Achieving Density

60th Annual Asphalt Paving Conference
March 29, 2016

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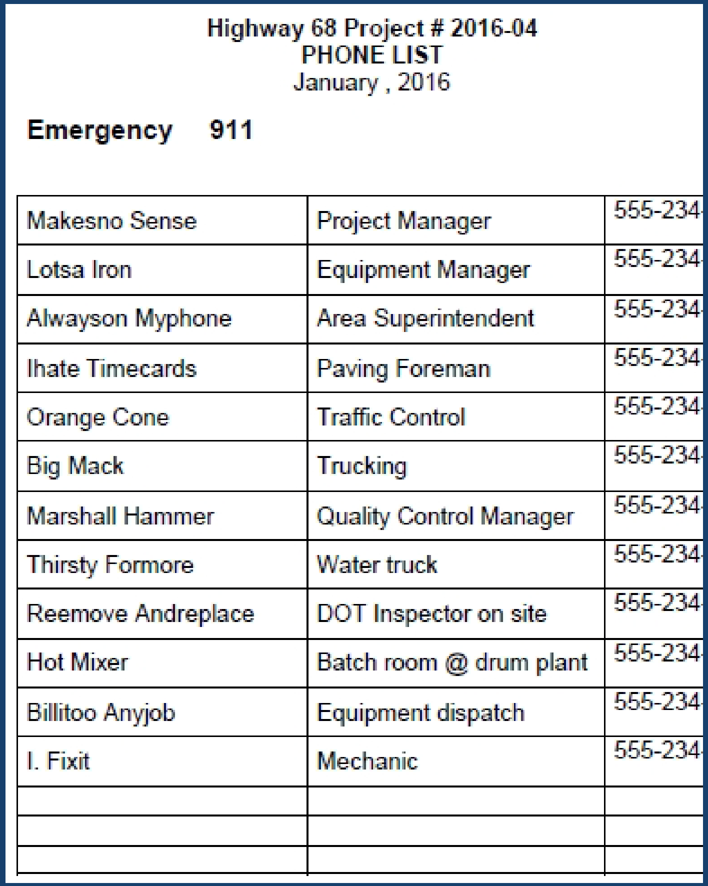
Why do we chase density instead of manage it?

- Lack of training
- Lack of good communication
- Not sure where to start

How do we Manage Density?

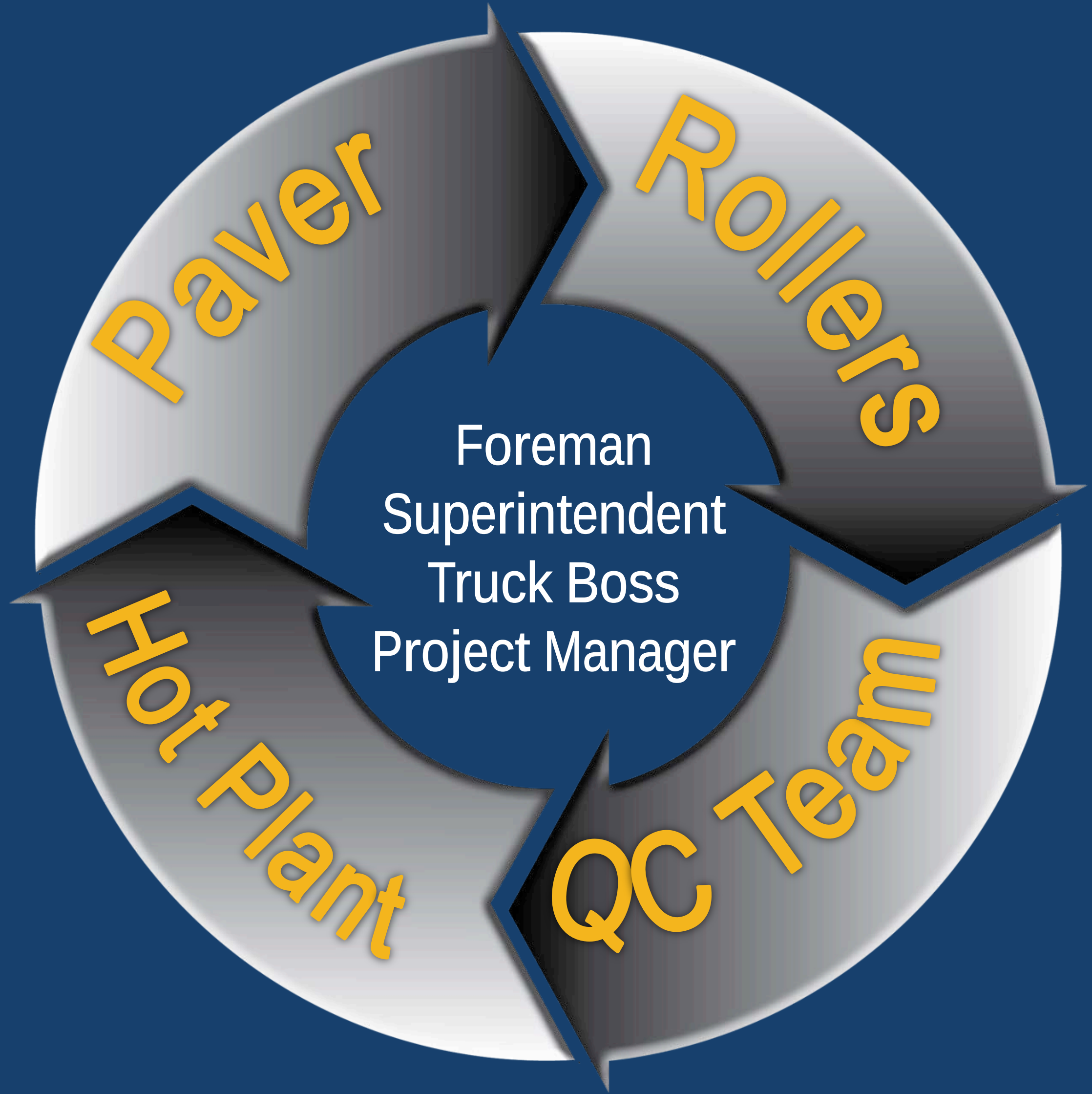
1. Know your lines of communication
2. Know your mix design properties, job specifications, targets
3. Establish an effective and efficient rolling pattern
4. Troubleshoot the root cause(s) when we’re not getting density
5. Plan for unplanned events
   - Plant breakdowns
   - Equipment breakdowns – paver, roller, trucking, MTV
   - Trucking problems

Lines of Communication


Highway 68 Project # 2016-04
PHONE LIST
January , 2016

Emergency 911

Makesno Sense	Project Manager	555-234
Lotsa Iron	Equipment Manager	555-234
Alwayson Myphone	Area Superintendent	555-234
Ihate Timecards	Paving Foreman	555-234
Orange Cone	Traffic Control	555-234
Big Mack	Trucking	555-234
Marshall Hammer	Quality Control Manager	555-234
Thirsty Formore	Water truck	555-234
Reemove Andreplace	DOT Inspector on site	555-234
Hot Mixer	Batch room @ drum plant	555-234
Billitoo Anyjob	Equipment dispatch	555-234
I. Fixit	Mechanic	555-234



Know mix properties

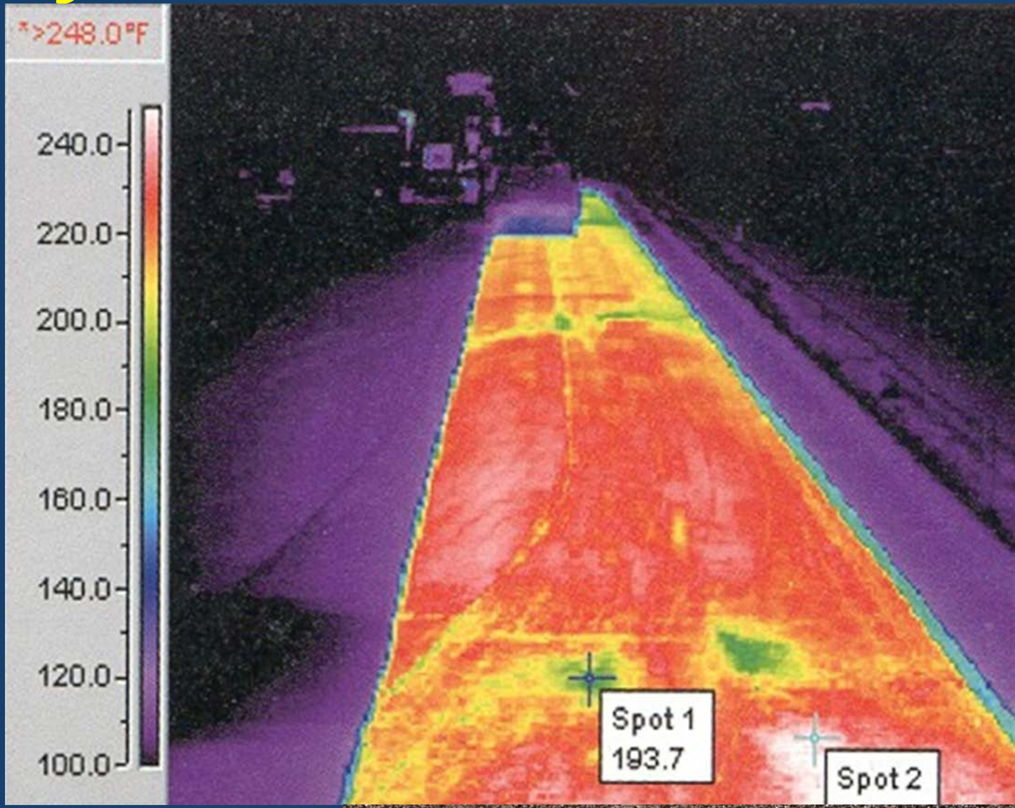
- Marshall mix or Superpave? Relative density or Rice (TMD)?
  - Mix selection – did we submit the best mix for the job based on experience?
- Have we had success or problems with this mix in the past?
  - Do we have experience with getting density with this mix?
  - Is it a harsh mix or a tender mix?
- What is the lab-compacted unit weight of the mix?

What does it take to get density?

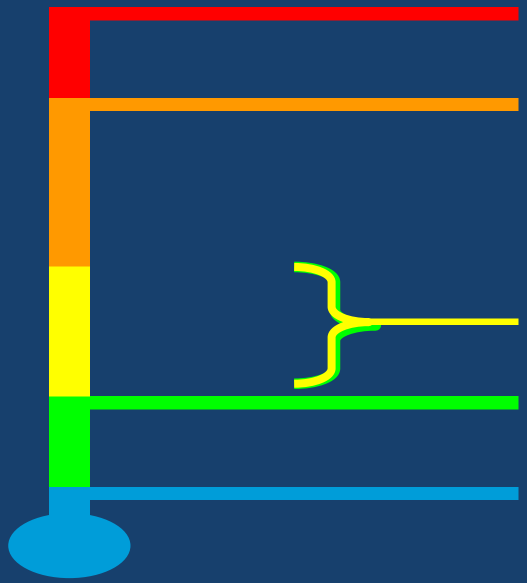
Temperature

Temperature

Temperature



Temperature is Critical



300 - 260 Breakdown rolling

260 - 220 Intermediate rolling

240 - 190 possible tender zone

220 - 160 Finish rolling

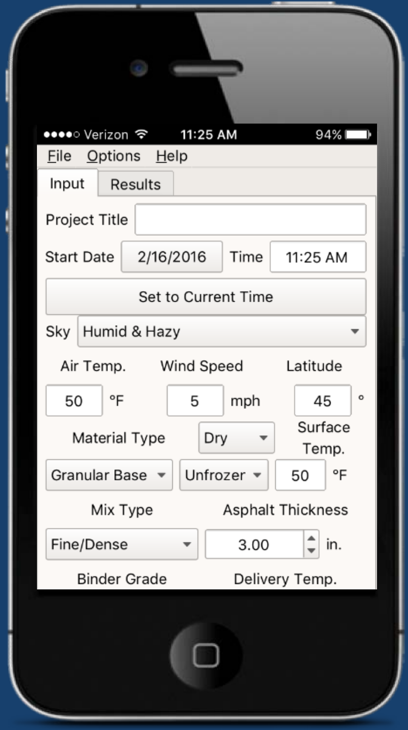
160 – Stop rolling

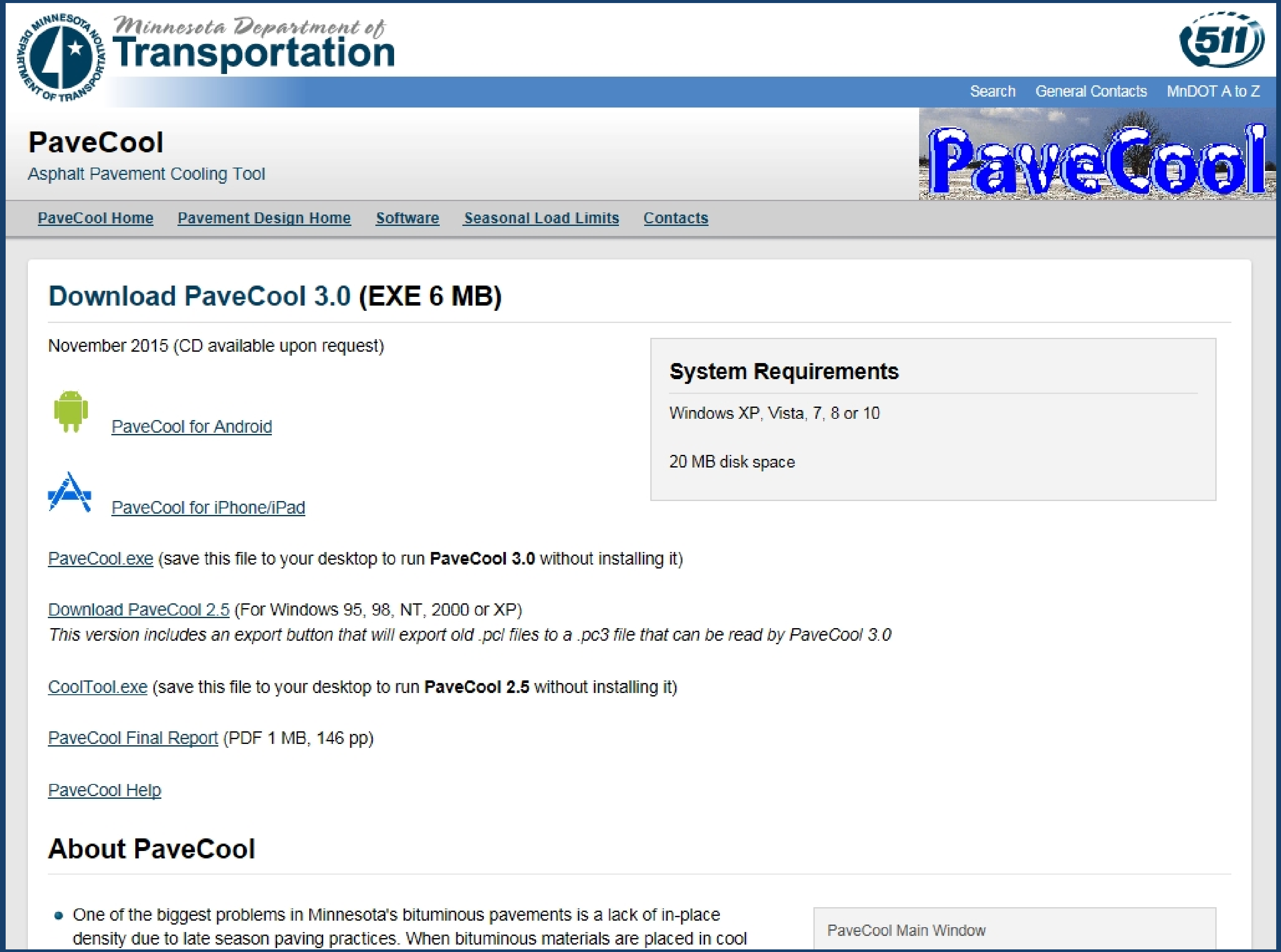
Keep steel drums off the mix!!!

