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NEBRASKA
Good Life. Great Journey.
DEPARTMENT OF TRANSPORTATION

2024 Nebraska Asphalt Paving Workshop

Asphalt Compaction and Considerations

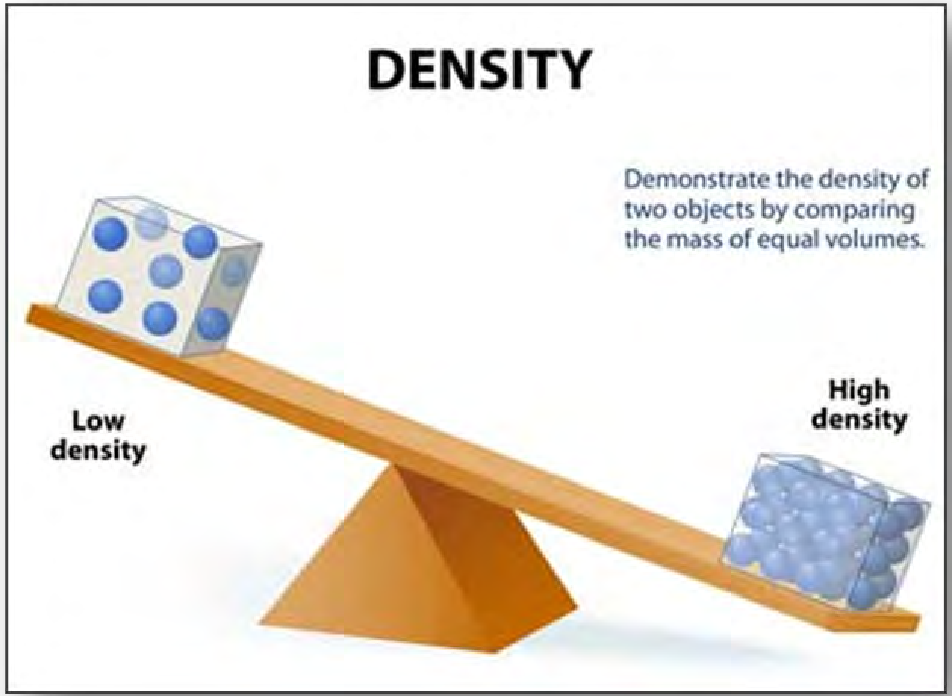
Density vs. Compaction

Density:

- Weight of the material that occupies a unit volume of space.
  - Measurement

Compaction:

- Process by which the asphalt mixture is compressed and reduced in volume
  - Action



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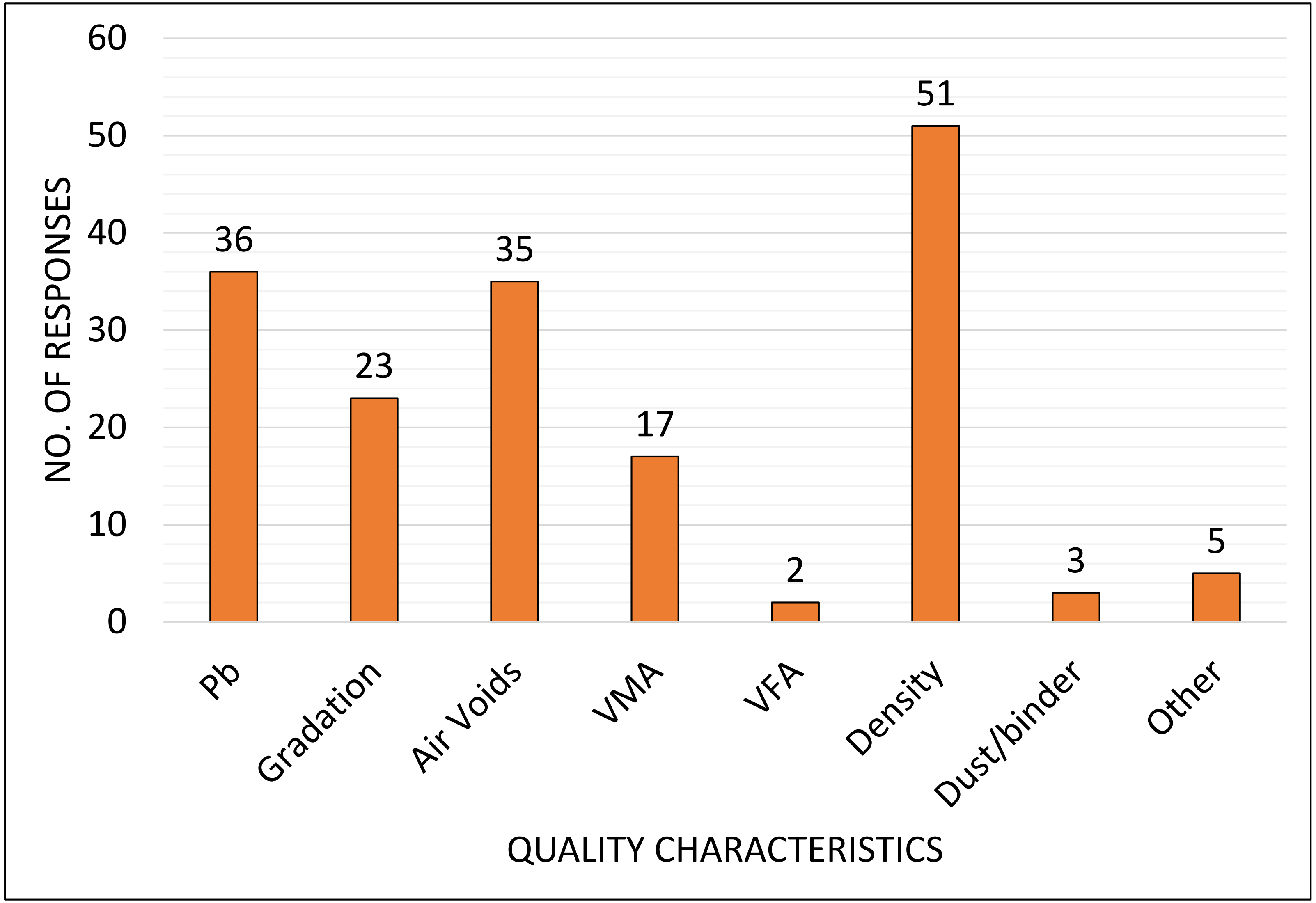
State DOT Acceptance Quality Characteristics



2020 NCAT Survey on Quality Assurance

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Importance of Density

- One of the most important factors related to the performance of an asphalt pavement is density.

- A small increase in in-place density can potentially lead to a significant increase in the service life of asphalt pavements.

It is generally believed a marginal mix that is properly compacted will out perform a superior mix that is not properly compacted.

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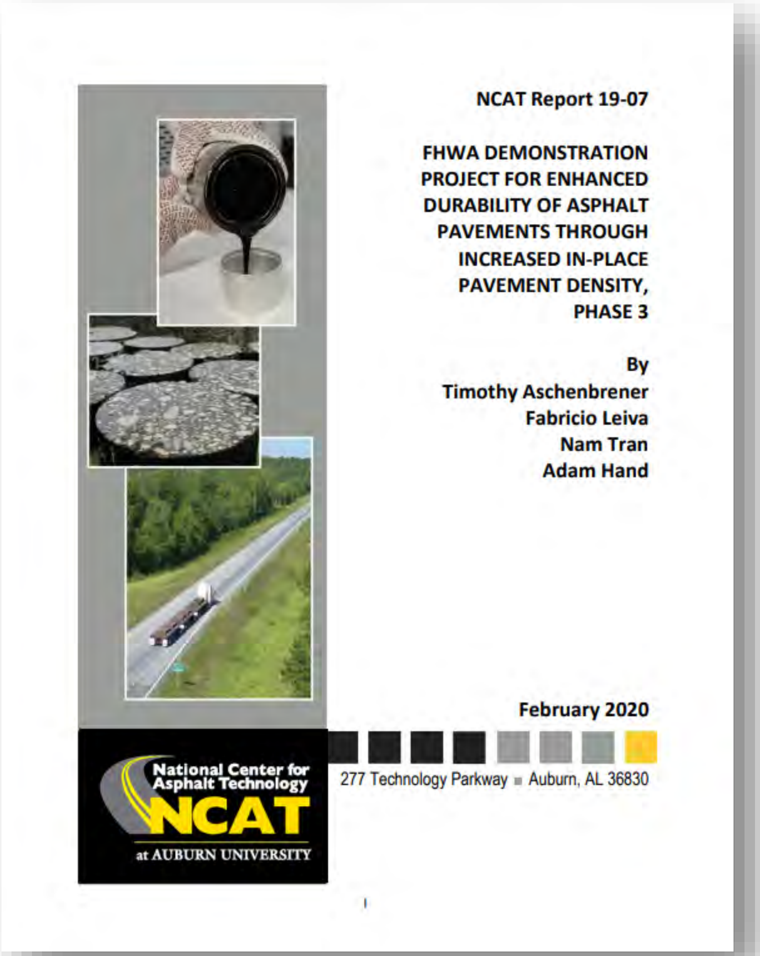
Importance of Density

The squeezing together of the aggregate particles increase their surface-to-surface contact and inter-particle friction, resulting in higher stability and pavement strength.

The reduction of in-place air voids leads to less exposure to oxygen and moisture, all which cause the asphalt binder to oxidize and harden – which causes cracking.

Importance of Density



- 1% decrease in air voids:
  - Estimated to improve the fatigue performance between 8 and 44%
  - Estimated to improve rutting resistance by 7 to 66%.

- 1% decrease in air voids would extend the service life by 10%, conservatively.

