Compaction Principles

The A, B, Cs

- Asphaltic concrete mix is like eggs, meat and milk…it has a ‘shelf life’ and must be compacted before it cools (spoils)
- Binder content makes it either more difficult to compact, or easier to compact HMA and WMA mixes
- Compaction is a means-to-an-end…to reduce air voids and increase density
- Density is a pay factor in many states; Air void content is a pay factor in WI
- Emulsion (tack coat) is essential to proper bonding between asphalt pavement layers and to prevent mix movement (creep) during rolling procedures

The A, B, Cs

- Fine-graded mixes are typically easier-to-compact
- Gap-graded mixes are typically more difficult-to-compact
- Hot Mixed Asphaltic Concrete (asphalt) is America's most recycled material
- Intermediate rolling adds up to 2-3% density following breakdown rolling
- JMF (Job Mix Formula) is guidance to gradation, AC content and admixture dosage
- Joint density is critical to pavement life; many states now have joint density specifications
- Kneading action (using the rubber-tired roller) provides superior compaction on leveling courses (vs steel drum); PennDOT PUB 408/2016 requires "using pneumatic-tire rollers for compacting scratch courses"

The A, B, Cs

- Leveling courses placed over irregular bases will contribute toward superior final pavement smoothness
- Longitudinal joint density is critical to pavement life; NAPA produced TAS-33A, a publication outlining recommended Longitudinal Joint Construction procedure; PennDOT PUB 408/2016 includes longitudinal joint density as a pay factor using PWT factoring
- Marshall mix designs are typically easier-to-compact than Superpave mixes; Marshall asphalt mix design reference was removed from PUB408/2016 in Change No. 4
- Modified binders provide benefits which enhance pavement life but also potentially make compaction more difficult

The A, B, Cs

- Oscillatory rollers can be effective for both intermediate and finish rolling applications
- Oxidation of asphalt binders is more rapid if high density is not achieved during the compaction process (AVC remains too high)
- Potholes result from weakness in bases or subgrades… rather than from improper rolling/compaction of flexible pavements
- QA and QC are utilized to measure/evaluate the effectiveness of the laydown and compaction process
- RAP and RAS content is increasing in some mixes and can make the compaction process more difficult; PennDOT Pub 408/2016 Superpave Mix Design states “use at least 5% RAP” and “use 5% by mass RAS”

The A, B, Cs

- Smoothness is a pay factor impacted by rolling procedures; PennDOT PUB 408/2016 includes IRI (inches/mile/lot) as incentive/disincentive [Schedule A IRI ≤70 or Schedule B IRI ≤90 as maximum acceptable values with incentives for superior smoothness]
- Superpave mixes sometimes exhibit a ‘tender zone’ which complicates the compaction process and affects TAC
- Temperature is one of the most important considerations during laydown and compaction
- Time Available for Compaction TAC is critical for all mixes
- Understanding the compaction process helps roller operators to be more effective, efficient and productive