Time Available for Compaction

Density must be achieved while the mix is still *HOT*

PaveCool or MultiCool tools:





What are the job specs?

- What is the minimum density requirement for mainline? 92-97%
- Joint density? 90%   Shoulders? n/a
- Smoothness? IRI improvement? 60% - one lift
- How will density be measured and accepted? Cores?

What is a good target density?

- Job spec is 92-97%
- Our job target for final density is 94%
- A good goal for breakdown compaction is 95% of our overall target density

$0.95 \times 94\% = 89\%$

Establish an effective rolling pattern

1. Based production and density
2. Equipment Selection

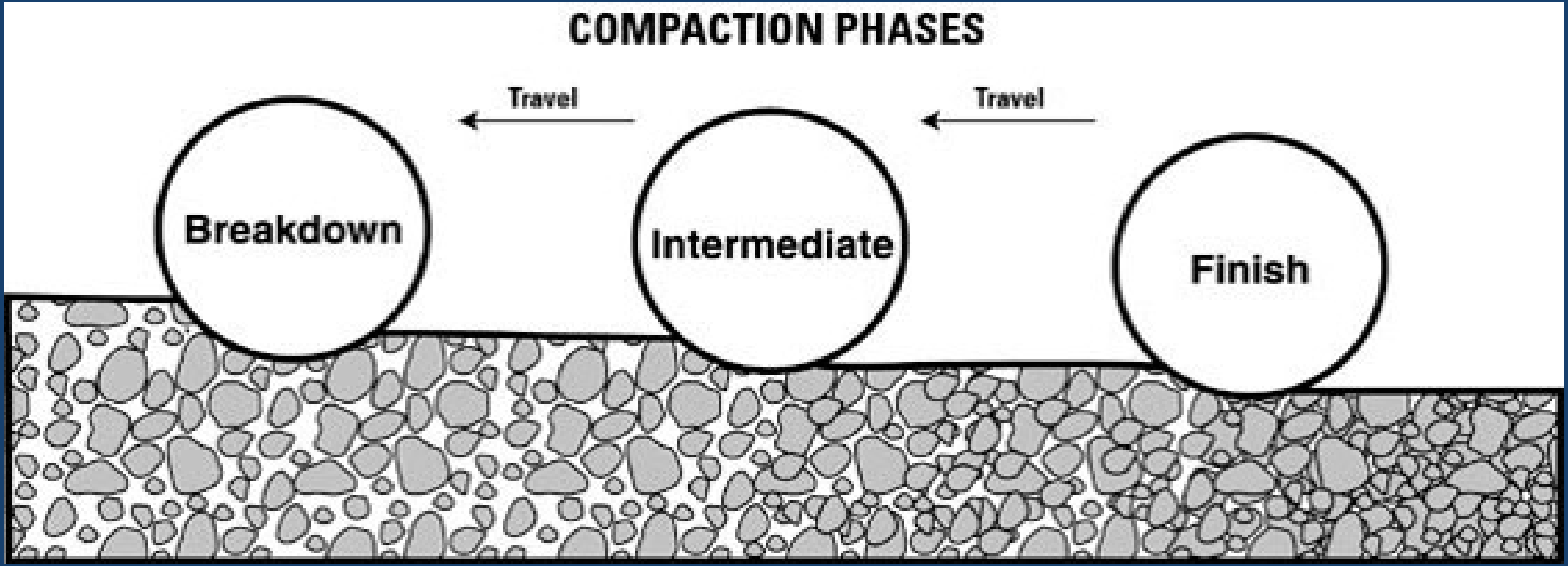
   ↕ **Decision Point**

3. Balance paver & roller speed

   ↕ **Decision Point**

4. Test Strip
5. Verify during production

3 Phases of Roller Compaction



What is a rolling pattern?

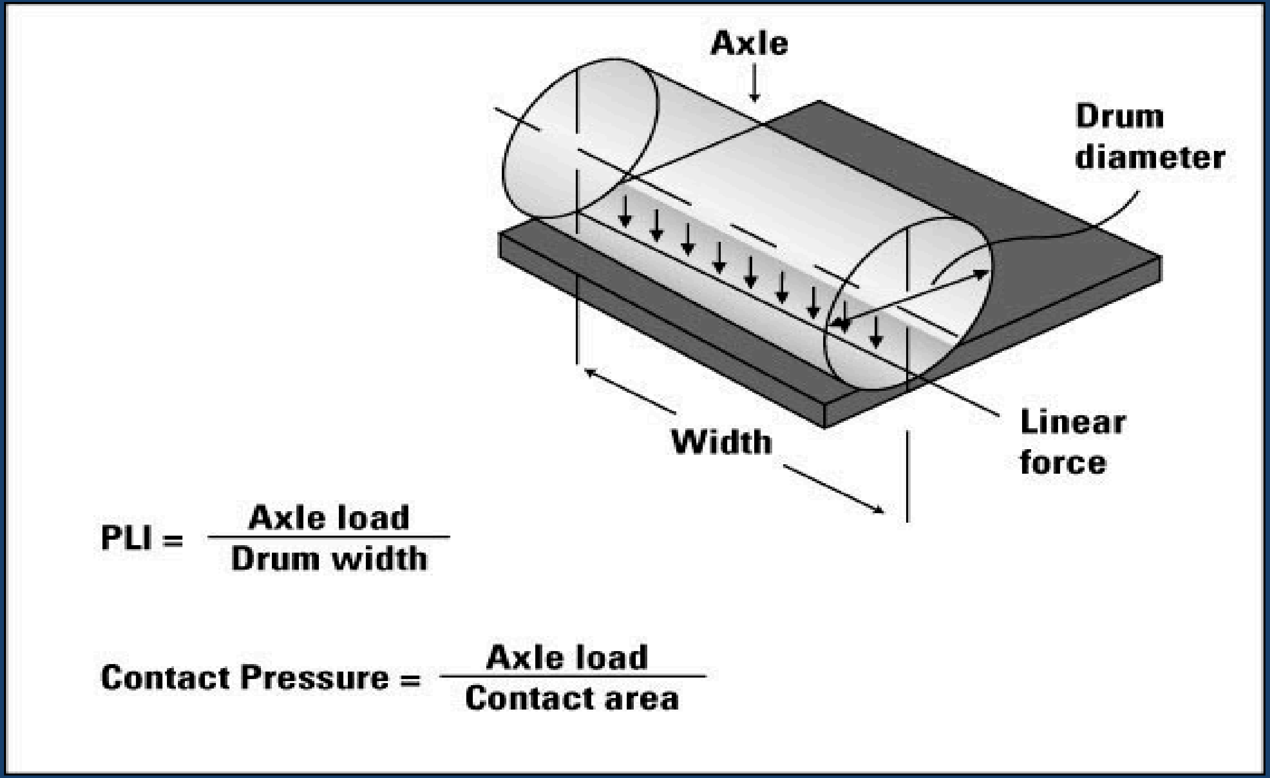
	Breakdown	Intermediate	Finish
%TMD	90-92%	92-94%	94+ %
			
Temp	300-260˚F	260-200˚F	200-160˚F
Coverage	3	2	2 (1 vibe, 1 static)
Settings	High A, Low F	90 psi	Low A, static
	↔ 126 feet	↔ 200 feet	↔ 200 feet

Review: Types of rollers

- Static steel drum
- Oscillation
- Vibratory steel drum
- Vibratory pneumatic
- Pneumatic
- Combination

Static Steel Drum

- PLI
- Smaller contact area = higher pressure



Oscillation

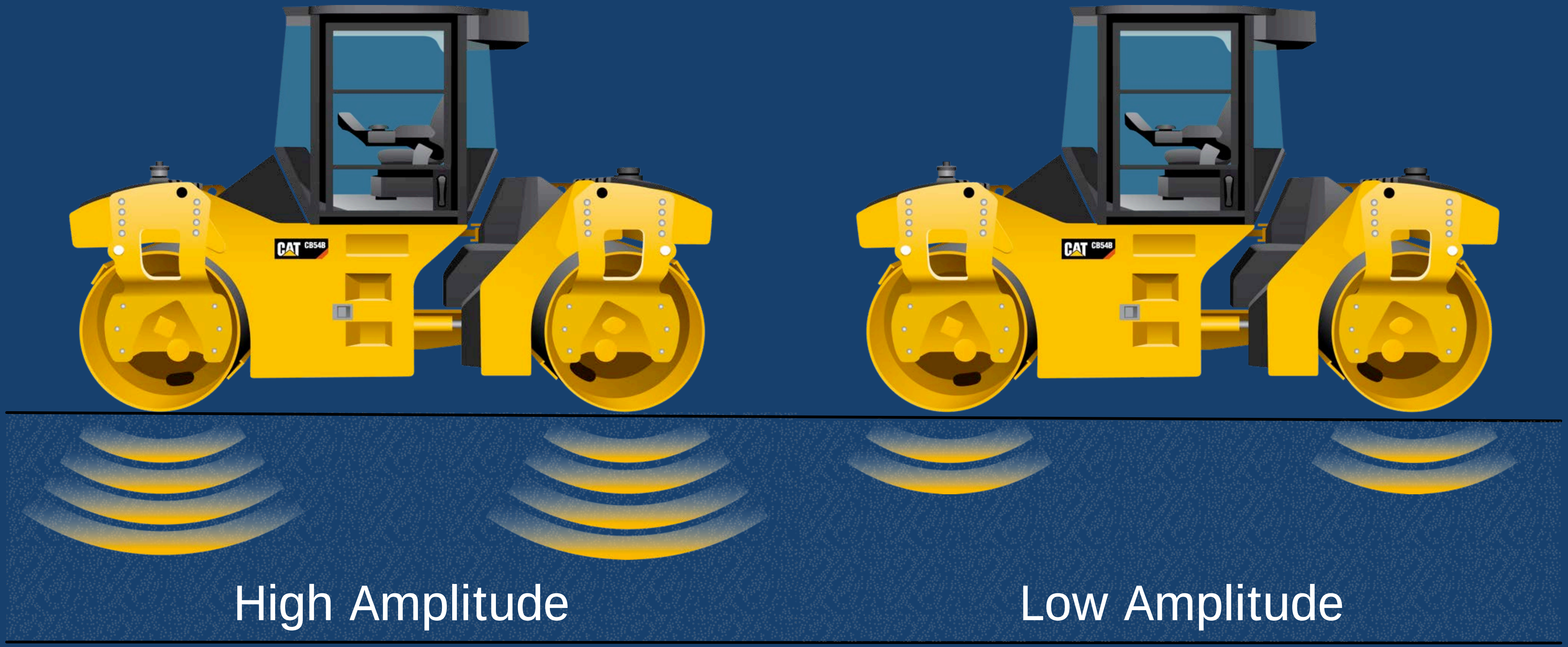
- Back and forth drum movement
- Maintains contact with surface
- Less aggressive compaction

Vibratory Steel Drum

- Breakdown, intermediate and finish rolling
- Settings for amplitude and frequency
- Static mode for finish rolling