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Impact of Density – Traveling Public Perspective

- Less rutting – Reduced risk of hydroplaning in wet weather
- Less fatigue and thermal cracking
- Pavement’s last longer – Less delays/inconvenience due to resurfacing

Impact of Density – Agency Perspective

- Properly compacted pavements last longer
  - Extends resurfacing budget
  - Increasing density 1% extends the pavement life by 10%

- Life Cycle Cost Analysis:
  - The Owner would see a net present value (NPV) cost savings of $88,000 on a $1,000,000 paving project (8.8 percent) by increasing the minimum required density by 1 percent of G_{mm}

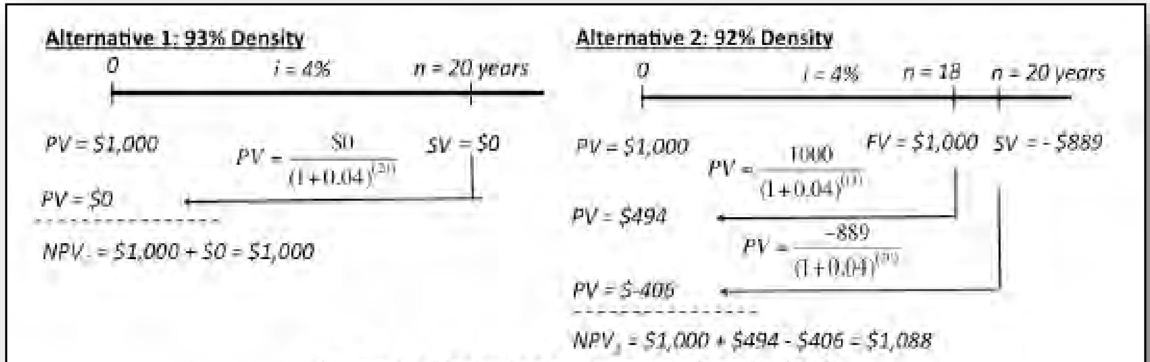
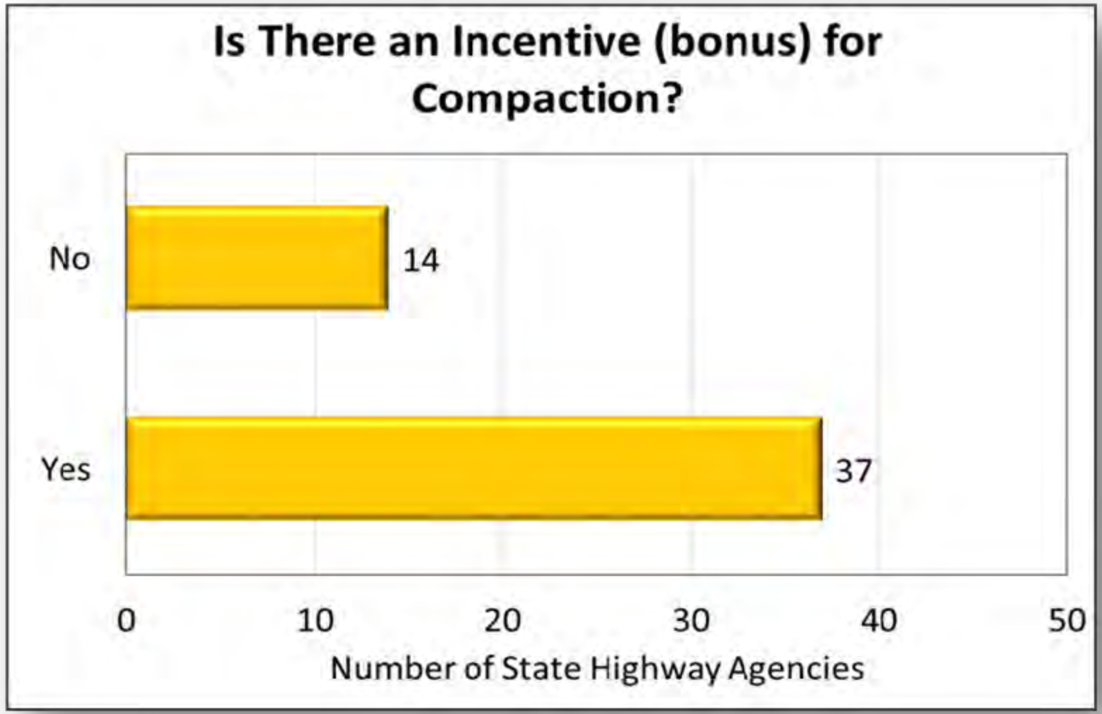


Figure 3. Life Cycle Cost Analysis (per $1,000)

Impact of Density – Contractor Perspective



Financial:

- Majority of states have an Incentive/ Disincentive specification for Density/Compaction

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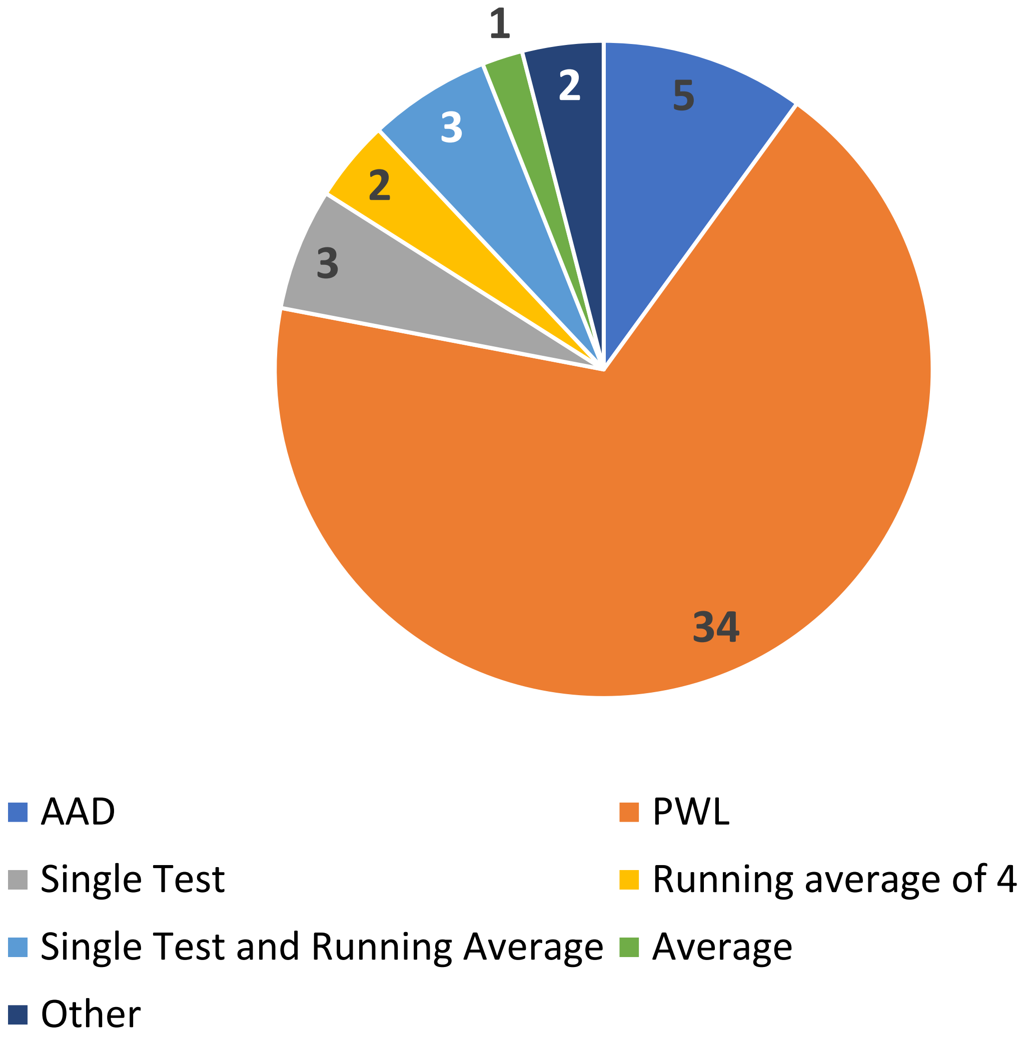
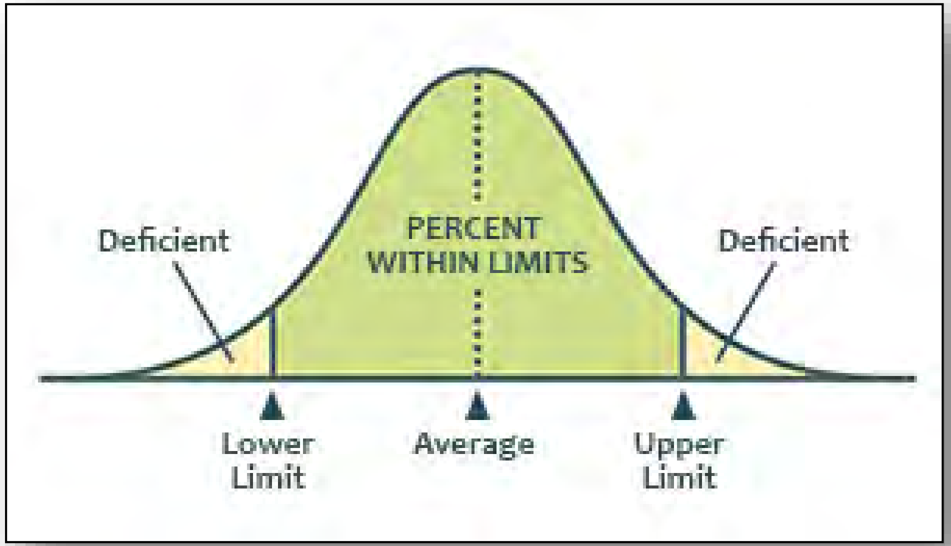
Quality Measures for Pay