The A, B, Cs

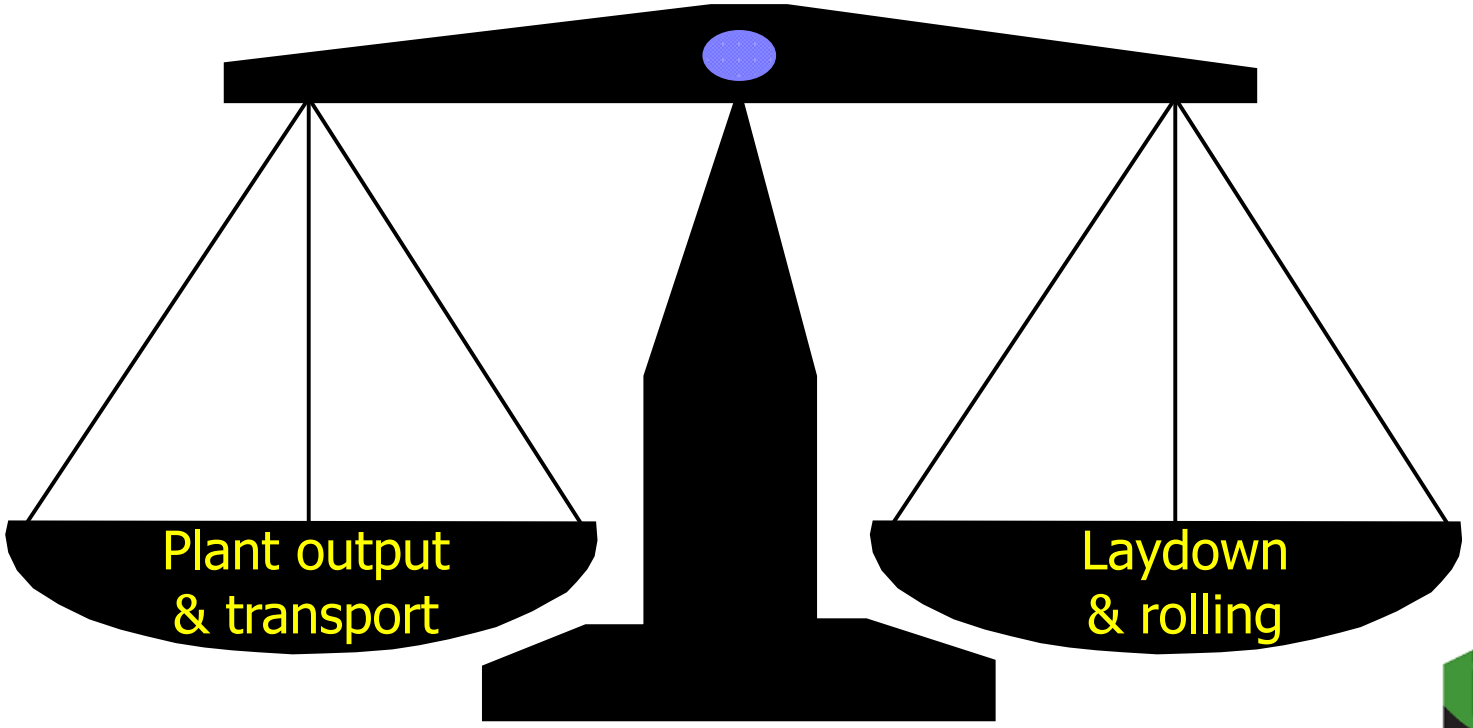
- Vibratory rollers are typically the best choice for breakdown rolling applications
- Warm Mix Asphalt is a rapidly growing mix type which is easier-to-compact on most applications; PennDOT PUB 408/2016 includes requirement to "Use Warm Mix Asphalt (WMA), in accordance with temperature restrictions specified in Section 411, Table A…Superpave Mixture Design"
- Xenon lighting (on rollers) provides superior job site visibility, thereby enabling safer night-time operations; LED lighting is becoming common
- Yellow is a preferred color for visibility on work sites
- Zigzag rolling patterns cannot provide uniform pavement density, nor acceptable surface smoothness

Compaction Principles I've Learned

my 'silver bullets'…

- Keeping up with the paver keeps 'THE MAN' happy
- Not creating roller marks is better than rolling out marks
- Over-rolling will damage soft aggregates
- Proper rolling speed with vibration is critical to achieve smoothness
- Smooth starts, stops and reversals lessen or prevent marks
- Technology makes everyone's jobs easier

Productivity Balance



Not Creating Marks is Better…

Over-Rolling Will Damage…

Layer thickness to NMAS ratio?

- In the past, logic was to lay down mix in layer thickness ~2.5 times NMAS
- Current PennDOT PUB408/2016 guidance requires greater ratio…refer to Table G

TABLE G
Mixture Minimum Compacted Depths

	Mixture	Minimum Depth
Laid ~4.5X NMAS	9.5 mm Wearing Course	1 1/2 in.
Laid ~3.5X NMAS	12.5 mm Wearing Course	1 1/2 in.
Laid ~3.75X NMAS	19 mm Binder Course	2 1/2 in.
Laid ~3.5X NMAS	25 mm Binder Course	3 in.