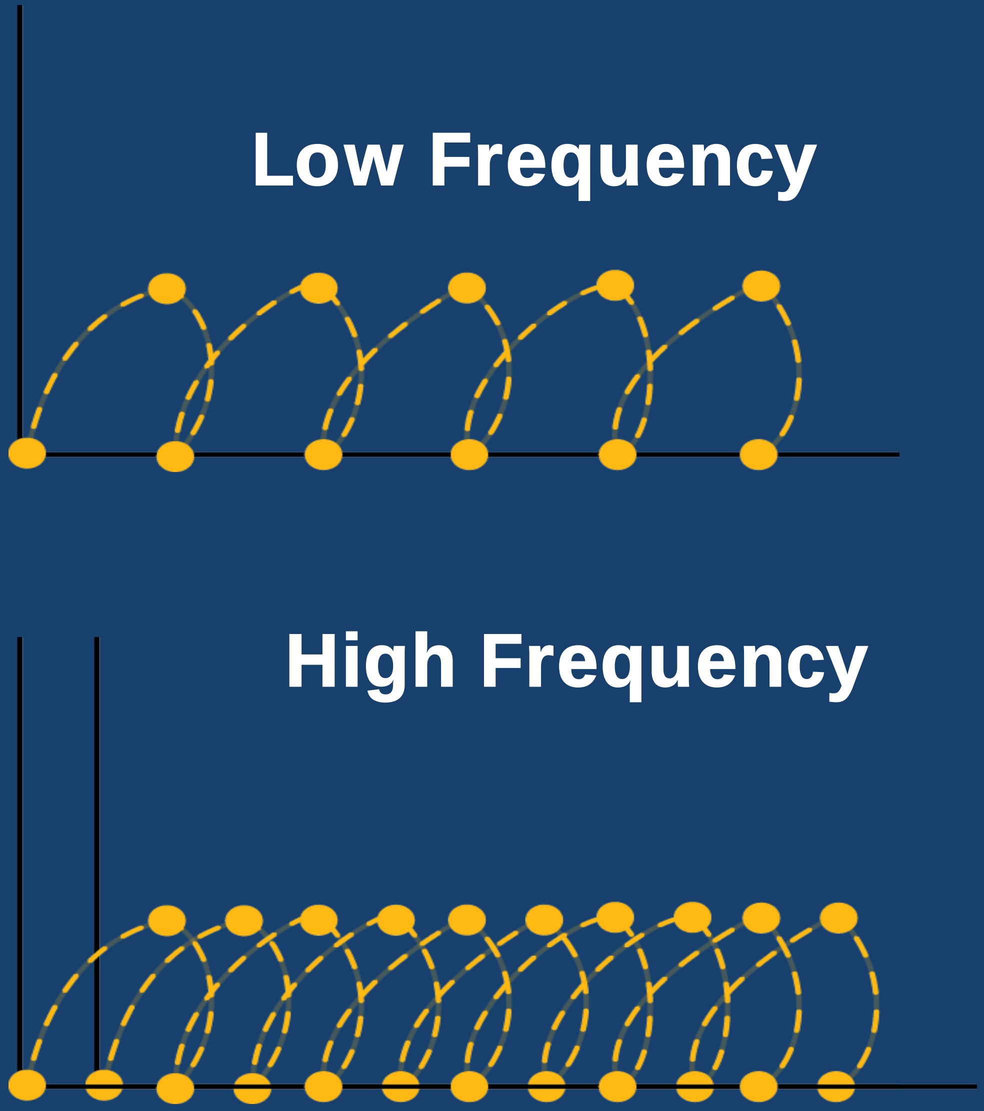
Build density from the top down

Amplitude = compactive effort



Frequency = speed

Speed is constant



Frequency & Roller Speed & Impacts per foot

10 to 14

Calculating impacts per foot (IPF)

$$\text{Impacts per foot} = \frac{\text{Frequency (vpm)}}{\text{Actual roller speed (fpm)}}$$

$$\text{IPF} = \frac{\text{3,000 vpm}}{\text{300 fpm}} = \text{10 impacts per foot}$$

Re-arrange the equation to solve for speed

$$\text{Roller speed (fpm)} = \frac{\text{Frequency (vpm)}}{\text{Impacts per foot}}$$

$$\text{Speed} = \frac{3{,}000 \text{ vpm}}{10 \text{ ipf}} = 300 \text{ feet per minute}$$

Connecting Amplitude and Frequency

Higher Amplitudes associated with Lower Frequencies

High Amplitude (<0.80 mm) = Low Frequency (>2800 vpm)

Medium Amplitude (0.5 mm – 0.8 mm) = Medium Frequency (2800-3400 vpm)

Low Amplitude (0.2 mm – 0.5 mm) = High Frequency (3400 vpm)

Balanced Roller Vibration

When compaction is balanced, most of the vibratory force is transmitted into the mat.

- Optimum compaction occurs when all forces are accepted by the asphalt layer
- Balance between forces of compaction and the asphalt layer

Balanced Roller Vibration

Some compaction energy will be transferred back to the machine if compaction is not balanced.

- Forces out of balance create drum bounce
- Inefficient operation
- Solve bouncing:
  - change speed
  - lower amplitude
  - higher frequency
  - one drum static
  - both drums static

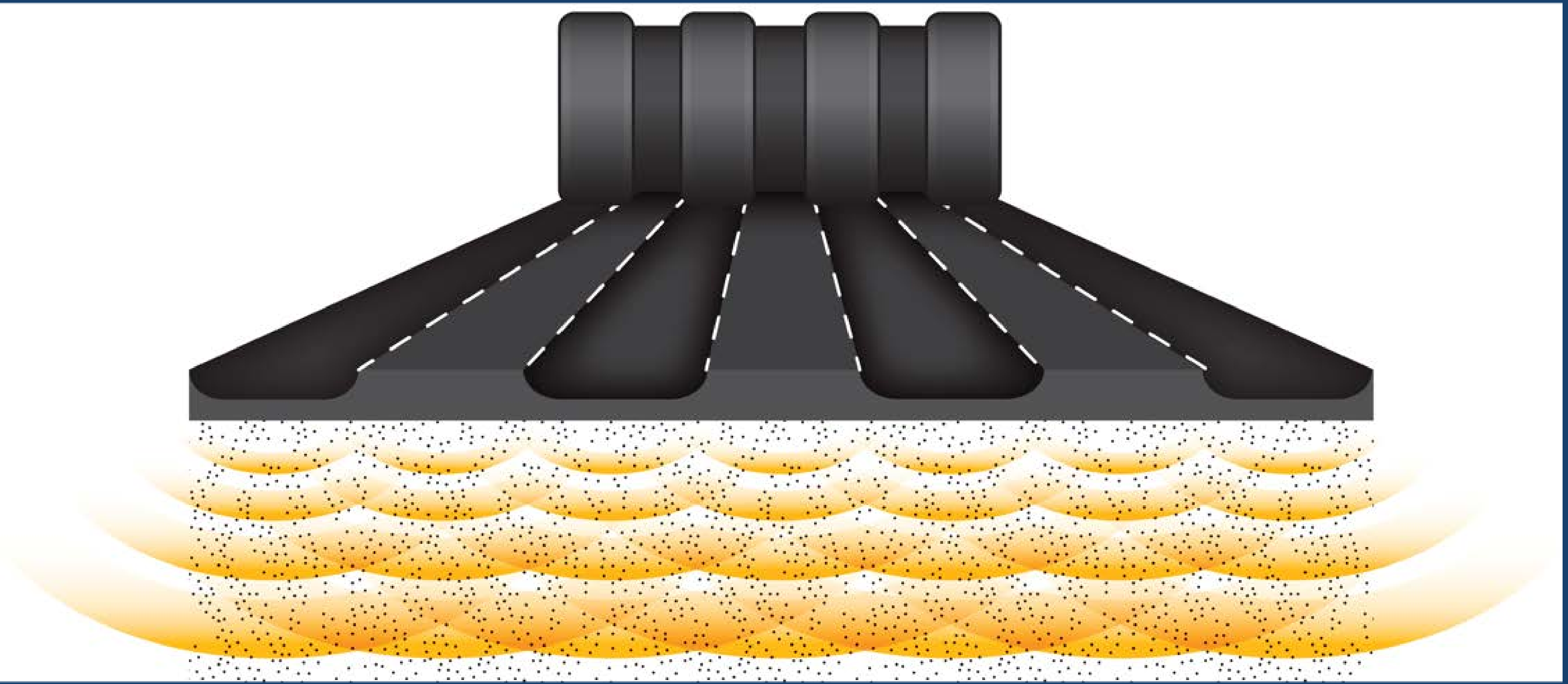
Pneumatic Rollers

- Most commonly used for intermediate rolling
- Knead the mix

- Close up surface voids and tension cracks
- Efficient building density

Build density from the bottom up

Manipulation



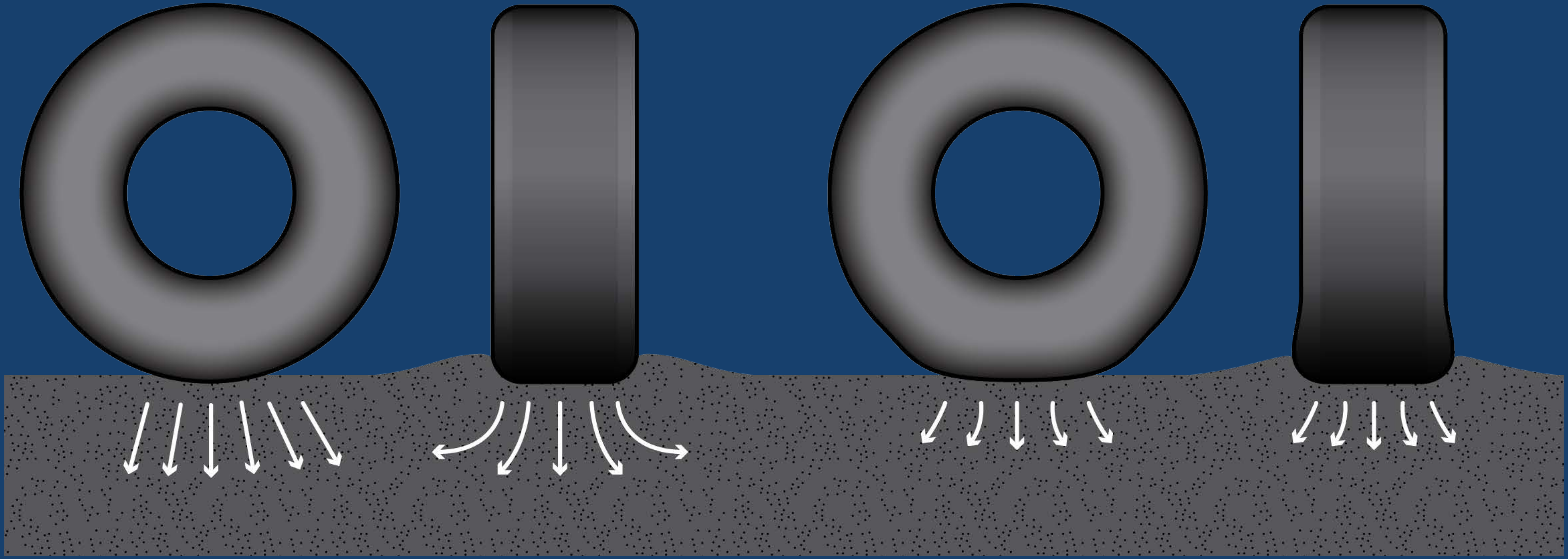
Overlapping tires develop overlapping areas of contact pressure, creating manipulation forces.

- Manipulation occurs due to overlapping tires
- Some forces move sideways
- Tightens surface texture

Pneumatic tire rollers

- Adjust tire pressures based on mat thickness
- Ballast weight is usually sand, water or steel plates

Adjusting Tire Pressures



Higher Pressure

Lower Pressure

Keep Tire Pressures Equal

- Keep tires hot
- Within 30°F of pavement
- Tire pressures equal
- Warm up before paving