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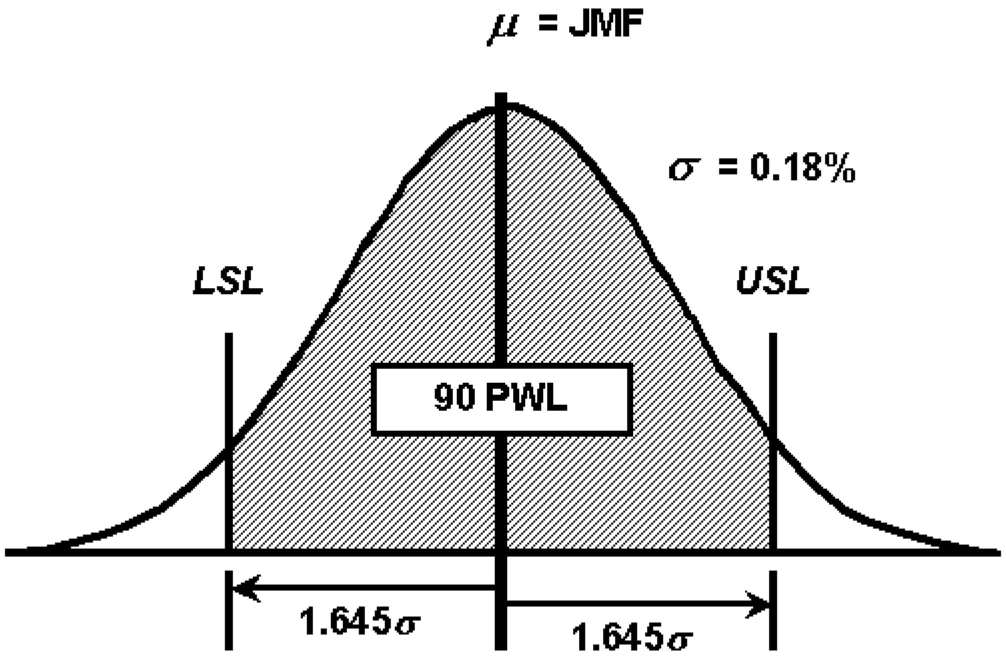
Impact of Density – Contractor Perspective

Typical Density Specification:

Pay Factor (PF) = (55 + 0.5 x PWL) / 100

PWL = 100 → PF = (55 + 0.5 x 100/100) = 1.05

PWL = 50 → PF = (55 + 0.5 x 50/100) = 0.80



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Financial Impact – Incentive/Disincentive

Example:

Assume 20,000-ton project; Bid Price $95.00/ton

Incentive: Assume 5% Max Bonus

5% x $95/ton x 20,000 tons = $95,000/project

30 projects/year = $2.9 Million (Opportunity)

Disincentive: Assume 20% Max Penalty (before Remove and Replace)

20% x $95/ton x 20,000 tons = $380,000/project

30 projects/year = $11.4 Million (Risk)

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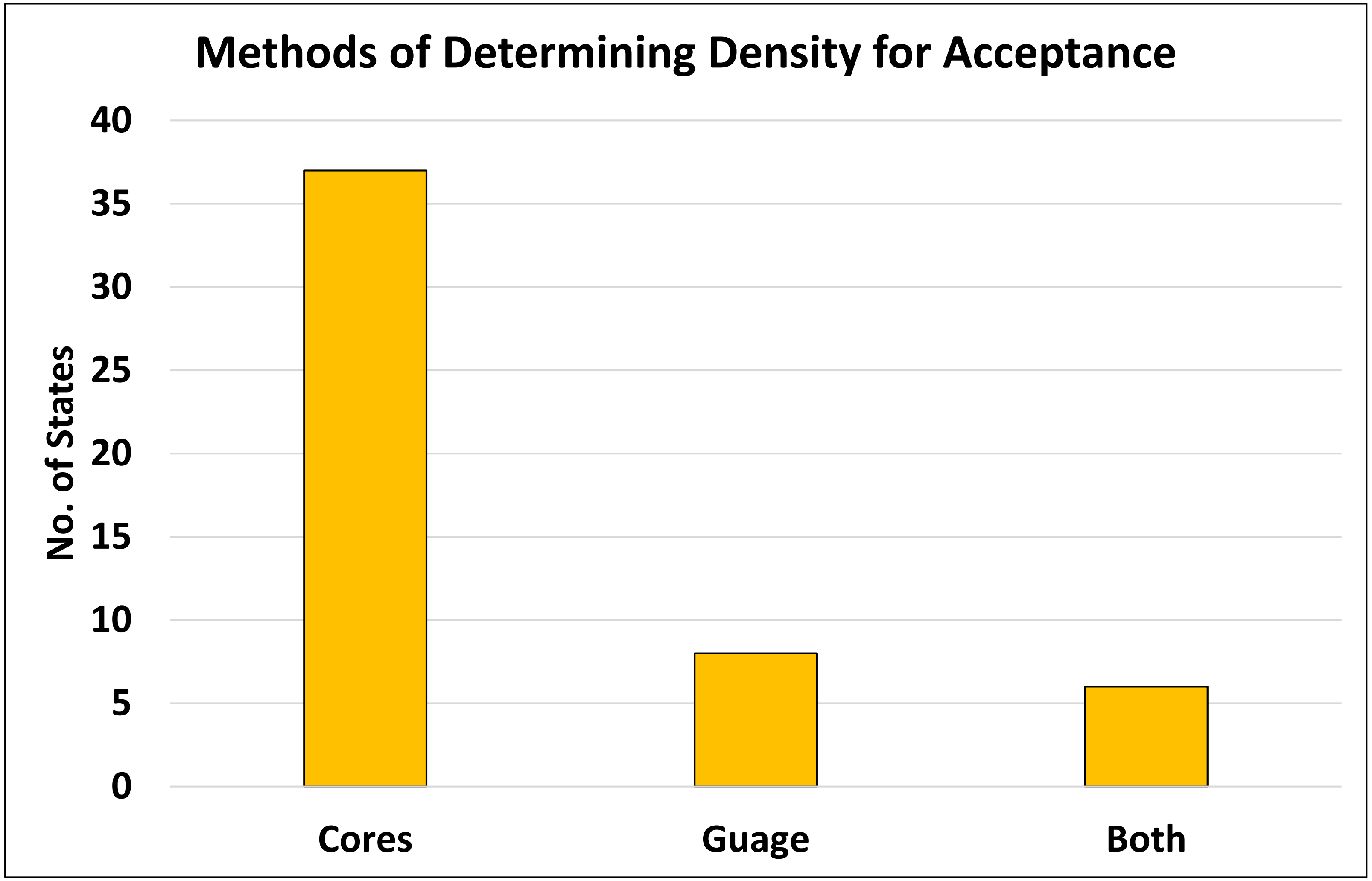
How is Density Commonly Measured?



Methods of Measuring Density

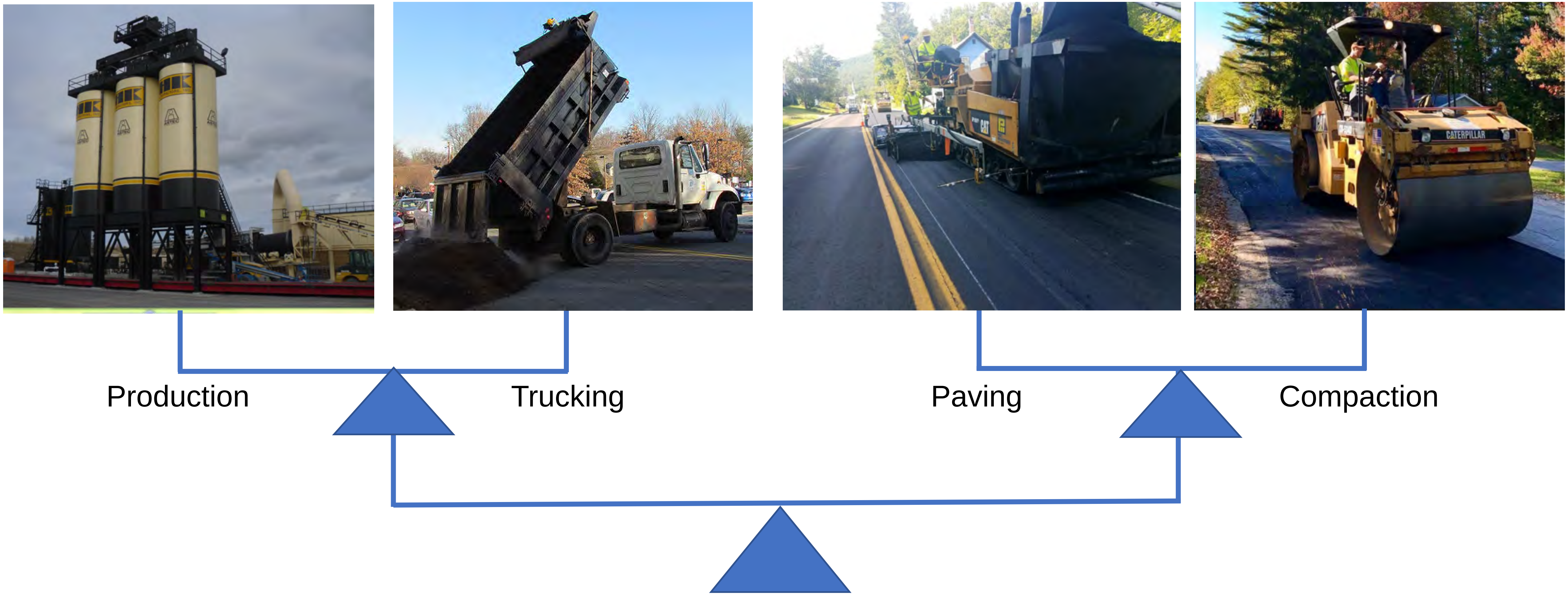
- Roadway Cores
  - Determine the bulk specific gravity (G_{mb})
  - Typically based on mixture's maximum specific gravity (G_{mm})

- Density Gauge
  - Nuclear
  - Non-Nuclear
    - Electrical Impedance

Keys to Getting Good Pavement Density

- Pay attention to the details of good construction
- Use the proper mix design and material selection
- Use good judgement on appropriate equipment selection and operation
  - The type of compaction equipment used has a significant impact on the density achieved in-place
  - Know the capabilities of the equipment selected
    - Weight
    - Speed
    - VPM
    - Amplitude
    - Coverage
- Identify and address the factors affecting compaction – especially the Time Available for Compaction (TAC)

Balancing the Paving Operation



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Mechanics of Compaction

Three forces at work:

1. Compressive force of the roller
2. Forces within the mix that resist the force of the rollers (interparticle friction & viscosity or stiffness of asphalt binder)
3. The layers below the mat (base and subgrade stability & strength)