Proper Rolling Speed with Vibration…

Based on Drum Diameter…

- For optimum surface smoothness:
  - Drums up to 35 inches in diameter: 14 impacts per foot
  - Drums between 35 to 50 inches in diameter: 12 impacts per foot
  - Drums between 50 to 55 inches in diameter: 10 impacts per foot
  - Drums over 55 inches in diameter: 8 impacts per foot

Max. Rolling Speed with Vibration…

$$\frac{\text{2500 vibrations per minute}}{\text{(10 impacts per foot)}} = 250 \text{ fpm}$$

$$\frac{\text{3000 vibrations per minute}}{\text{(10 impacts per foot)}} = 300 \text{ fpm}$$

$$\frac{\text{4000 vibrations per minute}}{\text{(10 impacts per foot)}} = 400 \text{ fpm}$$

Five Pass Breakdown Rolling Pattern…

5 pass pattern

Paver Speed to Roller Speed…

Compactor with 3000 VPM making five pass pattern at 300 fpm average rolling speed can keep up with paver moving at average speed of 60 fpm

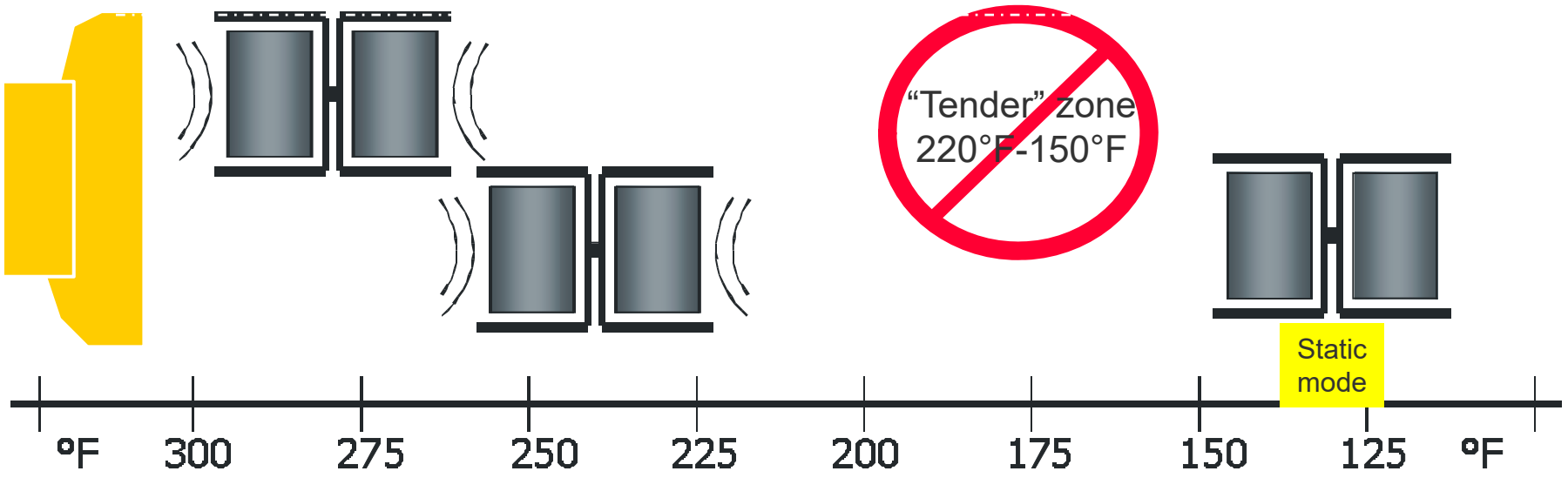
Typical Paver Speed…

- The tonnage placed per day is most commonly less than 3,000 tons.
- The typical paver speed is between 20 and 40 feet per minute, although most respondents indicated that a slower speed would be advantageous to optimize density.

NCHRP Research Report 856 ©2017

Maintain Proven Rolling Patterns…

PA 19mm Superpave paving train



DD-110 amplitude 7 achieved 89% RC
DD-110 amplitude 7 achieved 91% RC
DD-110 static achieved 92-96% RC