Vibratory pneumatic tire roller

Adjustable amplitude settings instead of ballast

Combination

Vibratory steel drum & pneumatic tires

Establish an effective rolling pattern

1. Based production and density
2. Equipment Selection

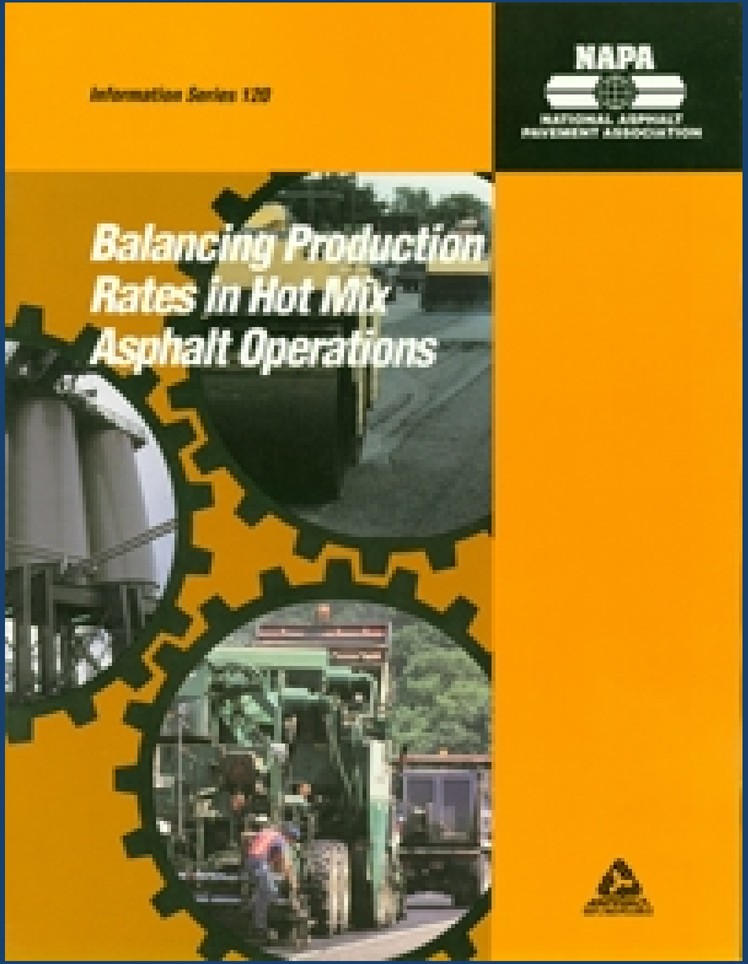
   Decision Point

3. Balance paver & roller speed

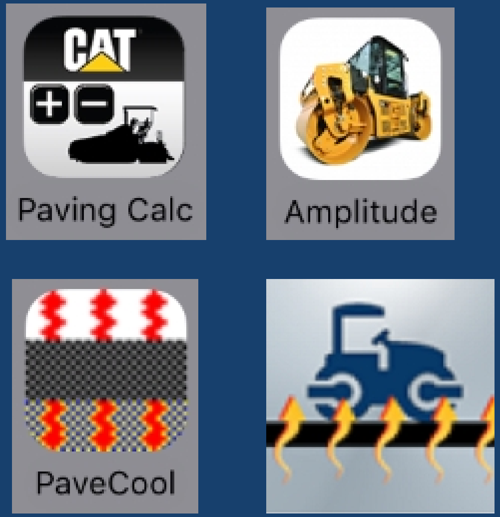
   Decision Point

4. Test Strip
5. Verify during production

Planning



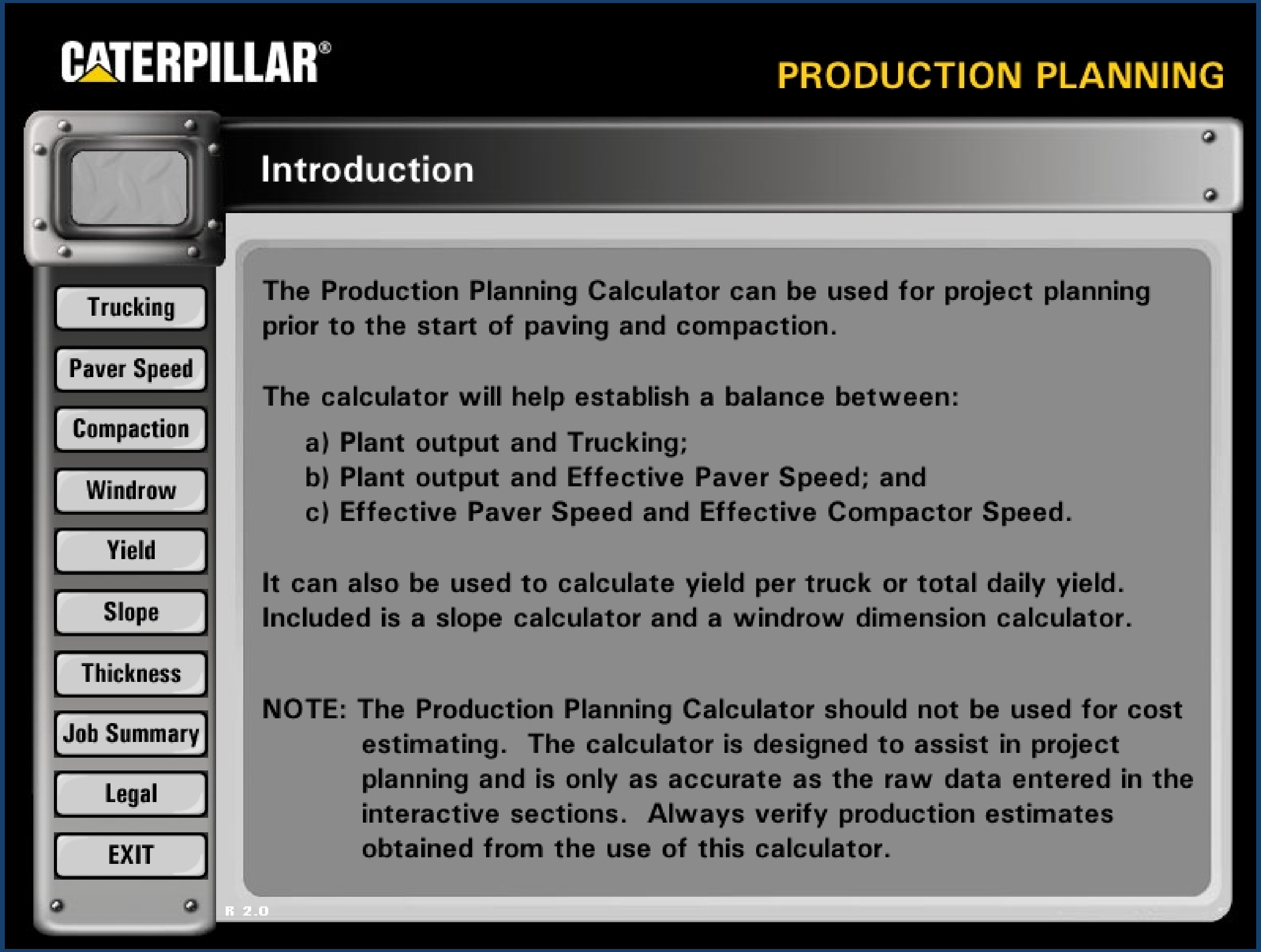
- Pre- paving planning
  - Tons per day
  - Paver speed
  - Roller speed
  - Target densities, IRI
- Tools available
  - NAPA IS-120
  - Paving Production Calculator App
  - Amplitude Selection App
  - PaveCool App



Balancing Paver Speed & Roller Speed

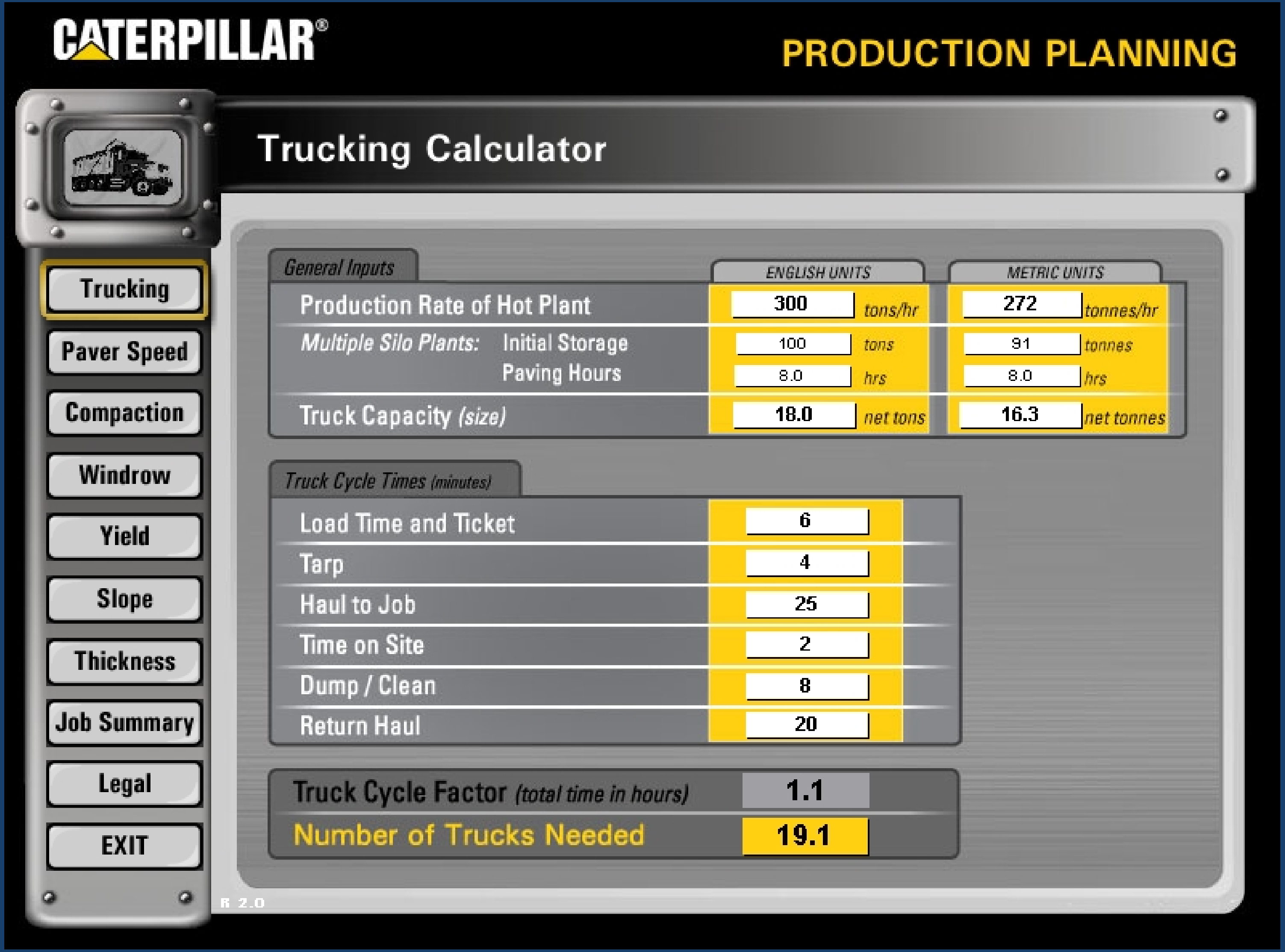
- Expected 2,500 tons/day
- 8-hr paving window
- End dumping (18-ton)
- 12-ft paving lane – highway
  - Unconfined edges on first lane
- 2-inch overlay
- 12.5mm polymer-modified mix
- Given 3 rollers
  - 79” steel vibratory x 2
  - 82” pneumatic

Paver speed to place 2,500 tons/day



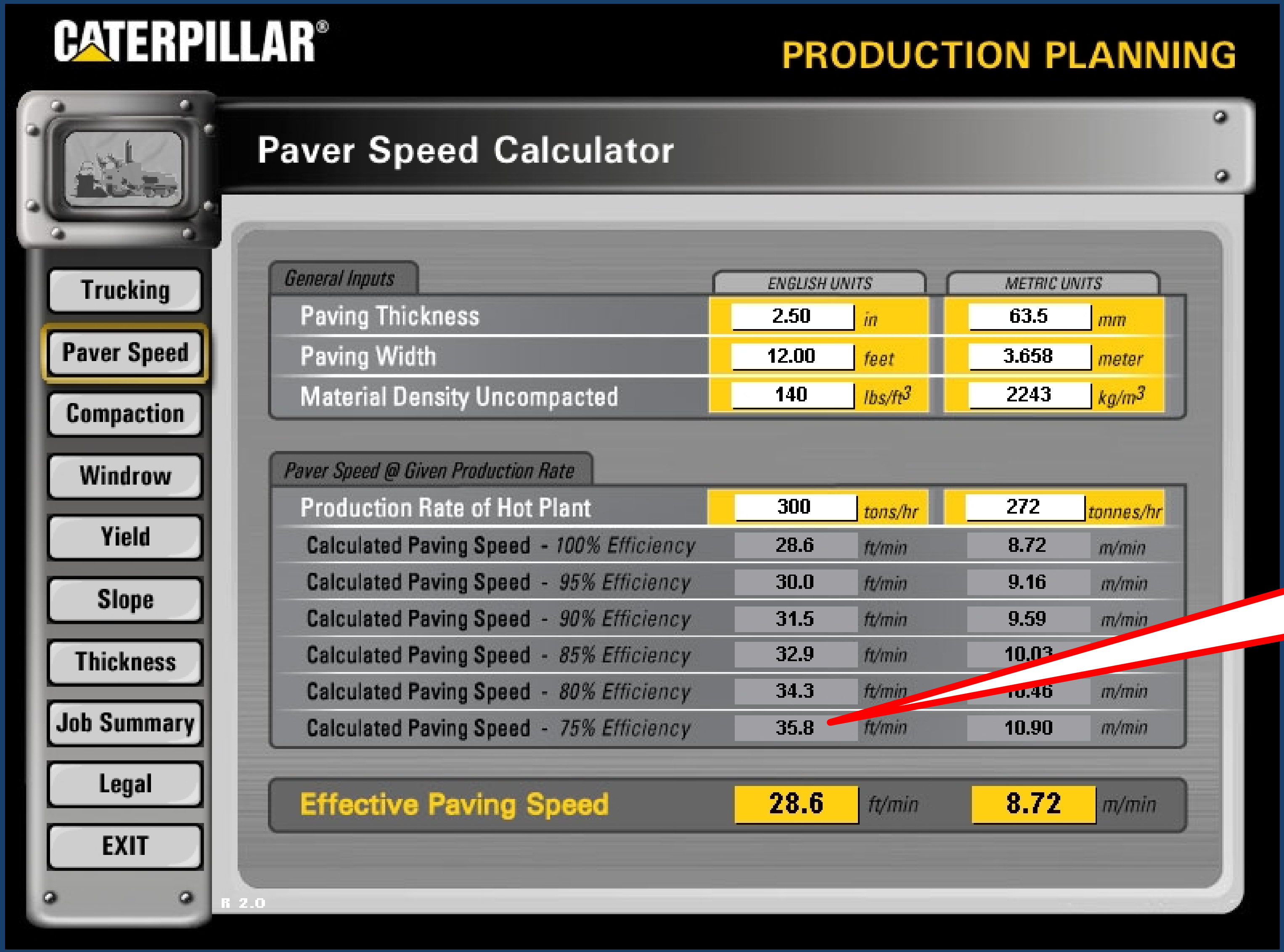
Use Paving Production Calculator <u>or</u> calculate by hand