Factors Affecting Compaction

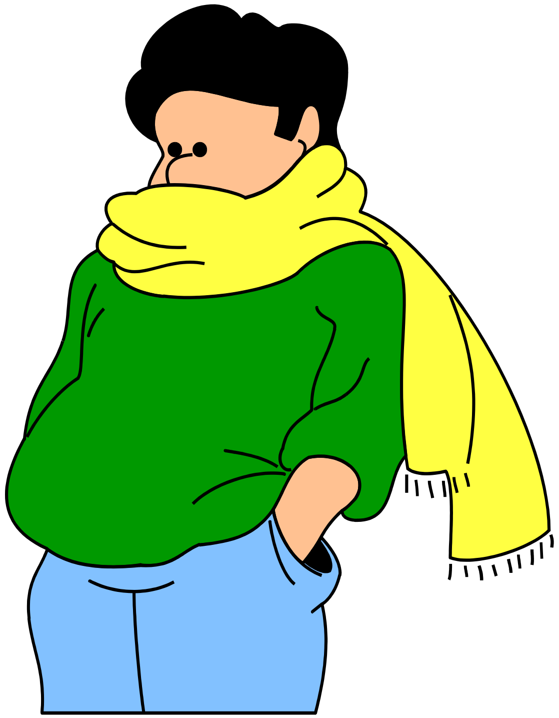
- Mixture Type
- Properties of the Materials
- Environmental Variables
- Laydown Site Conditions

Properties of the Materials

- Nominal maximum size
- Angularity of coarse and fine aggregate (tends to be rounded)
- Amount of natural sand
- High dust content
- Asphalt binder grade

Environmental Variables

- Layer Thickness
- Air Temperature
- Base Temperature
- Mix Laydown Temperature
- Wind Velocity
- Solar Flux



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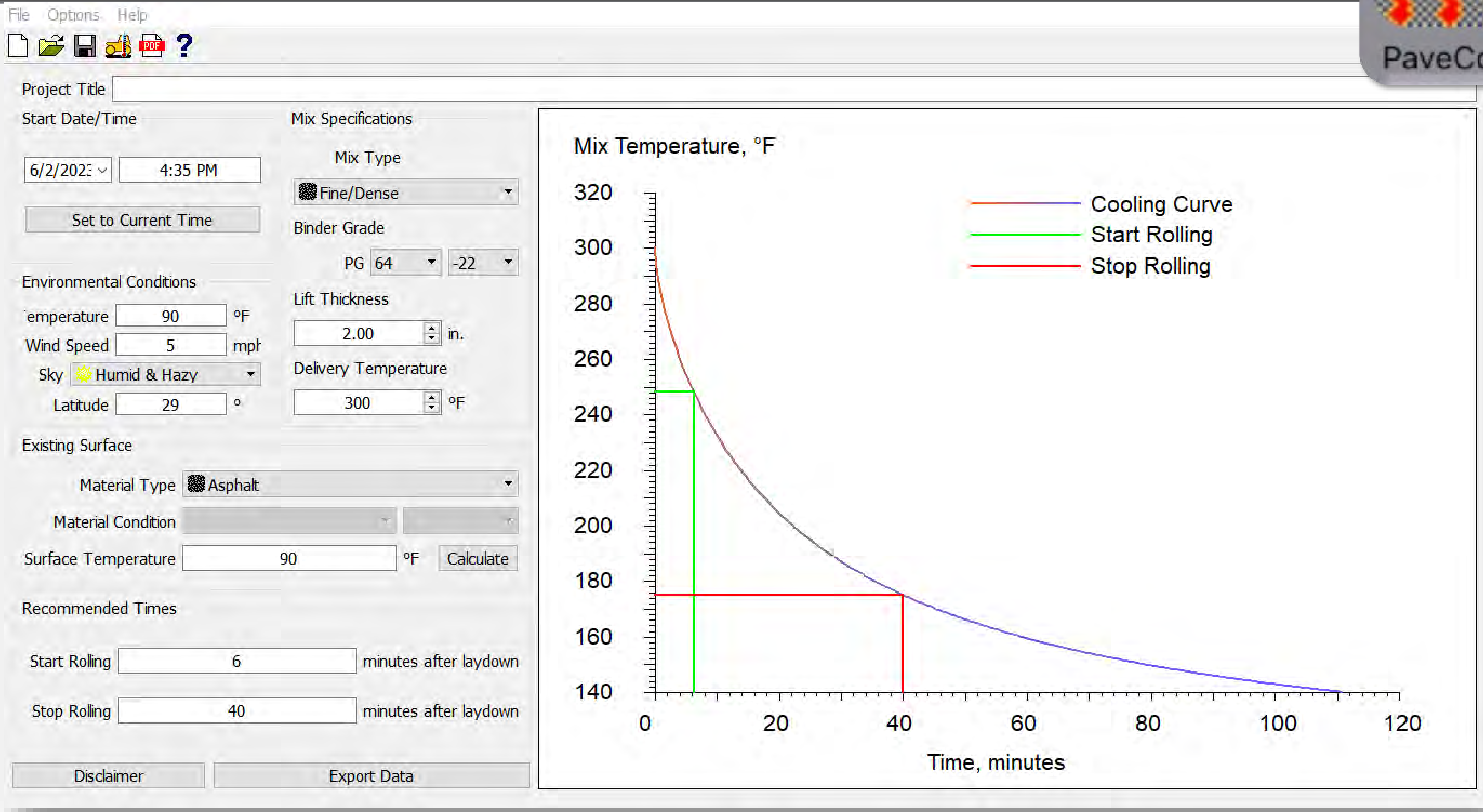
Time Available for Compaction (TAC)

The time it takes from when the mix first passes under the screed, until it cools down to a temperature where it can no longer be compacted.

Factors Affecting TAC

- The major factors affecting time available for compaction are:
  - Mat or lift thickness
  - Initial mat temperature
  - Temperature of the surface on which the mat is placed
  - Ambient temperature
  - Wind speed

Time Available for Compaction



Importance of Thickness - Example

- Mixture produced at 300ºF with ambient air temperature of 75ºF
- PG 64-22 binder
- Cutoff temperature for compaction is 175ºF
- 2” lift versus a 1” lift

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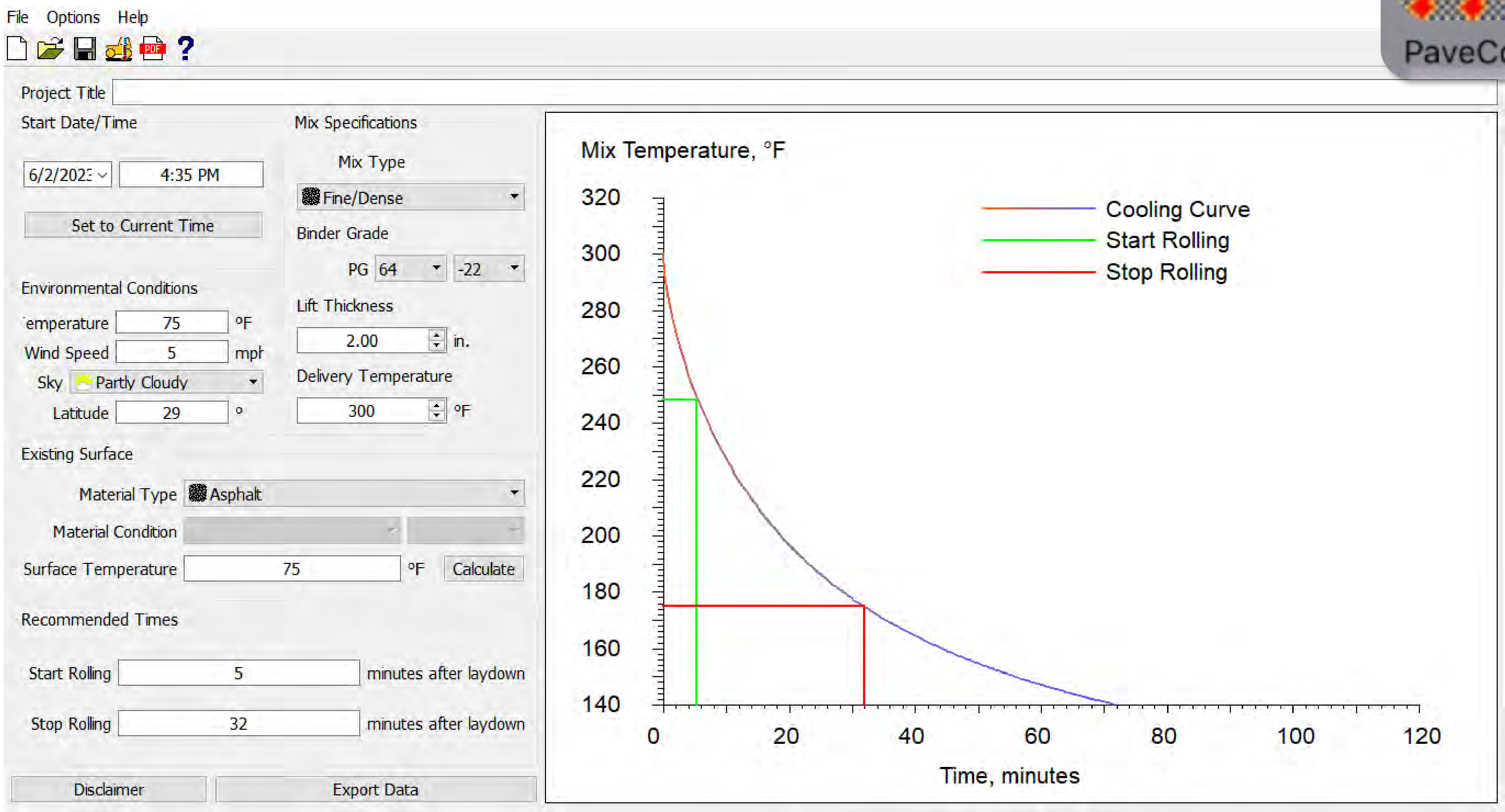
2” Lift (27 minutes)