Smooth Starts, Stops and Reversals…

End Passes in an Arc…

Standing the Test of Time…

Traditional Three Roller Train…

Alternative Roller Train…

Bituminous Seal Coat Application…

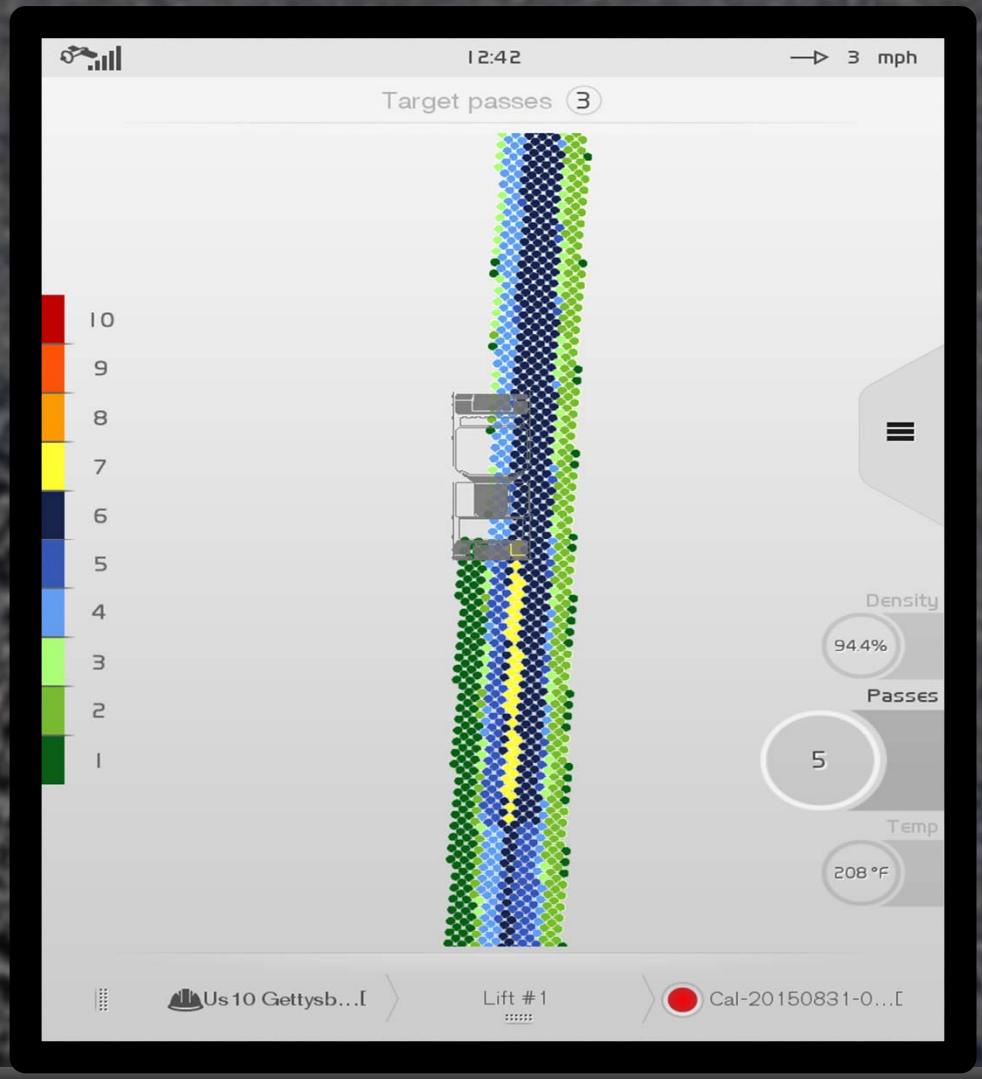
Technology…

Oscillatory Drums…

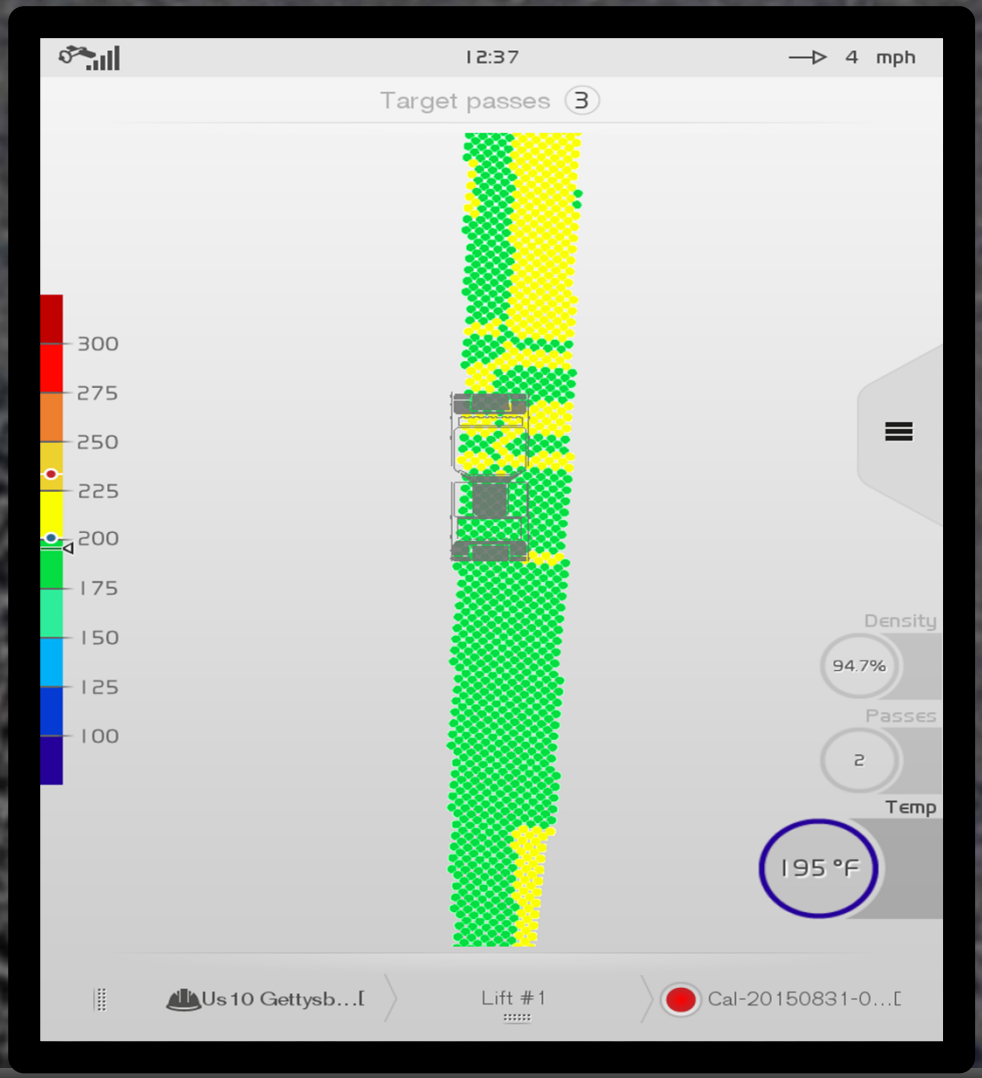
Oscillatory Drums…

Intelligent Compaction Systems…