Paver speed to place 2,500 tons/day



- Total daily tonnage
- Paving window
- Truck capacity
- Cycle time

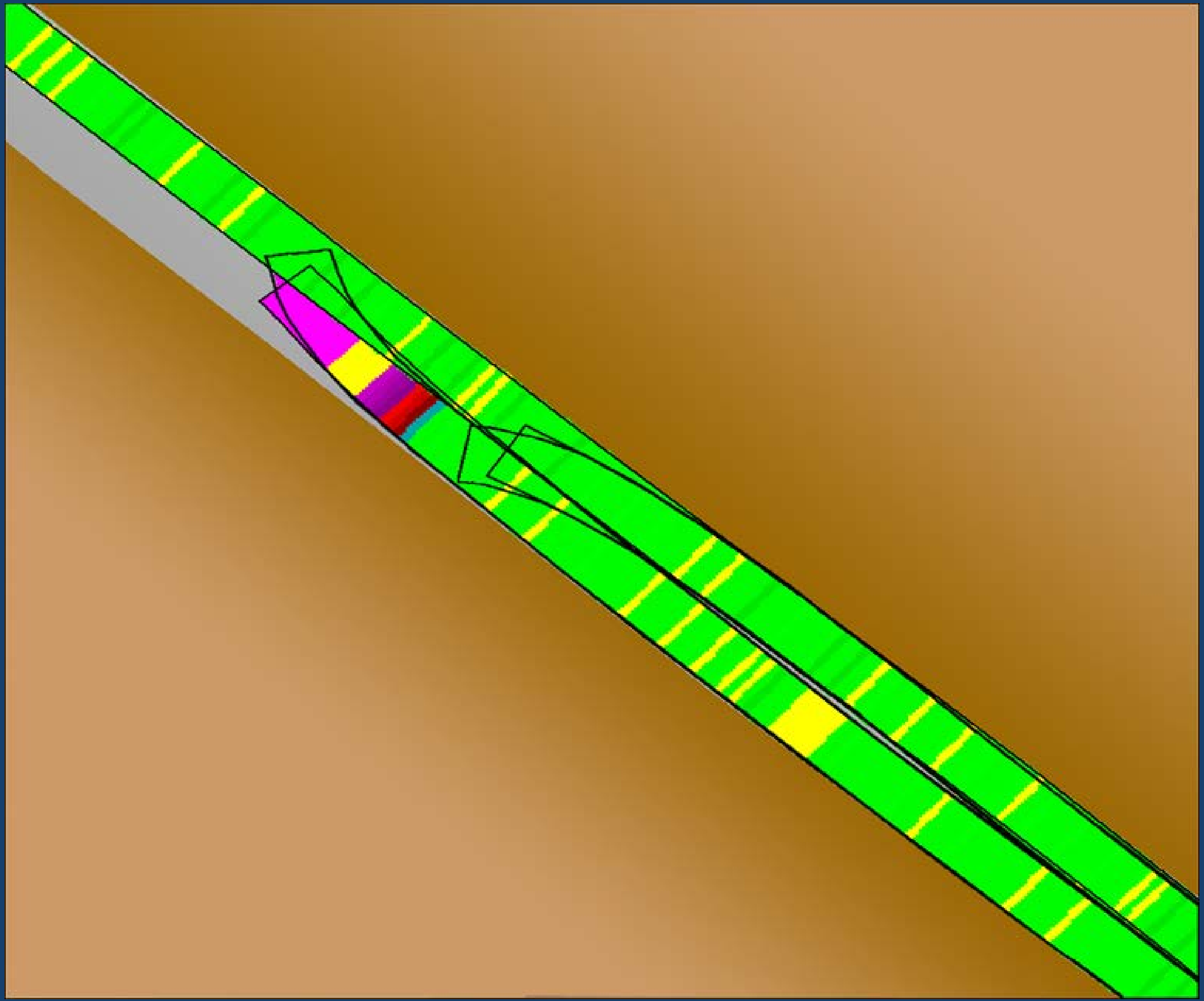
Paver speed using end dumps



- Lift thickness
- Width
- Loose density

36 fpm

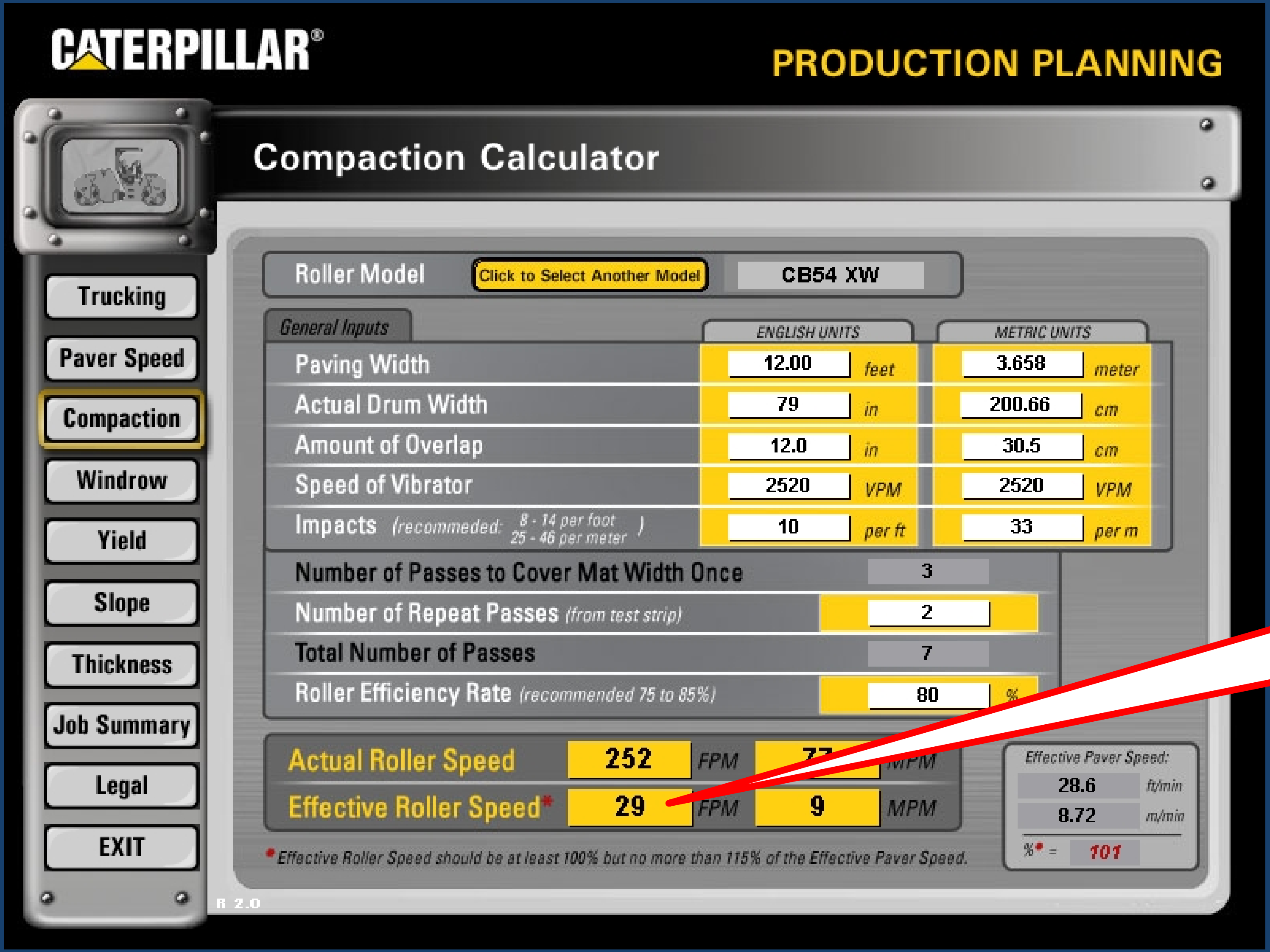
Determine Number of Passes Required



- Experience
- Test Strip
- Amplitude Selection App
  - Inputs to App
  - Confirm with Test Strip

- CB54XW 79” drum
  - Low Amp = 0.012”
  - High Frequency = 3,800 vpm
  - High Amp = 0.032”
  - Low Frequency = 2,520 vpm

Roller Speed: High Amplitude/Low Frequency



- Impacts per foot
- Drum width
- Frequency = 2,520
- 2 Passes (test strip)

29 fpm

29 fpm < 36 fpm

Roller speed calculated by hand

$$\text{Roller speed} = \frac{\text{Frequency (vpm)}}{\text{Impacts per foot}}$$

$$\text{Roller Speed} = \frac{\text{2,520 vpm}}{\text{10 ipf}} = \mathbf{252}\ \text{fpm}$$

252 ÷ 88 = 2.8 mph

Calculated Roller Speed

$$\text{Actual roller speed} = \frac{252 \text{ fpm}}{7 \text{ passes}}$$

Actual roller speed = 36 fpm

Effective Roller speed = 36 fpm x 0.80 = 29 fpm

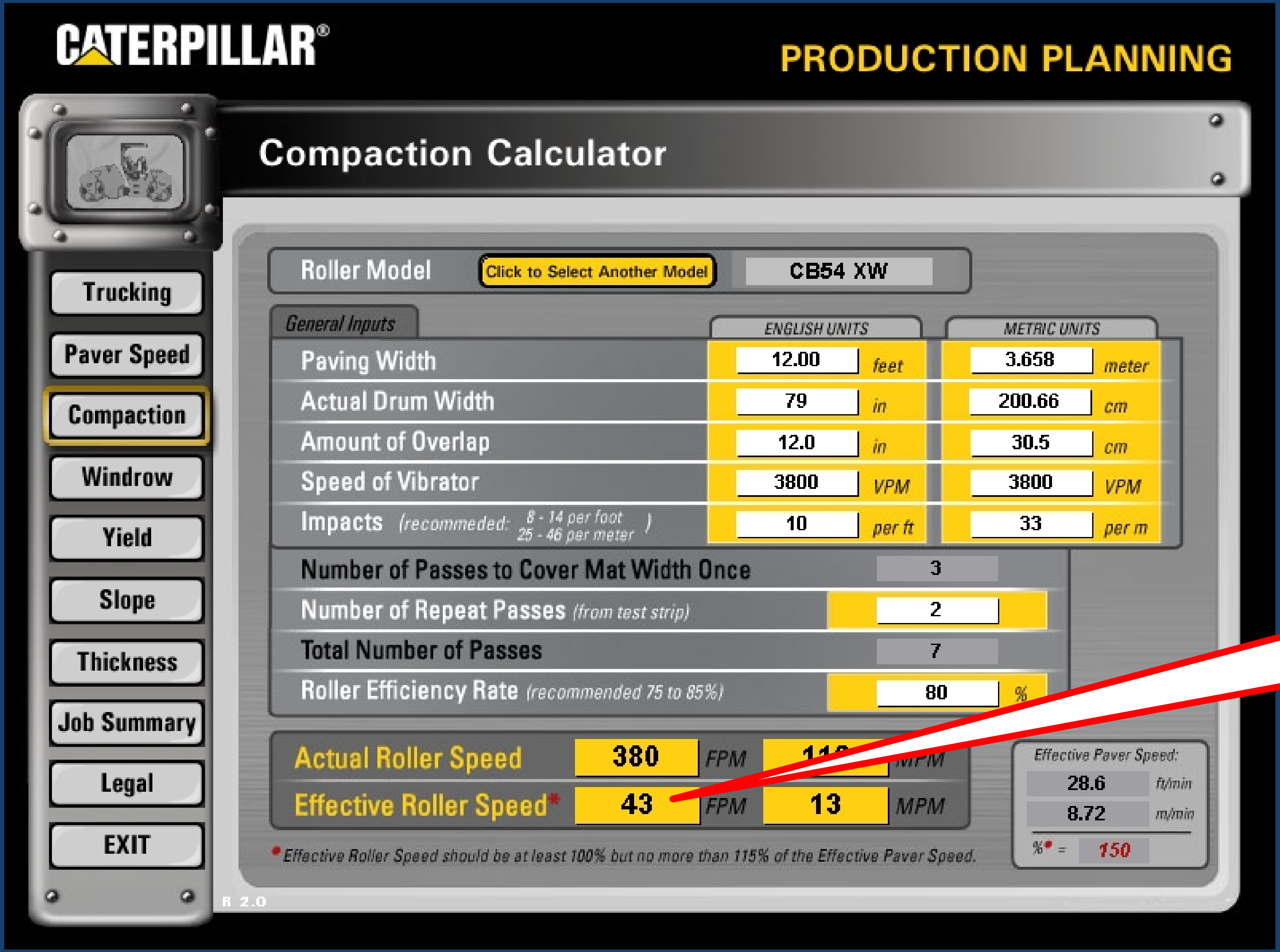
Paver can not exceed **29** fpm

Need 36 fpm to get 2,500 tons per day!!

What can I do now!?!?

- Slow down paver to 29 fpm
- Set roller at a higher frequency
- Get an 84" wide roller
- Get an additional 79" roller

Roller Speed: Low Amplitude/High Frequency

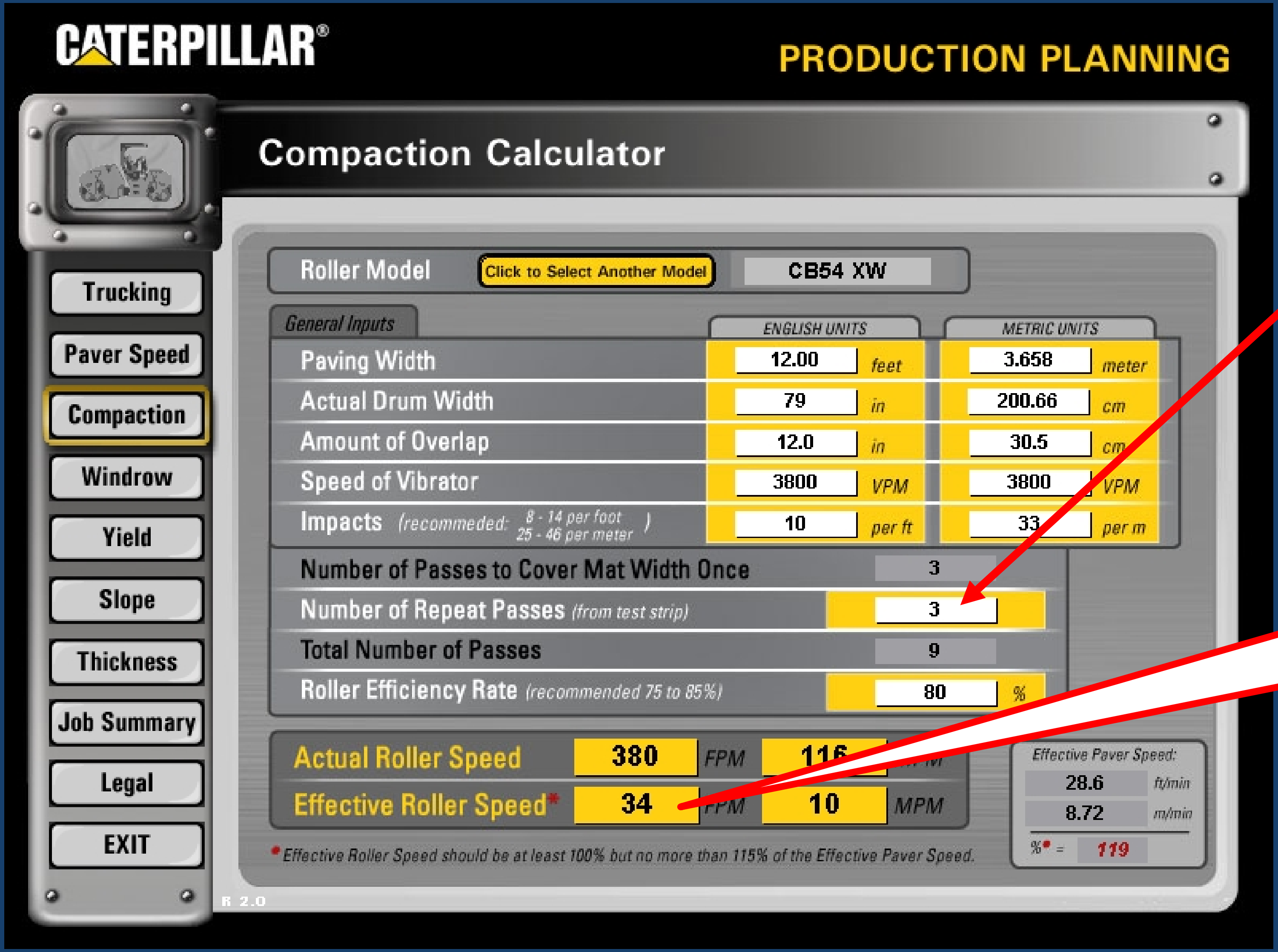


- Frequency = 3,800 vpm
- Low amplitude
- Requires 3 passes (test)