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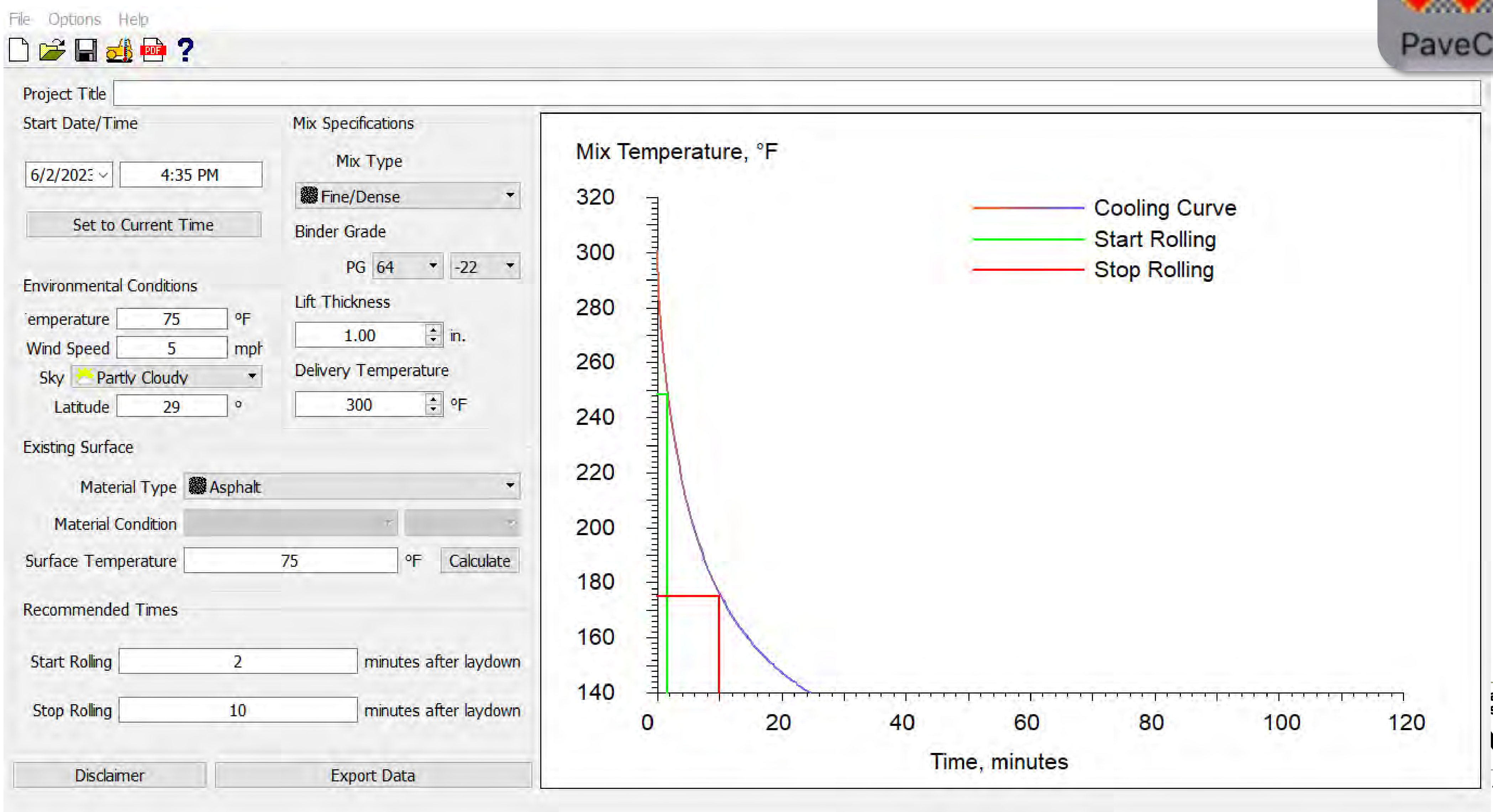
1” Lift (8 minutes)

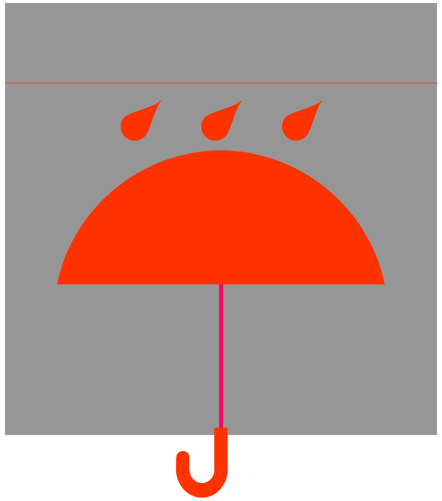


Ideally this…

Not this…

Binder and Compaction

- Asphalt binder holds particles together
  - Provides lubrication at high temperatures
  - Provides cohesion at in-service temperatures
- Prevents air and water intrusion into mat



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Major Factors Affecting Rolling Time

FACTORS	Allows MORE time	allows LESS time
Mat Thickness	THICK	THIN
Mix Temperature	HIGH	LOW
Base Temperature	HIGH	LOW

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Laydown Site Conditions

- Lift thickness versus aggregate size
- Lift thickness uniformity
- Base conditions

Relationship between Thickness and Nominal Maximum Aggregate Size (t/NMAS)

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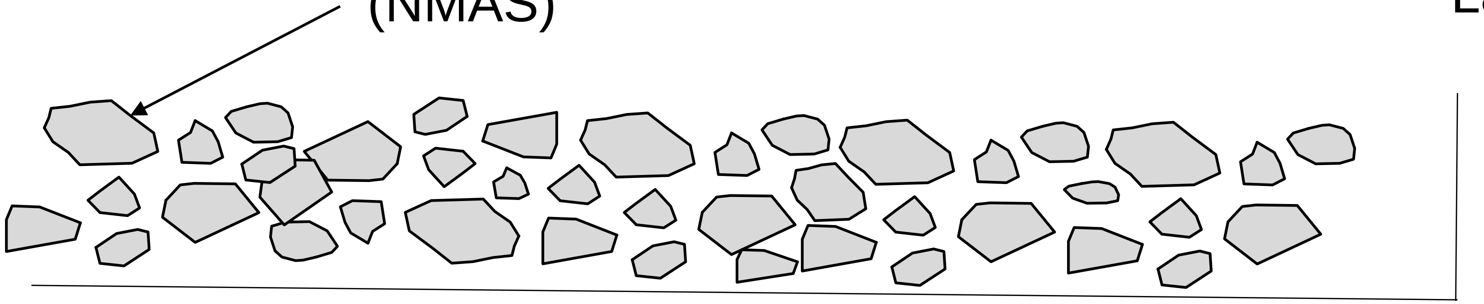
Relationship between lift thickness and aggregate size

Nominal Maximum Aggregate Size (NMAS)

Layer Thickness (t)

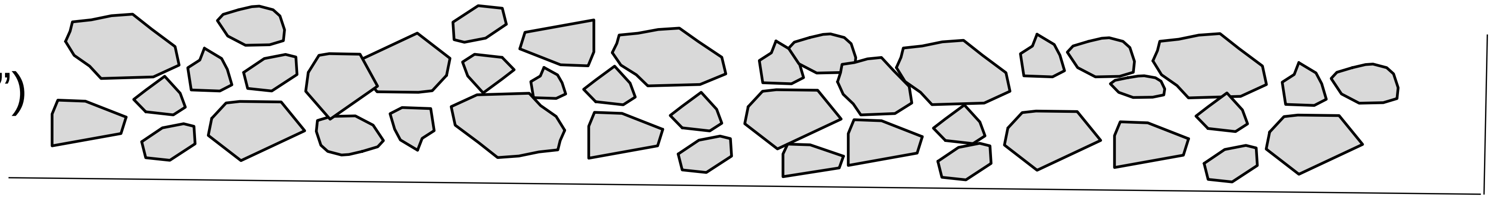
NMAS = 12.5 mm (1/2”)



2.0”

$$\frac{t}{NMAS} = \frac{2.0\ in}{0.5\ in} = 4.0$$

NMAS = 12.5 mm (1/2”)



1.5”

$$\frac{t}{NMAS} = \frac{1.5\ in}{0.5\ in} = 3.0$$

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Relationship between lift thickness and aggregate size

