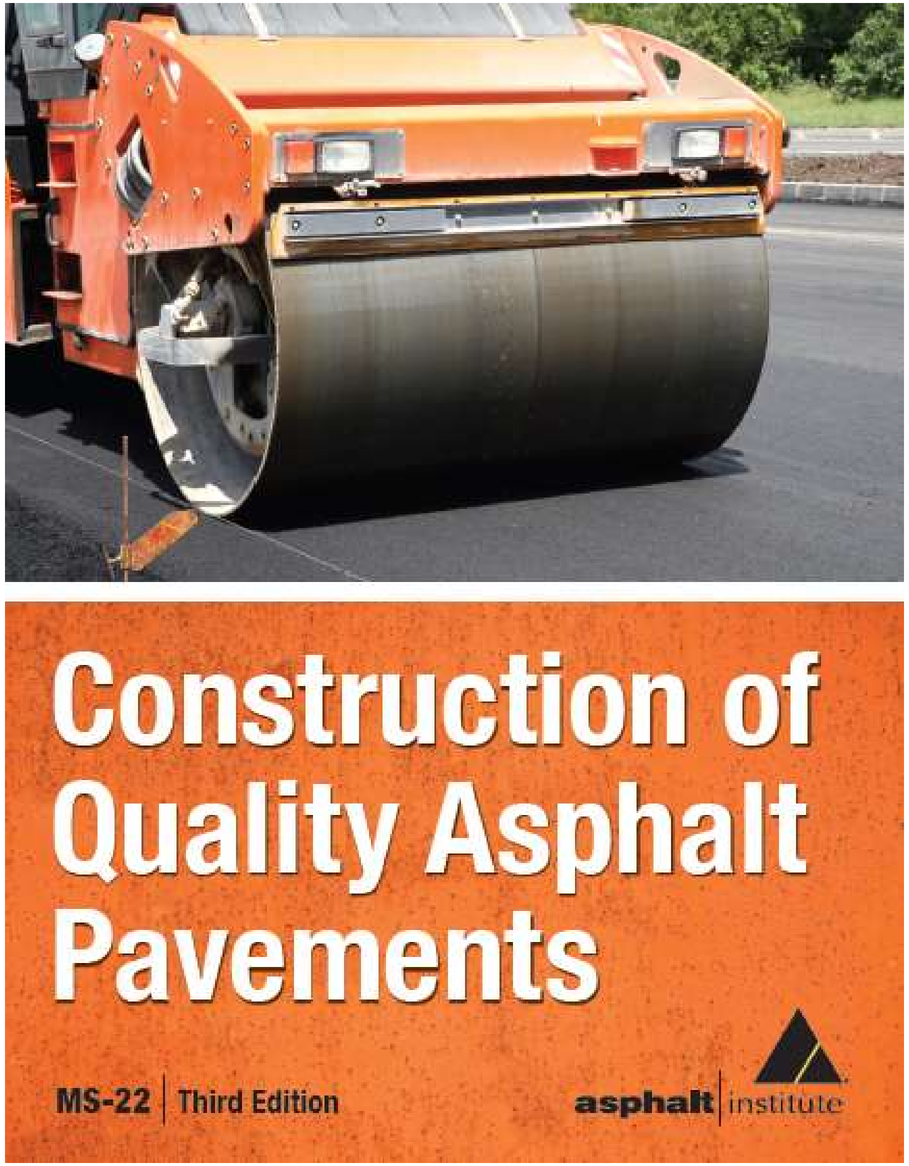
Post River Software

★★★★★ 5.0 • 6 Ratings

Free

- May only be available for iOS
- Build a spreadsheet

References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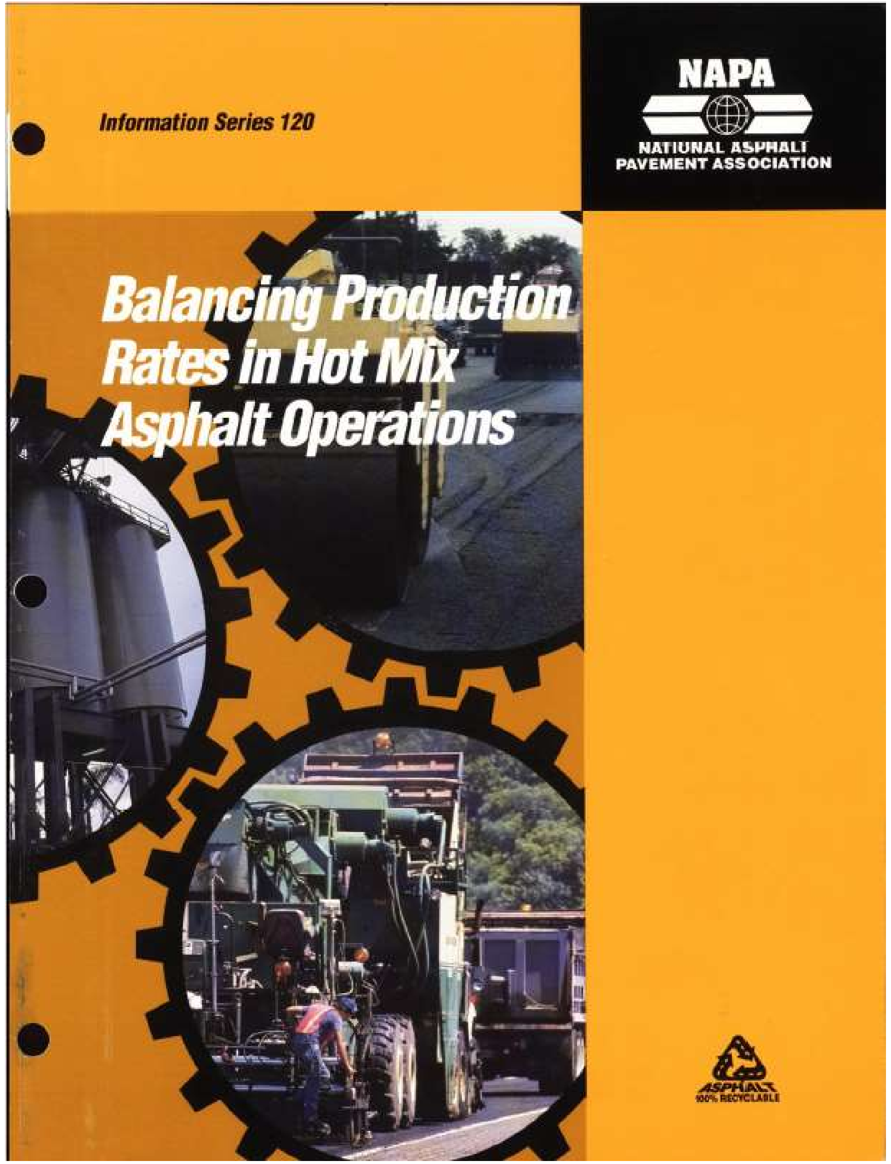
Information Series 120
NAPA
NATIONAL ASPHALT PAVEMENT ASSOCIATION
Balancing Production Rates in Hot Mix Asphalt Operations

Thank you! Question or Comments

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