43 fpm

43 fpm > 36 fpm

Roller speed at higher frequency



- Higher frequency ≈ lower amplitude which requires an additional pass to get same density

34 fpm < 36 fpm

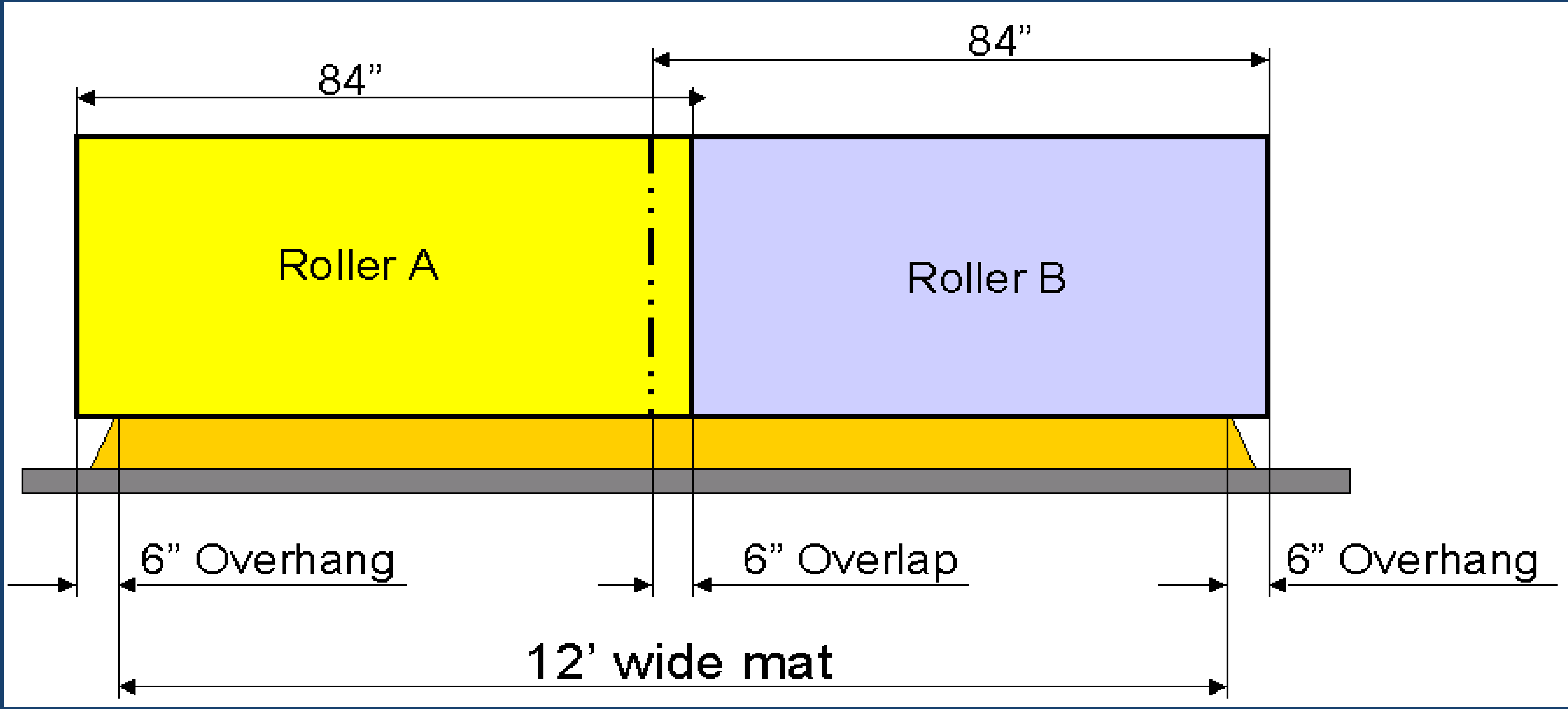
Roller selection – do we have a choice?

- Mix of roller types
- Drum width, weight, amplitude, frequency
- Number of rollers

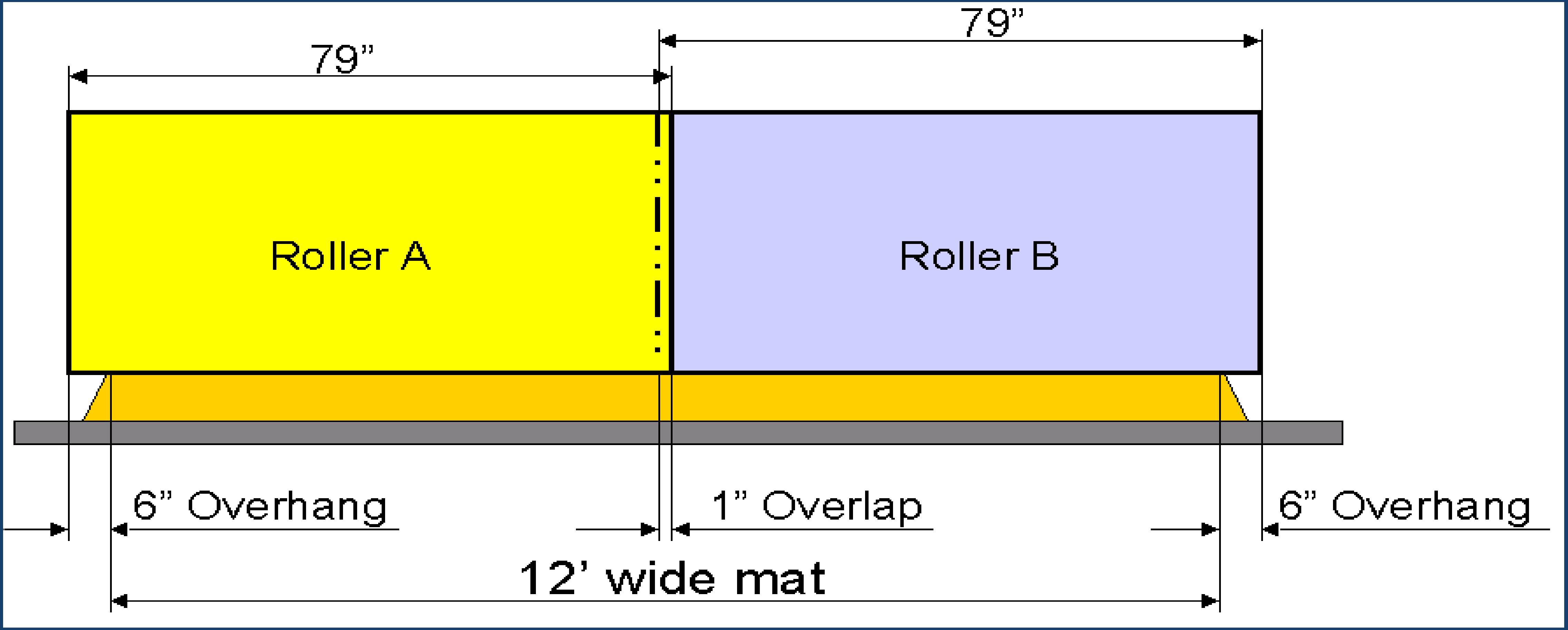
Roller drum width considerations

- Select the optimum drum width for the job to get coverage before the mix cools
- Fewer passes = higher production & profit
- Narrower drums generally have higher PLI
- Need to consider production vs. ability to get density

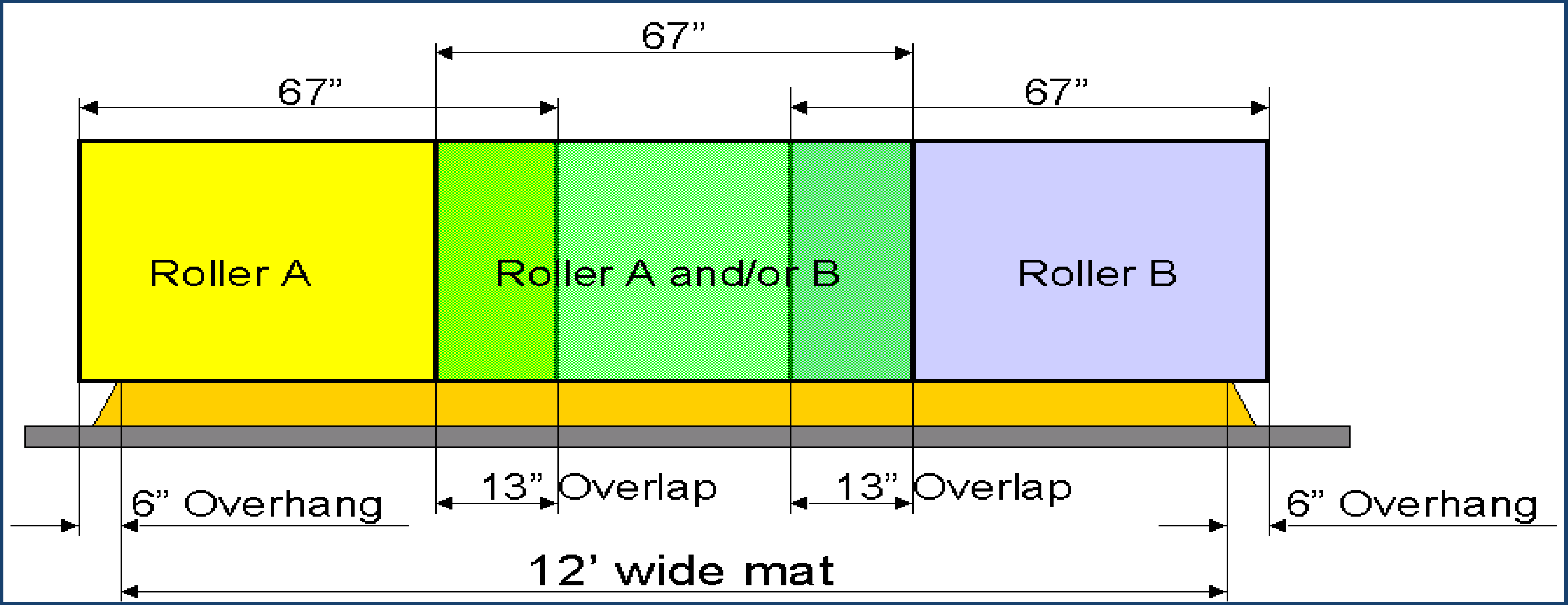
12-foot wide lane: 84” x 2 passes



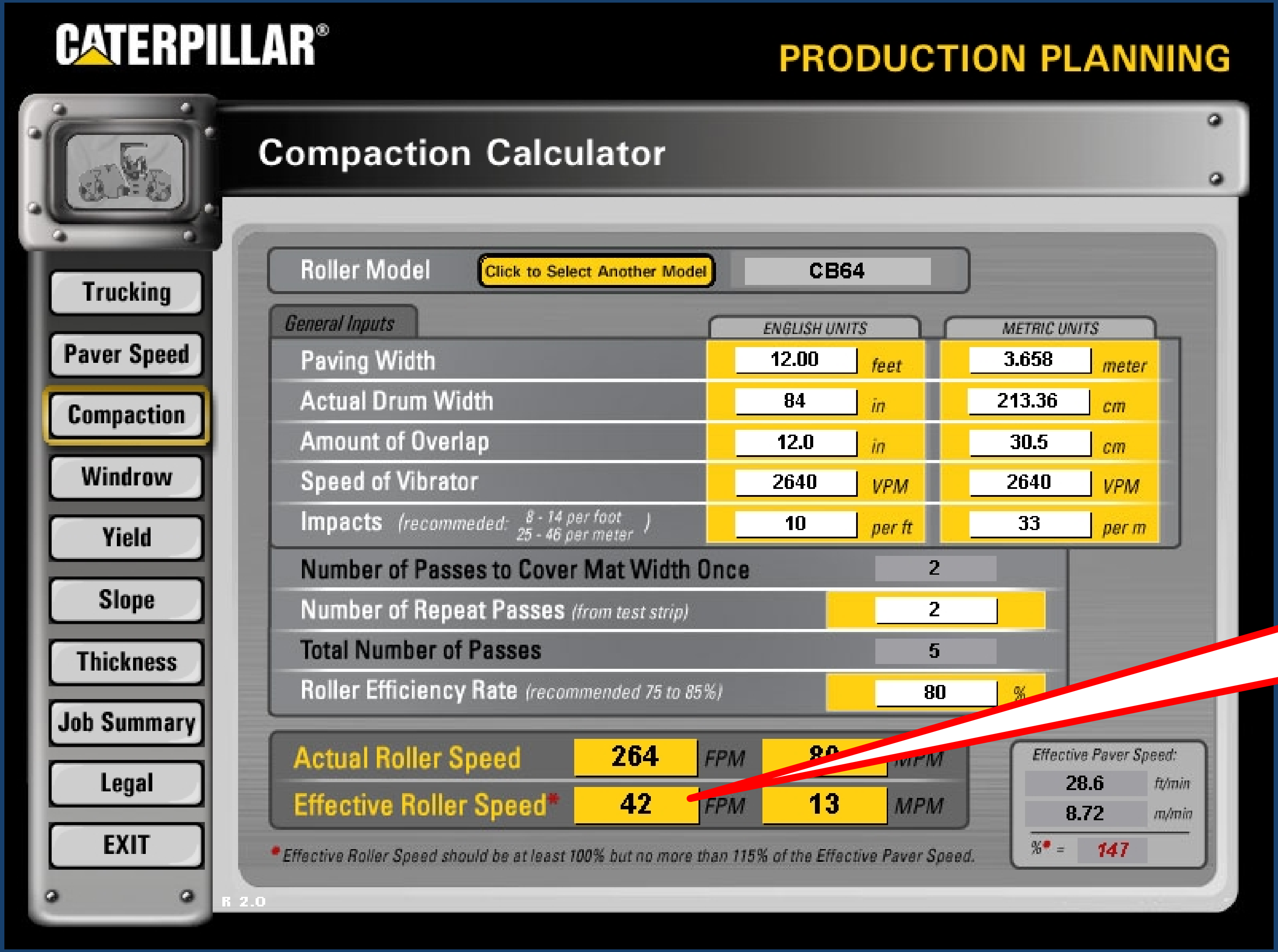
12-foot wide lane: 79” x 2 passes



12-foot lane: 67” x 3 passes



Roller speed (breakdown 84”)