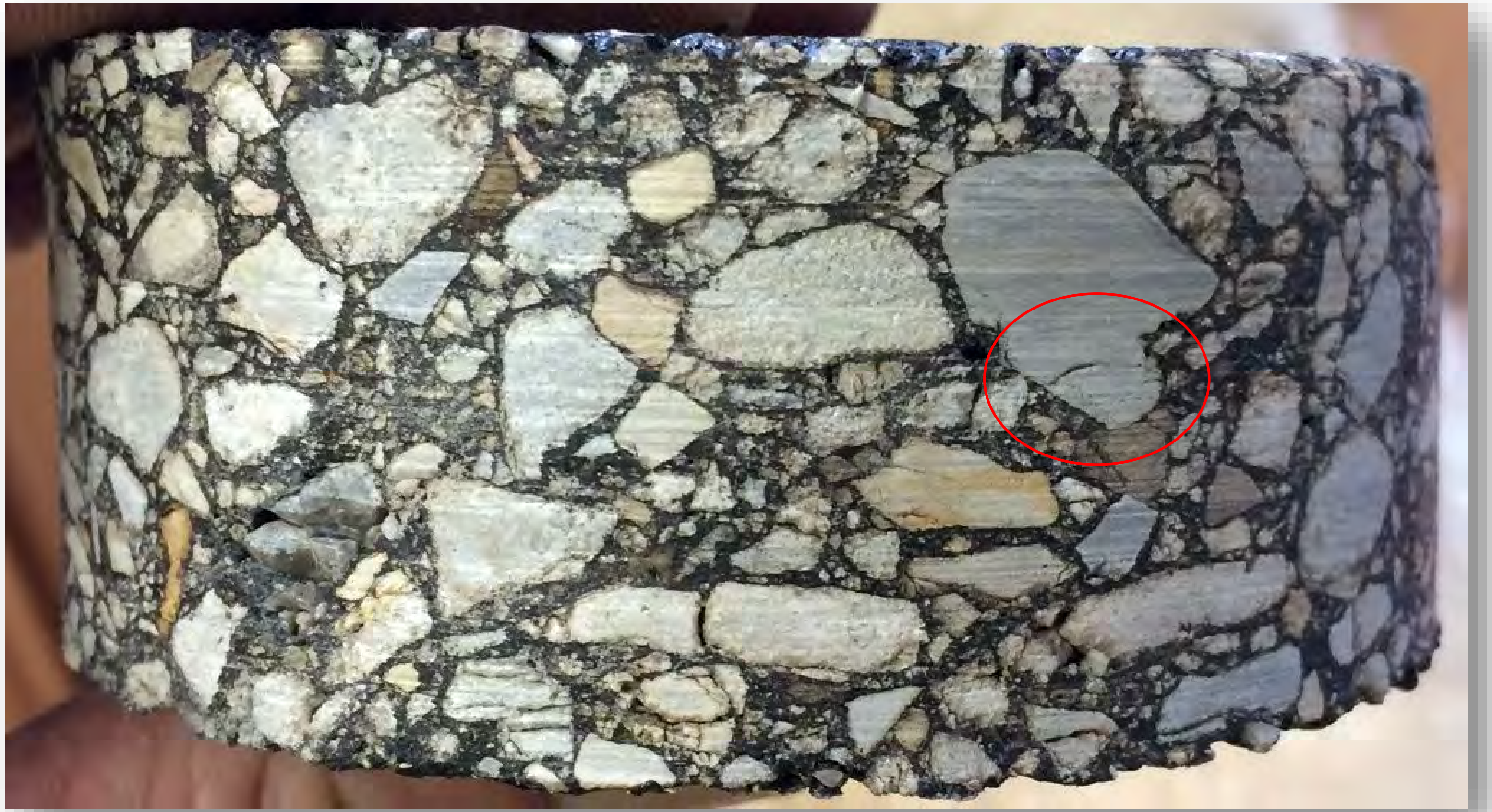
Cores at 2” thickness

95.5% of G_{mm}

Relationship between lift thickness and aggregate size

Cores at 1.75” thickness

93.0% of G_{mm}



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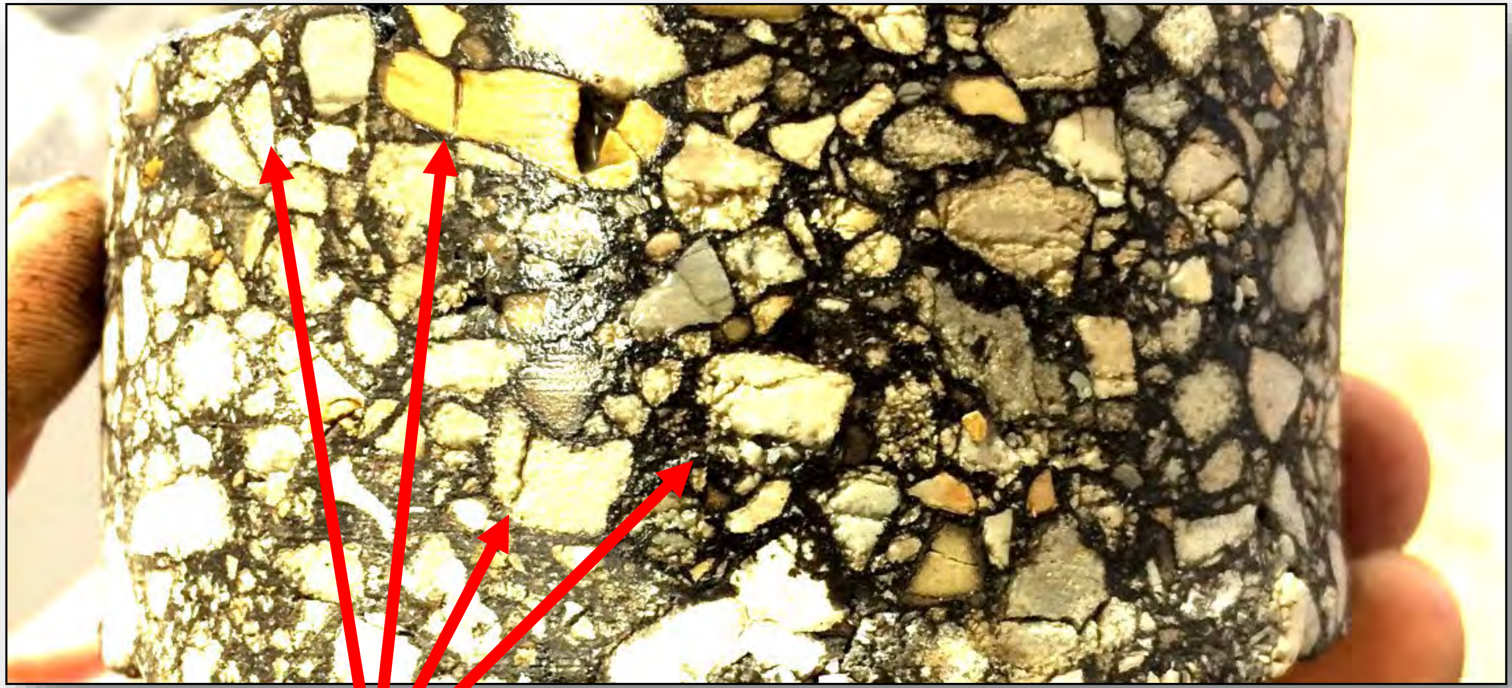
Relationship between lift thickness and aggregate size

Cores at 1.5” thickness

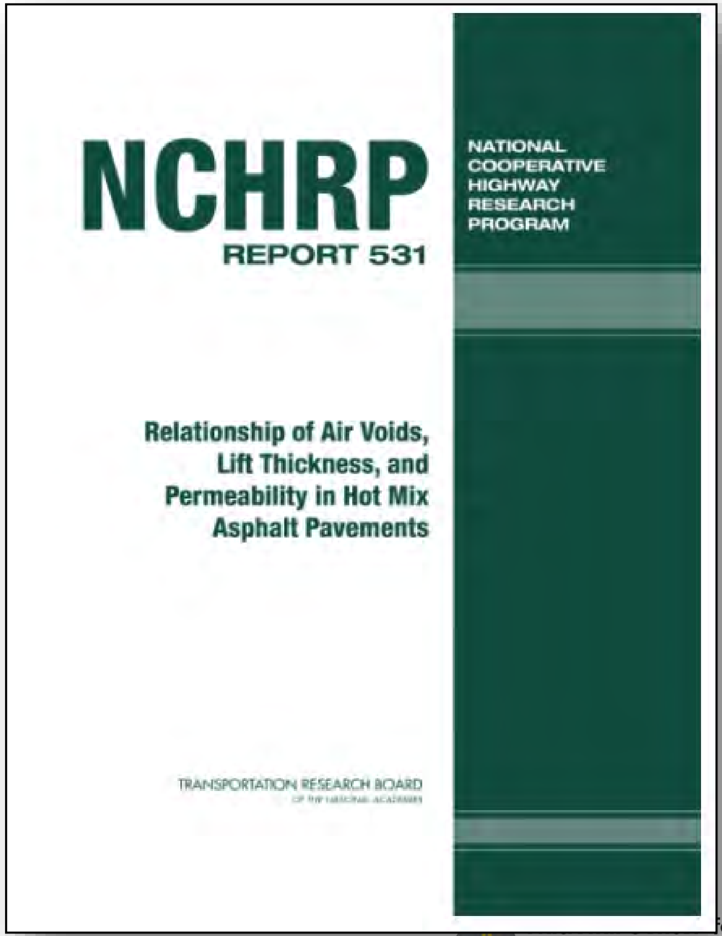
92.2% of G_{mm}



Broken aggregate

NCHRP Project 09-27

- For improved compactibility, it is recommended that the t/NMAS be:
- ≥3 for fine-graded mixes
- ≥4 for coarse-graded mixes.
- The results of the evaluation of the effect of mix temperature on the relationship between density and t/NMAS indicate that one of the reasons for low density at thinner sections (lower t/NMAS) is the *more rapid cooling of the mixture*.



Three Stages of Rolling

- Breakdown Rolling
- Intermediate Rolling
- Finish Rolling

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Types of Rollers

- Static Steel Wheel
- Pneumatic – Rubber Tired
- Vibratory Steel Wheel
- Oscillating Roller