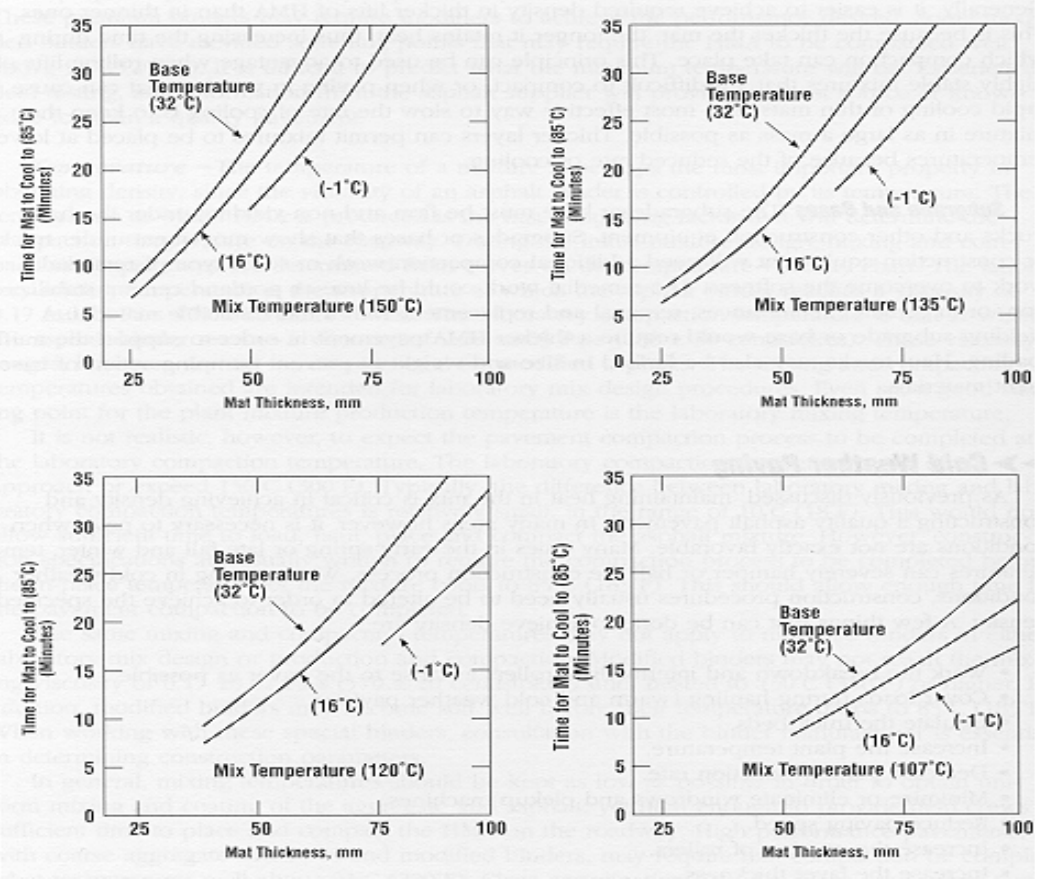
Pass Mapping



Temperature Mapping

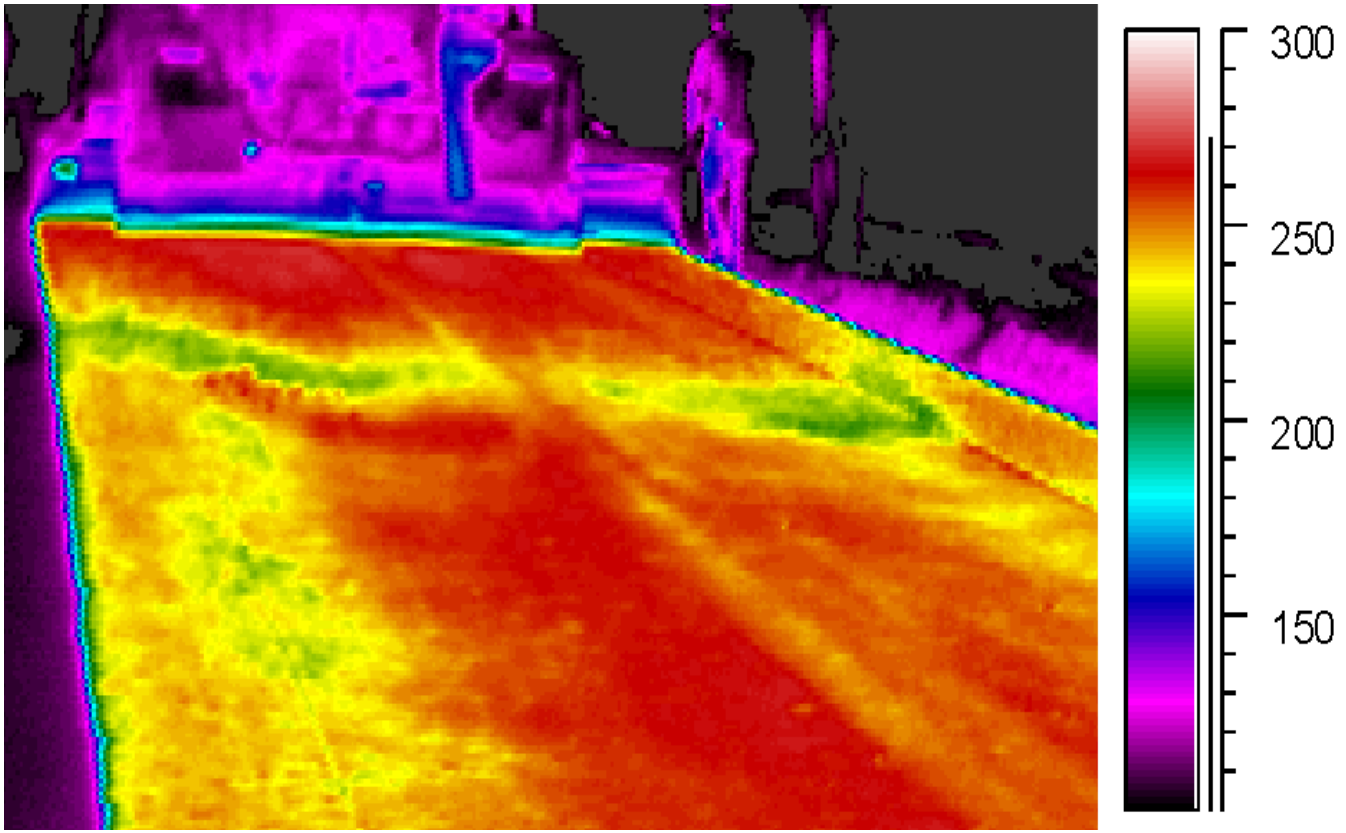


Time Available for Compaction…

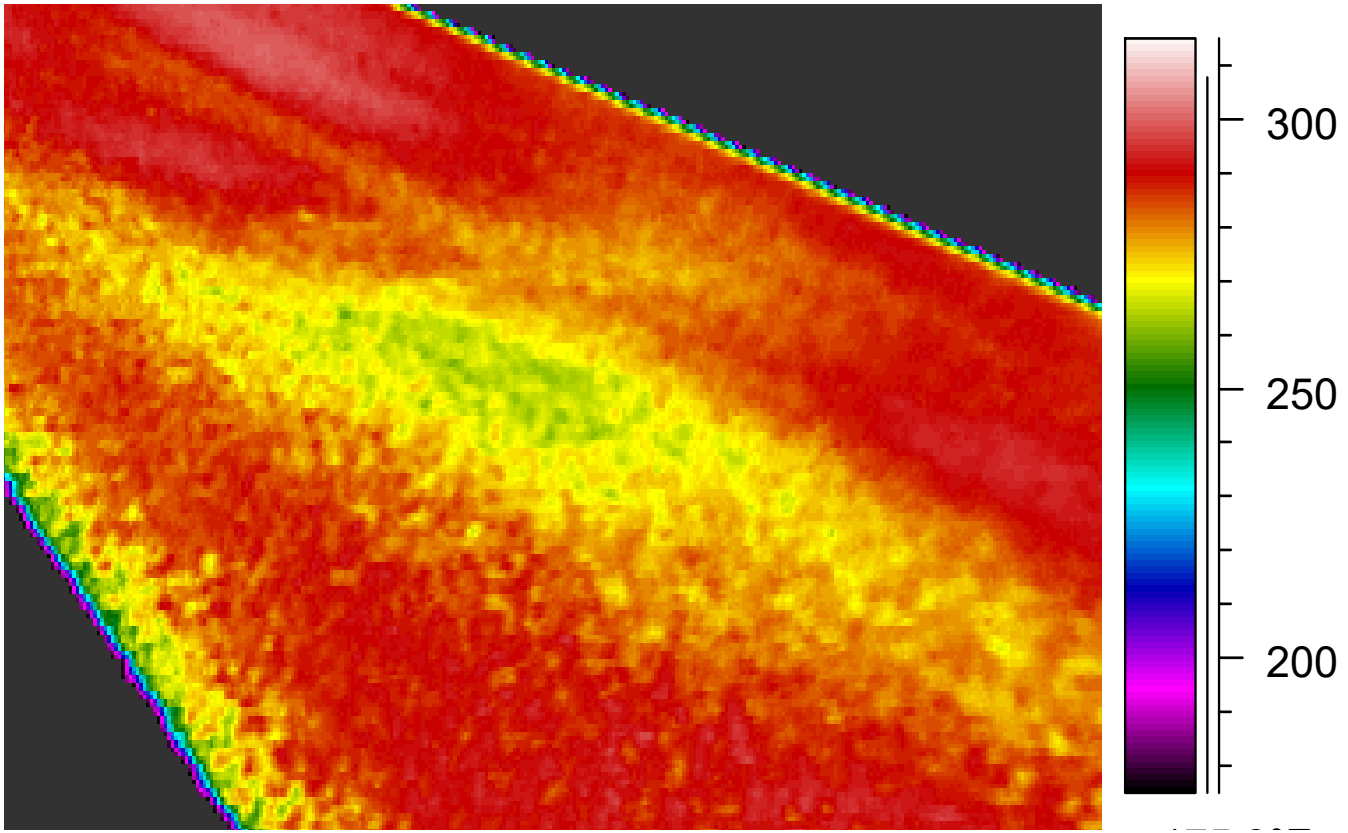


Density must be achieved in 25 minutes on 90ºF base, in 20 minutes on 60ºF base, in 15 minutes on 35º base with 2 in. (50 mm) thick lift laid at temp. 302ºF behind paver