- Wider drum
- Lower frequency
- Higher amplitude
- Passes (test strip)

42 fpm

42 fpm > 36 fpm

Test Strip

1. Based production and density

2. Equipment Selection

   ↕ **Decision Point**

3. Balance paver & roller speed

   ↕ **Decision Point**

4. Test Strip

5. Verify during production

Test Strip

- Simulate job site conditions – don't fake it
- Have a post Test Strip meeting

Rolling patterns based on the situation

- Tender mixes
  - Steel stay off!
- Stiff or harsh mixes
  - Pneumatic breakdown
  - Echelon rolling
- Longitudinal joint
  - Confined vs. unconfined edge

Number of roller passes

- Determine target density values for each roller
  - 95% of target for breakdown roller is a good target
- Determine number of passes with QC team
  - Take density readings after each roller pass
- Trial and error to ‘fine tune’ roller pattern

Number of roller passes

		Breakdown	Intermediate	Finish
	→	12-ton DDV	14-ton tire	8-ton DDV
Settings		High A, Low F		1 vibe, low A, high F, 1 static
1st Pass	Temp	275	250	200
	Density	88%	92%	94% (vibe)
2nd Pass	Temp	260	245	193
	Density	90%	93%	94% (static)
3rd Pass	Temp	252	230	
	Density	91%	93.5%	
4th Pass	Temp			
	Density			

How far back ?? Breakdown

Length of the Roller Pass

$$\text{Speed} = \frac{\textbf{Distance}}{\text{Time}}$$

Roller speed based on frequency (ipf)

Time available for compaction (PaveCool)

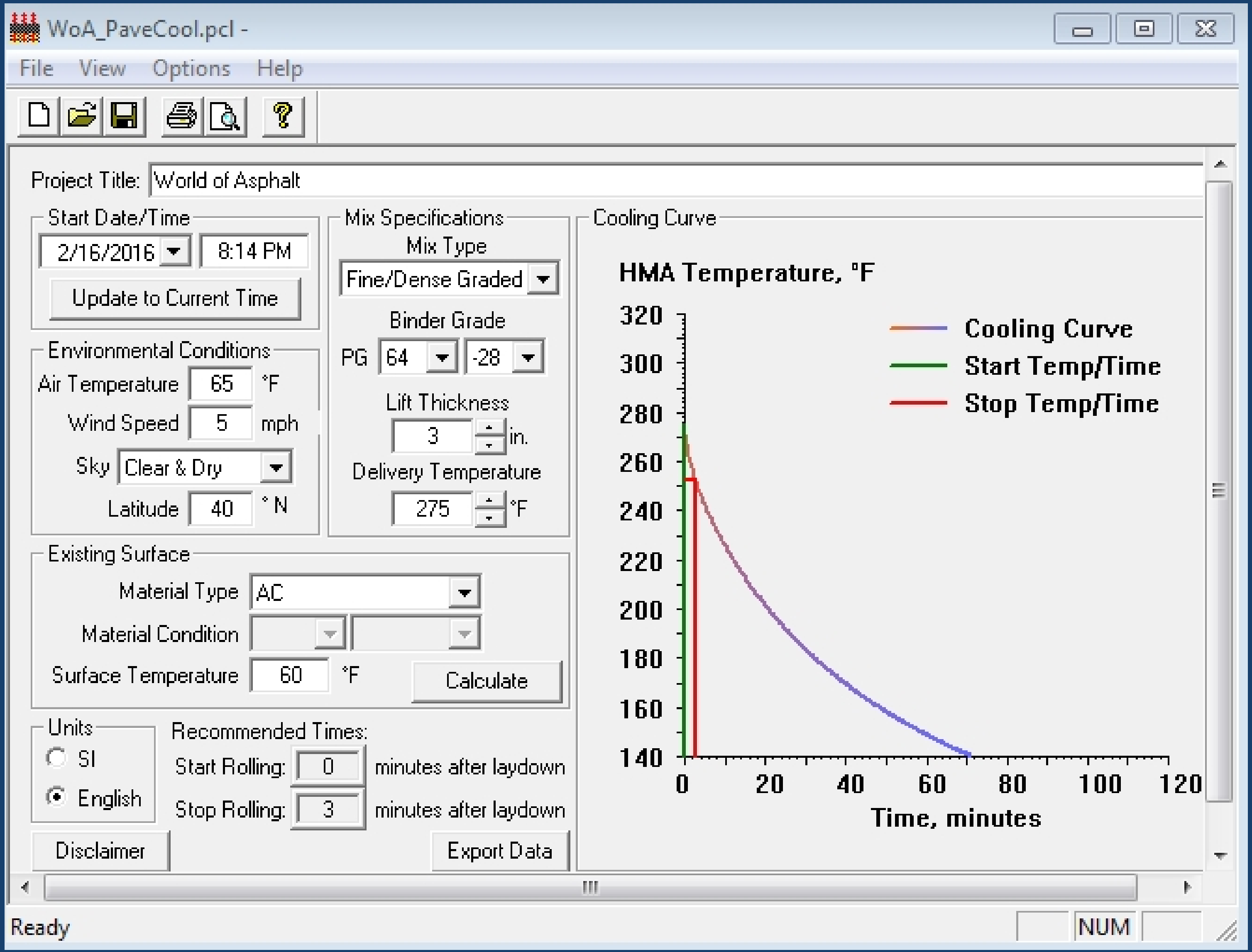
Solve the equation for distance

Length of the Roller Pass (cont’d)

Distance = Speed x Time

- Roller speed = 2,640 vpm / 10 ipf = 264 fpm
- Time to cool comes from PaveCool (or measure it)

PaveCool from 275°F to 252°F



Length of the Roller Pass (cont'd)

Distance = Speed x Time = 264 x 3 = 792 ft

Roller speed = 264 fpm

Time = 3 minutes

Roller distance = 264 x 3 = 792 ft

Length of the Roller Pass (cont'd)

We need a 5-pass pattern from Test Strip

Roller distance = 792 ft in 3 minutes

We lose some distance changing direction ≈ assume 0.80 efficiency

792 x 0.80 = 633 feet traveled in 3 minutes

633 / 5 = 126 feet

Length of roller pass = **126 feet**

**If conditions change – re-calculate the length of roller pass

Put it all together!

1. Types of rollers
2. Amplitude & Frequency – steel drum
3. Pneumatic tire roller settings
4. Time Available for Compaction
5. Number of roller passes

Sequence & Timing

	Breakdown	Intermediate	Finish
%TMD	90-92%	92-94%	94+ %
			
Temp	300-260˚F	260-200˚F	200-160˚F
Coverage	3	2	2 (1 vibe, 1 static)
Settings	High A, Low F	90 psi	Low A, static
	↔ 126 feet	↔ 200 feet	↔ 200 feet

Efficient Compaction of Stiff & Tender mixes

- Stiff mixes
  - generally very stable and can take high compactive forces
  - compact easier at higher temperatures
  - use higher amplitudes

- Tender mixes
  - temperature sensitive through a specific temperature range
  - achieve density before tender zone – rolling in echelon *OR*
  - wait until mix cools below tender zone and resume rolling

Pneumatic breakdown on a stiff mix

Tender Mix

Compacting tender mixes

- Does not compact in specific temperature range or zone
- Roll in echelon
- Resume compaction below tender zone temp
- Do NOT run a steel drum in the tender zone

Rolling in Echelon (side-by-side)

- Take advantage of TEMPERATURE
- Make more passes before the mix cools
- Can be done without a finish roller
- Ideal to use same size rollers

Echelon with same & different rollers

Echelon – steel drum

Echelon - pneumatics

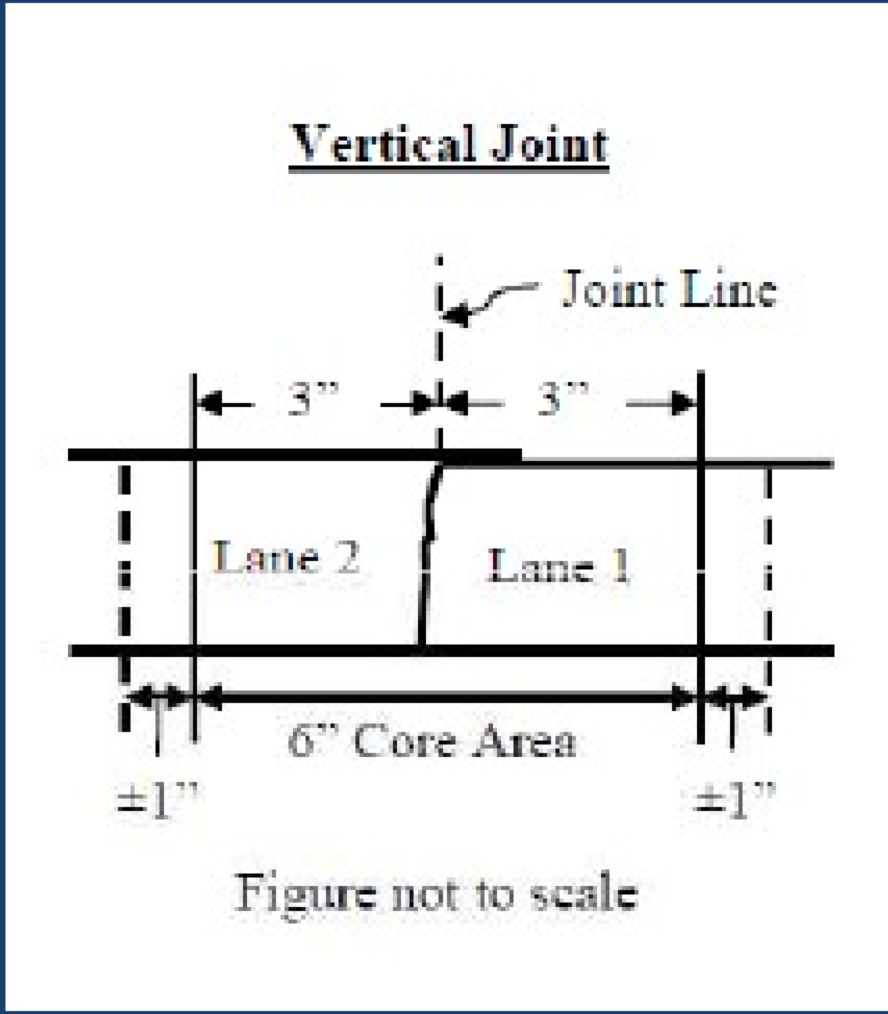
Longitudinal Joint - Build it Right

- Paver leaves straight edge to match
- Makes consistent joint overlap possible
- Can use edge cutter

Excessive Overlap

- Poor compaction, loose rock at joint
- Joint needed raking prior to compaction
- Real solution is to control end gate overlap

Keep end gates on the paver down



Have auger extensions when needed

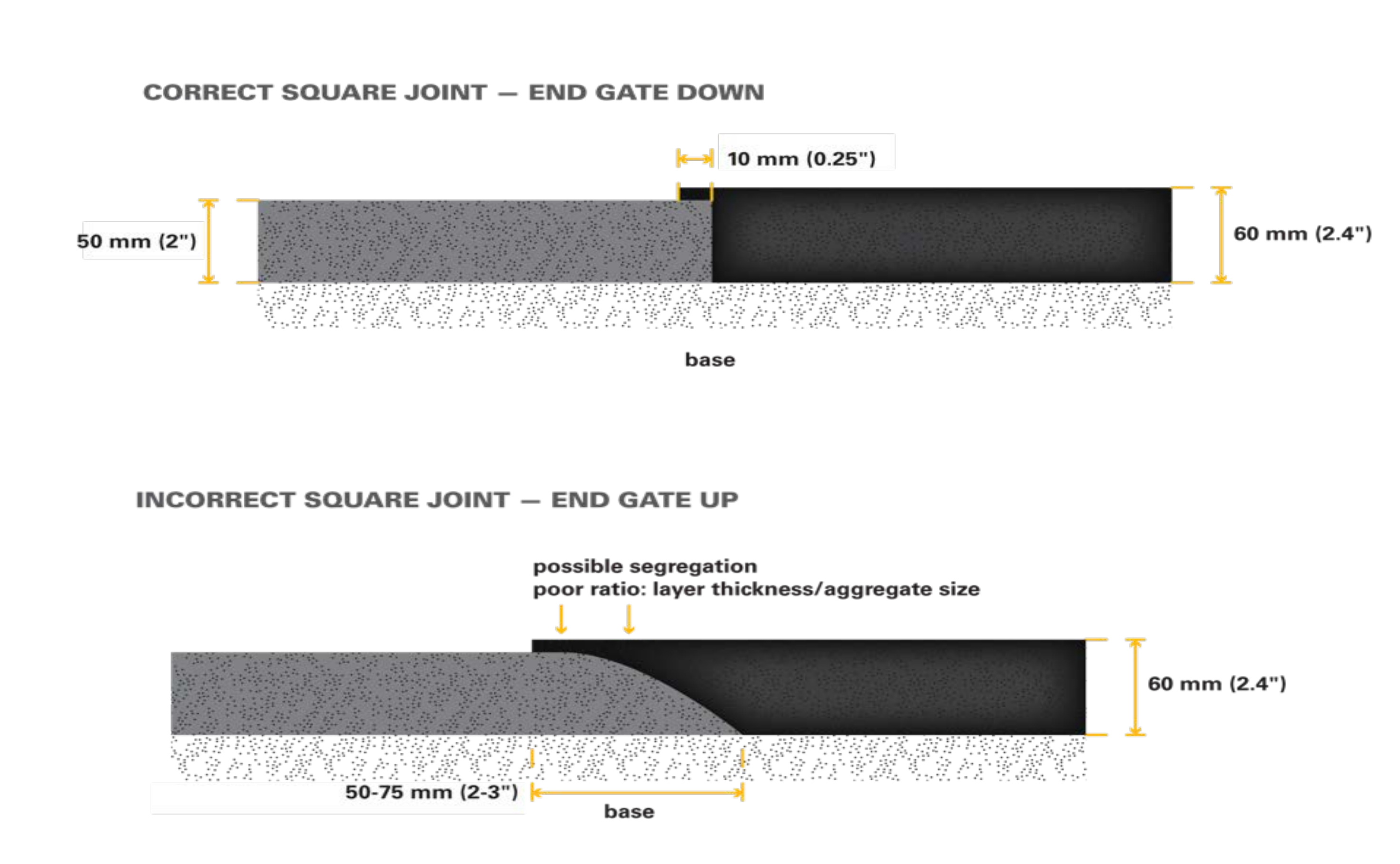
What we're trying to avoid...