Breakdown Rolling

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Oscillating Roller

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Vibratory Rollers

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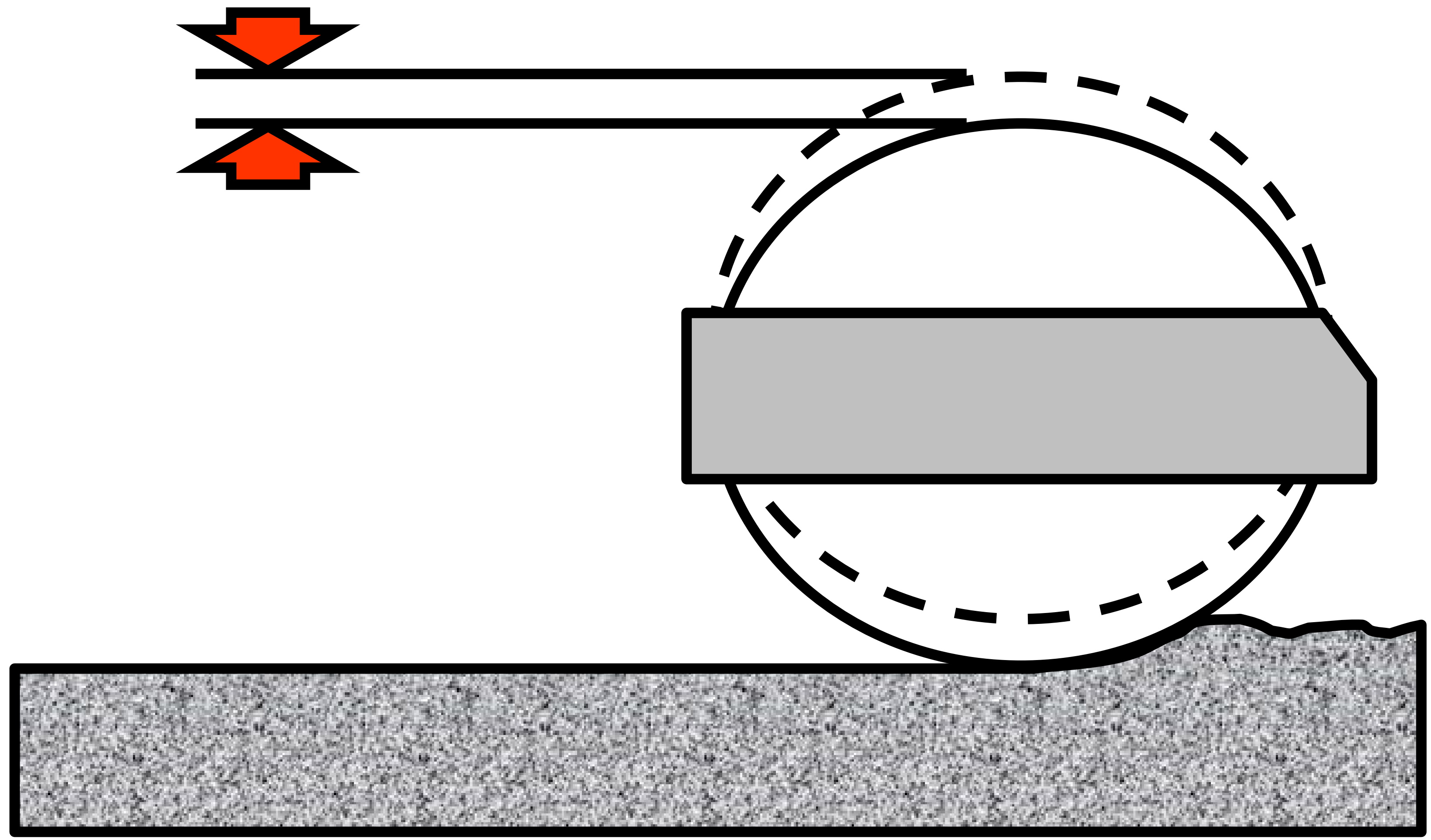
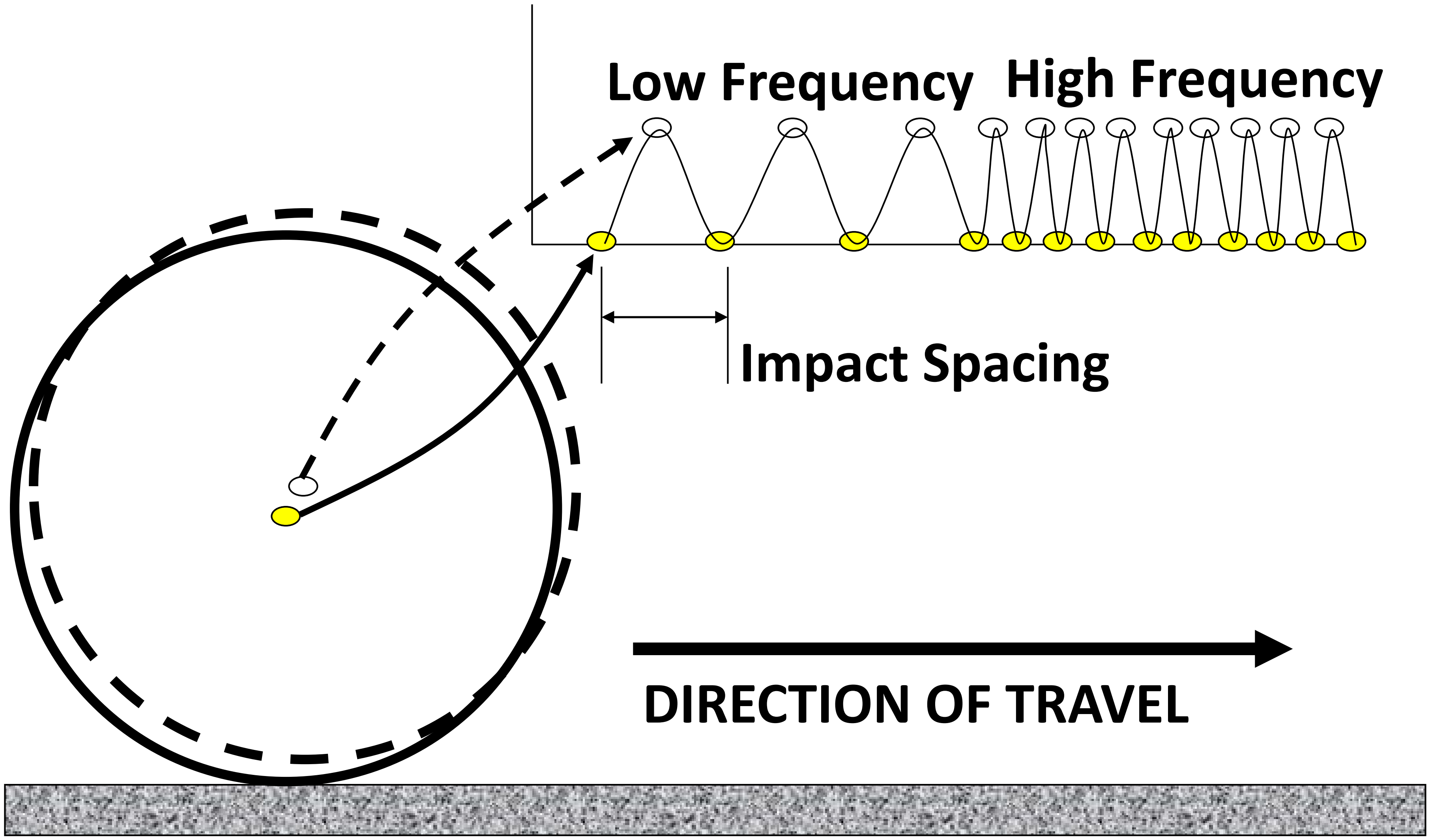
Amplitude



Frequency


Low Frequency
High Frequency
Impact Spacing
DIRECTION OF TRAVEL

Breakdown Rolling

- Vibratory Roller or Oscillating Roller
- Static Steel Wheel Roller
- Rubber Tired Roller (sometimes used for tender mixes)

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Keep Breakdown Roller Close To Paver

Make sure to always wear the required PPE and follow all safety requirements!

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Check Cracking Sometimes Occurs when Rolling with Steel Wheel Rollers

Intermediate Rolling

- Vibratory Roller
- Rubber Tired Roller

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Rubber Tire Rollers help Obtain Adequate Density

Rubber Tire Rollers Are Good for Tender Mixes & PCC/HMA Interface

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Skirts keep Tires Hot and Minimize Pick-up

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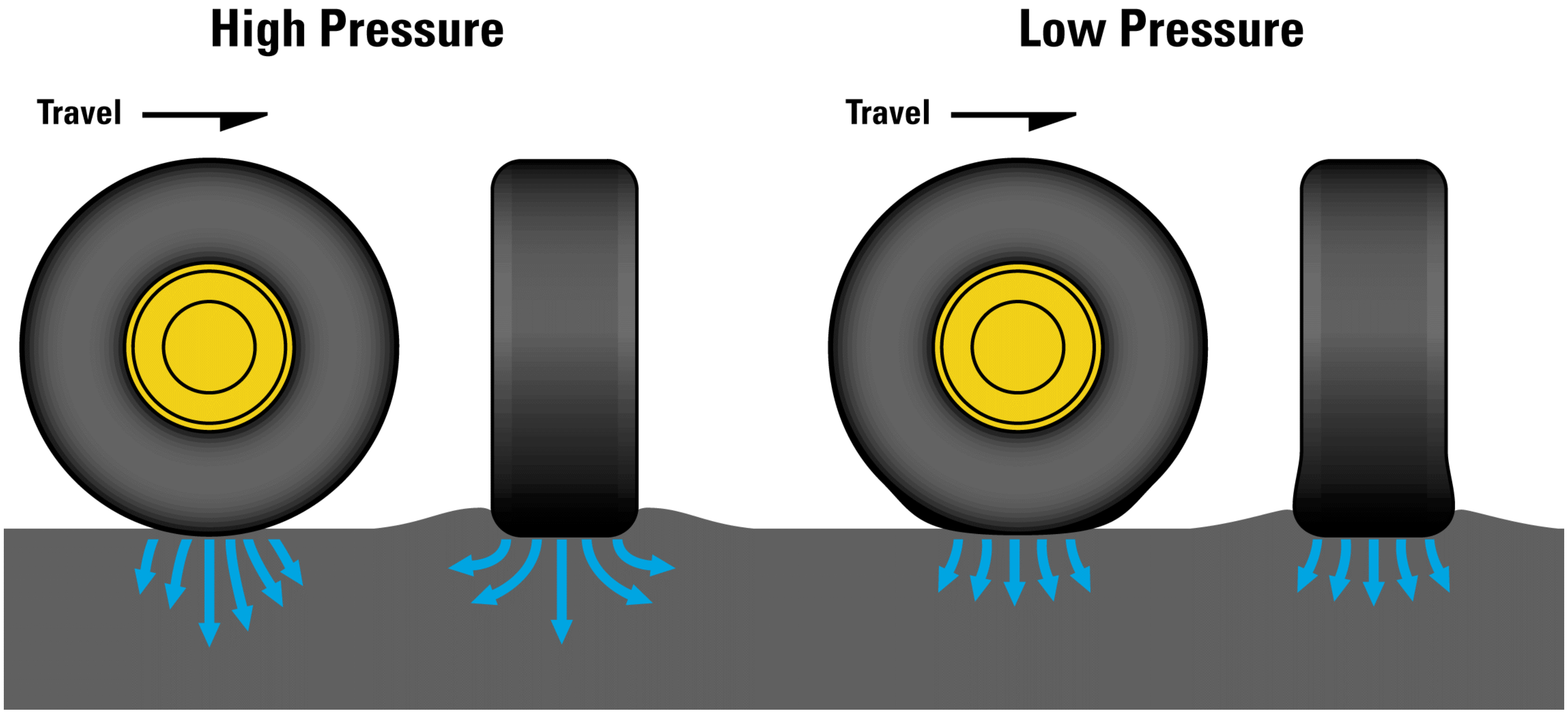
Tire Inflation Pressure Versus Ground Contact Pressure



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Rubber Tire Rollers are Good for Compacting Joints

Rubber Tire Rollers do Tend to Pickup if Operated Incorrectly

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Pads Must Be in Good Condition

Finish Rolling in Static Mode

Primary purpose of finish rolling is to roll out roller marks and other imperfections in the finished surface.