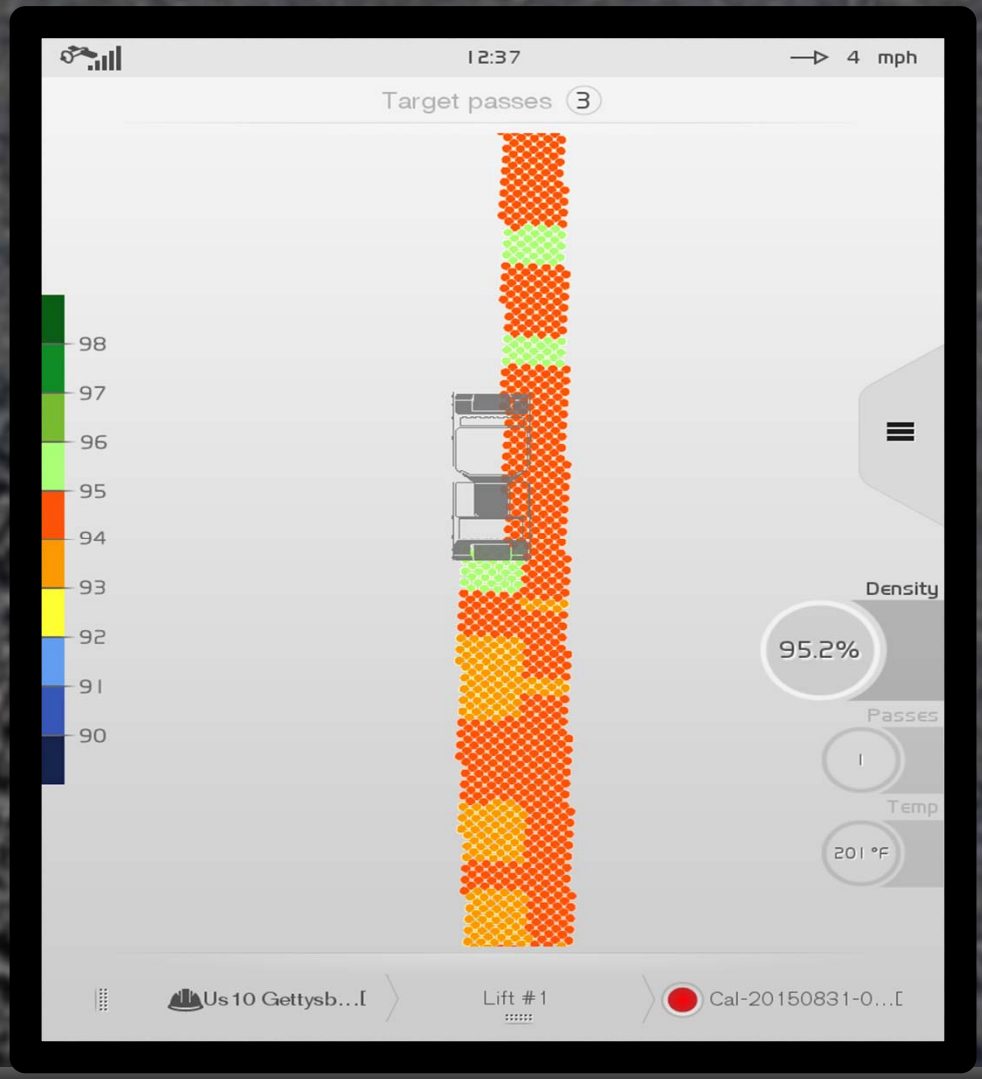
TAC…



TAC…



Density Mapping



Uniformity of Density Without IC?

Specifications…

- **“409.3(f) Rollers.** Use steel-wheel, pneumatic-tire, vibratory, or oscillating rollers as specified or allowed in Section 108.05(c)3a, 3b, 3c, 3e, 3f, 3h, or 4. Operate rollers according to manufacturer's recommendations. Use vibratory and oscillating rollers with separate controls for frequency and amplitude.“
- **“409.3(i) Compaction.** Compact the mixture to achieve the density acceptance requirements and to eliminate all roller marks. Compact the mixture while it is in proper condition and adjust roller speed, amplitude, frequency, pattern, and roller size to eliminate displacement, shoving, cracking
- mixture from adhering to the wheels. Use suitable methods to clean wheels of pneumatic-tire rollers.
- Use pneumatic-tire rollers for compacting scratch courses.
- For areas inaccessible to rollers, compact with mechanical vibrating hand tampers.”

Prescriptive or Performance?

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

Agency Objectives…

Contractor Objectives…

Common Objectives…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’

Never forget…At the end of each shift, everyone deserves to return home to family and friends…Have a prosperous and safe New Year!

Always More Difficult at Night!

Thank You!

PAPA