- Excessive head of material
- Segregation at end gate (joint)
- Lack of mix at joint

Proper Amount of Horizontal Joint Overlap

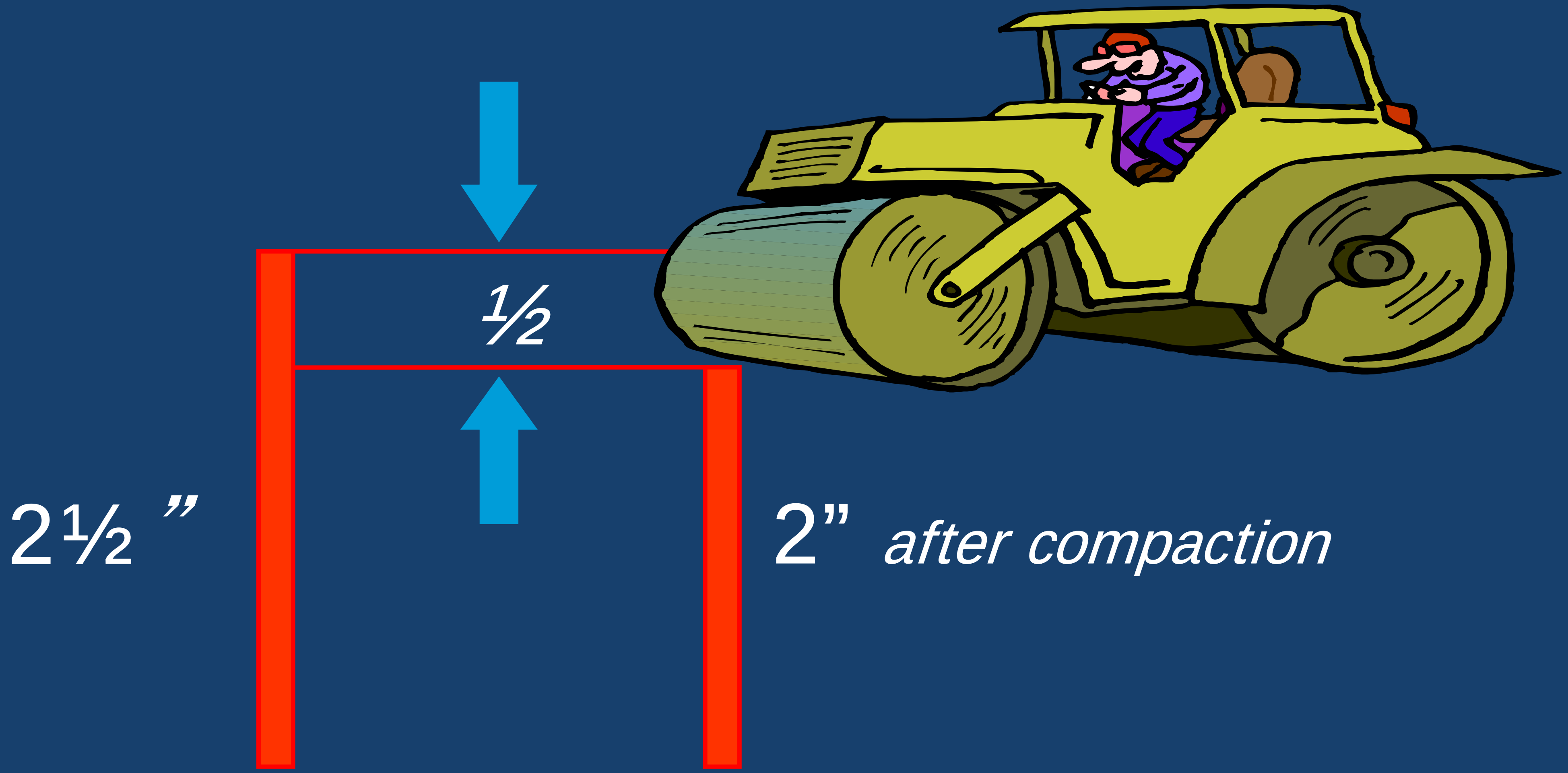
½ ” to 1” overlap

End Gate Overlap



- End gate down to create straight edge
- Overlap cold side 1/4in
- Correct pre-compaction height
- End gate up causes rounded edge, segregation and fractured aggregate

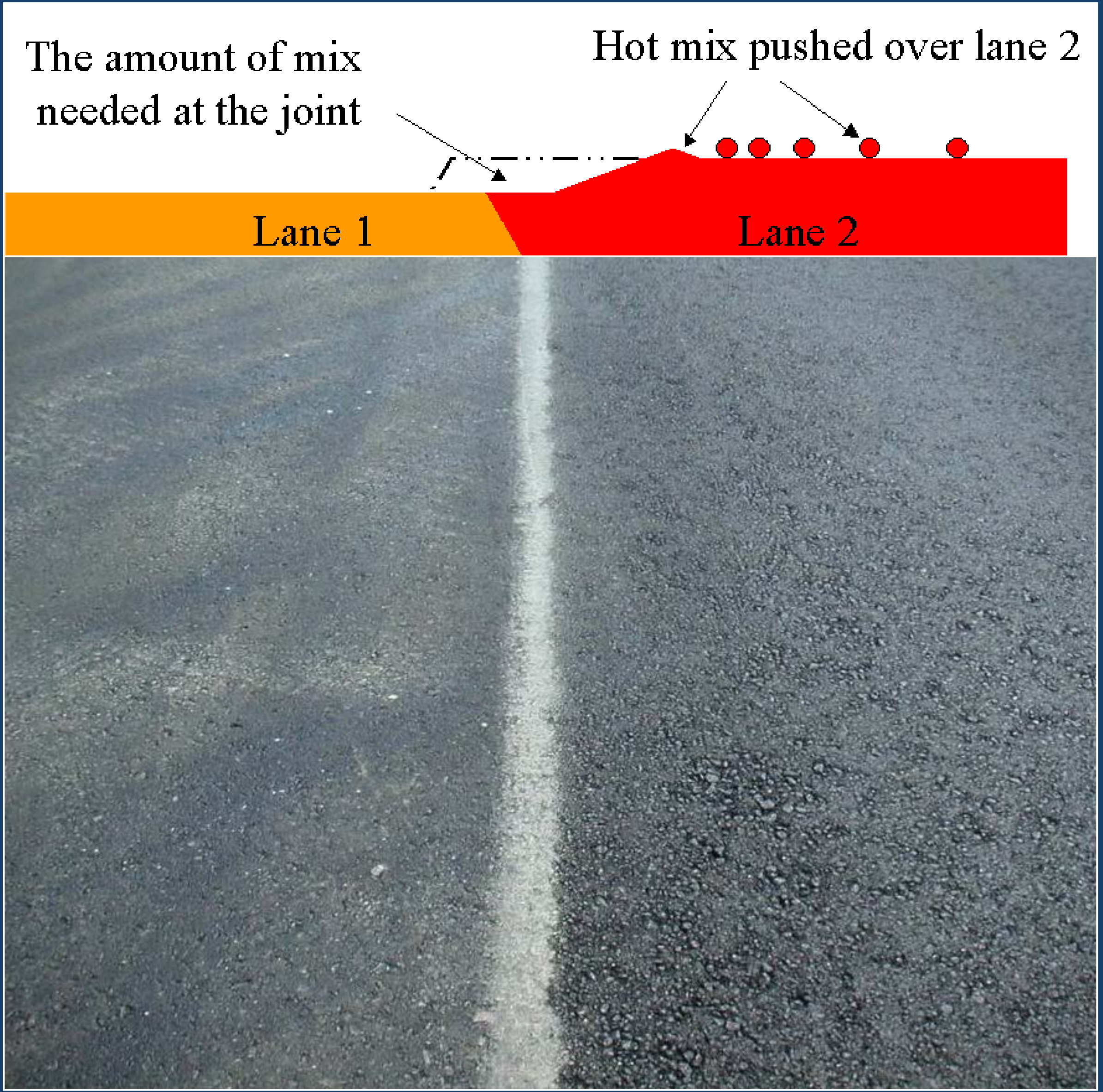
Fluff Factor (roll down) ¼” per 1”



No Raking

- End gates set properly
- Correct overlap
- Correct height match
- Sufficient material to joint

Which side was paved first?



Proper Overlap and Height Match – no raking

Rolling Pattern tools you have...

1. Finding the Time available for Compaction – PaveCool, measure
2. Calculating roller speed 10-14 ipf (formula, NAPA IS-120, Apps)
3. Calculating the length of roller pass (Distance = Speed x Time)
4. Different roller trains to consider - echelon, pneumatic breakdown
5. Compaction Troubleshooting guide

Not getting density: Root Cause

- Identify root cause(s) when density is *not* being achieved
- Systematic approach:
  - most likely reasons and easiest to check to less likely and more difficult to check
- Flowchart on the next slide is not "all inclusive", but it covers many of the most common reasons

Asphalt Compaction Troubleshooting

Are compaction goals being achieved?

No

*Is the mix temperature behind the paver hot enough? > 280°F

No → If mix is too cool, notify the Job Supervisor immediately.

Are the rollers close to the paver?

No → Move them into hot zone.

Is the mix exhibiting tender behavior under the roller(s)?

Yes → Keep the steel drum rollers OFF the mix until the tender behavior stops or they will tear up the mat. You can use a rubber tire in tender zone without doing any damage.

Verify that the nuke gauge lift thickness setting is less than the actual lift thickness being placed.

Verify that the roller settings of amplitude, frequency and speed are correct per test strip.

→ Typically lowest amplitude for lifts less than 2” thick. Higher amplitudes for lifts > 3” thick.

Check with the lab or plant to see if binder content of the mix and/or gradation changes have occurred.

→ If changes have occurred, assess the impact of these changes on compaction. Call the QC Manager if necessary. Got your phone list??

Verify the nuke gauge calibration with the mix and lift thickness.

Yes

Record the following

- Mix temp behind paver
- Number & type of rollers
- Roller settings (freq/amplitude)
- Pattern (# coverages)
- Air temperature
- Base temperature
- Asphalt lift thickness
- Mix type
- Average percent compaction
- Roller operators’ names

***Know the recommended compaction temperature for the mix design being used. Know the Time Available for Compaction.**

Troubleshooting situations

1. Mix temperature
2. Paver speed, roller speed
3. Verify roller settings of Amplitude, Frequency, Speed
4. Equipment not working as expected (low VPM, no vibe)
5. Nuclear gauge not calibrated/out of calibration
6. Sand changes at plant affects TMD (Rice), VMA
7. AC content, fines return at plant, gradation

Mix Temperature: Increase TAC

- Increase HMA temperature behind the paver
  - Increase plant production temperature
  - Manage silos
  - Tarp loads
  - Manage windrows
  - Manage trucking

- Increase the thickness of the HMA layer
- Use higher frequency rollers on thin lifts
- Breakdown with a pneumatic tire roller
- Breakdown in echelon with two double drums or pneumatics

Approximate temperature losses

- Mix sitting in trucks ≈ 10°F per hour
- Sitting in windrows ≈ 2°F per minute
- No tarps – not significant, sometimes worse with loose tarps, thicker crust will form
- Keep paver hopper full when waiting for 30 minutes or less

The mix is too cool – what now?!?!

1. Call the plant to see what they can do
2. Reduce paver speed
3. Add more rollers
4. Plan for the next day
   - Specify a load out temp when you order mix
   - Check your trucking operation

Verify Roller Settings

- Settings per test strip?
  - Amplitude
  - Frequency
  - Speed (10-12 ipf)
- Is the equipment in good working condition?

Managing for unplanned events

- Plant breakdown
- Equipment breakdown
  - Paver
  - Roller
  - Trucks
- Trucking problems
- Other...

Paver breakdown

- Mix on road
- Mix in MTV
- Finish rolling & build a joint?

Roller breakdown

- Stop paving?
- Backup roller on site?
- Have we calculated a paving speed and rolling pattern for the remaining rollers?

Trucking problems

- Interrupted trucking
- Delays longer than 30 minutes
- Build a new transverse joint

Plan for Excellent Compaction!

- Collect information
- Set targets
- Calculate paving speed
- Calculate roller speed
- Balance tons/hr, paver, rollers
- Confirm test strip
- Check, check, check...
- Make changes as needed

Thank you for your attention!

Questions?