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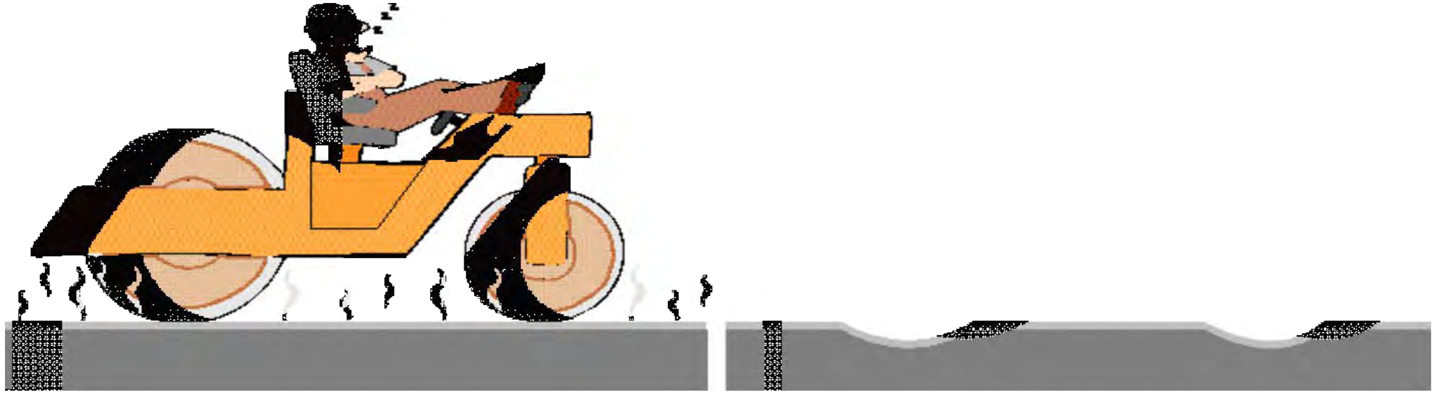
Do Not Park The Roller On A Hot Mat!!



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Excessive Roller Marks

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Several Rollers May Be Required

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Compaction Difficulties

- Some mixes are more difficult to compact than other mixes
- Generally, low asphalt content mixes and stiff mixes are more difficult to compact
- Stiff mixes can be due to:
  - Use of angular aggregate
  - High RAP or RAS contents
  - Modified binders
- Tender mixes – mixes that want to push and shove:
  - Too much natural sand or rounded aggregate
  - Excessive fluids content (binder and moisture)
  - Use rubber tire roller in intermediate position

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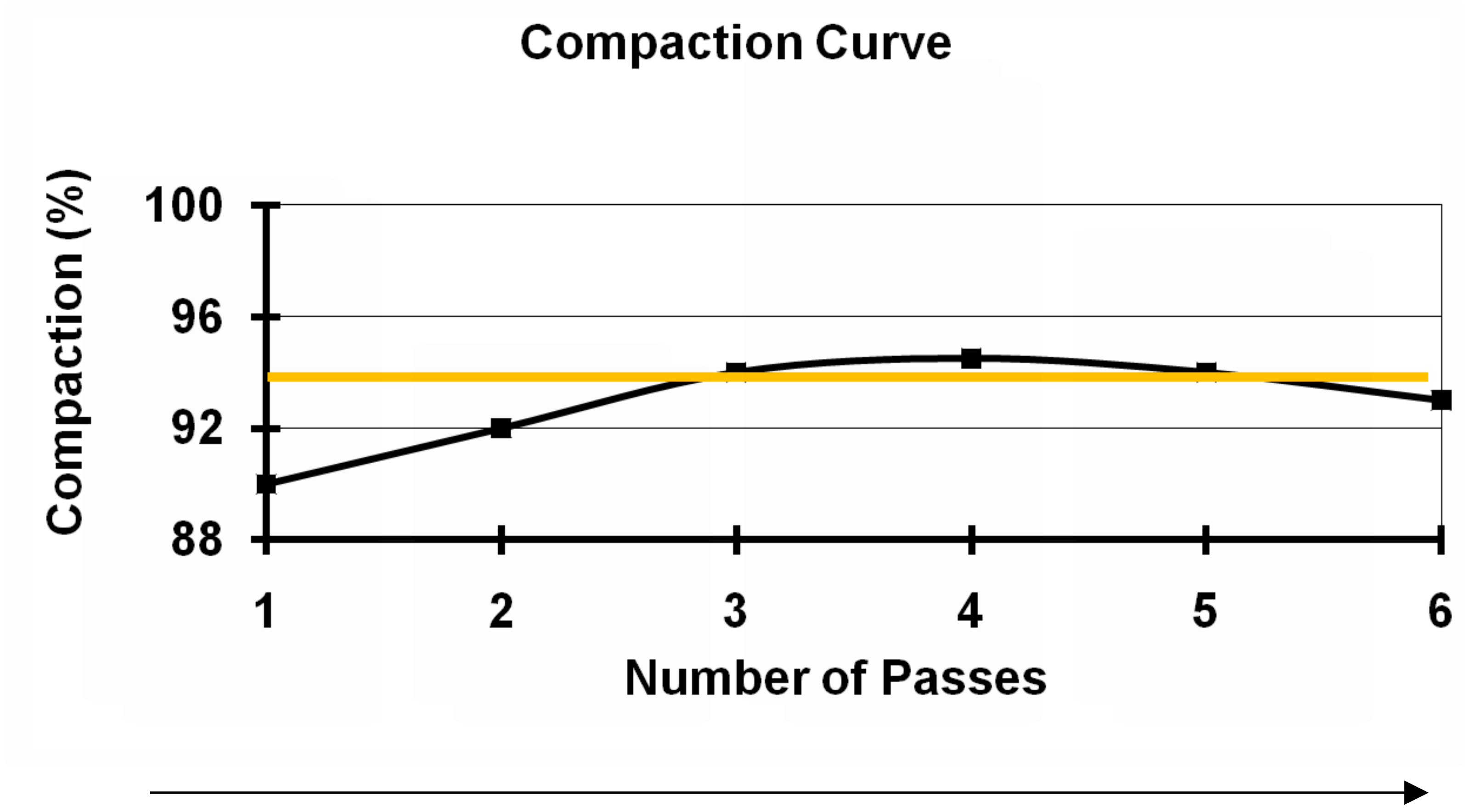
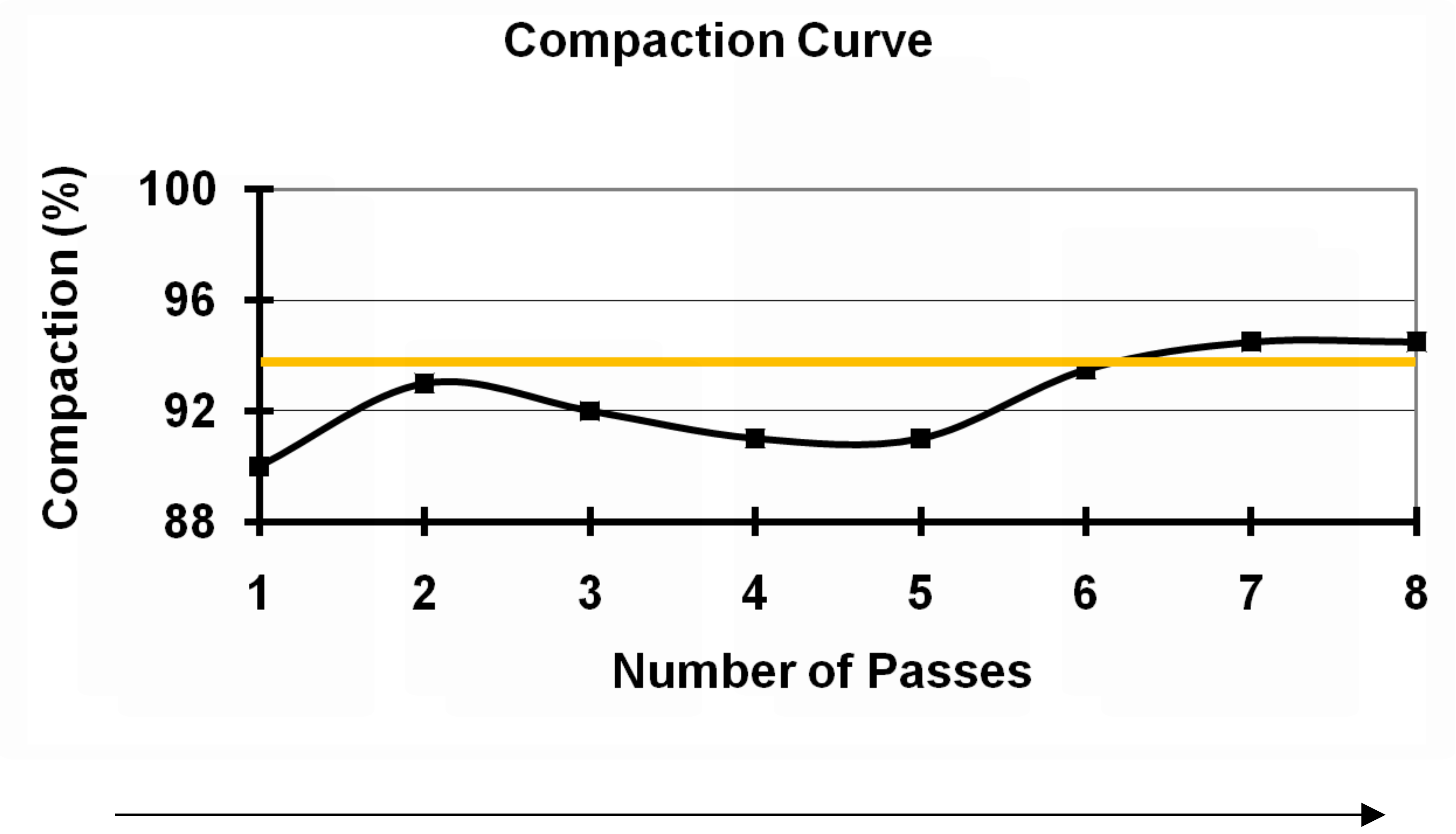
Roller Patterns



Decreasing Temperature

Roller Patterns



Decreasing Temperature

Good Surface and Density

Compaction Checklist

- Satisfactory Rollers
- Rolling Techniques – Pattern, Speed, Operation
- Thickness to Aggregate Size
- Joints
- Mix Properties
- Mix Temperature
- Air Temperature
- Density Control

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Questions