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# Enhanced Durability Through Increased In-Place Pavement Density

## FHWA—AI Cooperative Initiative

U.S. Department of Transportation
Federal Highway Administration

Federal Highway Administration
RESOURCE CENTER

# Workshop Outline

1. Introduction
2. Mixture Factors Effecting Compaction
3. Compaction Best Practices
4. Other Best Practices
5. Measurement & Payment
6. New Technologies
7. Wrap Up

# Premise:

- ✓ Compaction is essential for long-term pavement performance
- ✓ There are many compaction enhancements currently in use
- ✓ Compaction goals can be improved

# Current Technologies that Influence Compaction…

# Asphalt Pavement Compaction

Typical Asphalt Pavement Density requirements are based on ***what was achievable yesterday***.

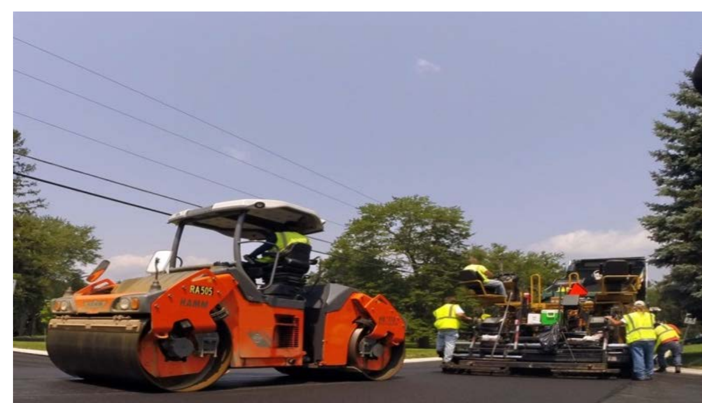
Today we have made ***significant advancements*** in material and construction technology and techniques.

Today we are **also placing more and more materials** containing higher levels of recycled, reclaimed, and reuse (RRR) products.

**Challenge:** Can we use today's technology and techniques to ***raise-the-bar on in-place density*** to improve durability and thus extend pavement service-life?

# Enhanced Durability through Increased In-Place Pavement Density

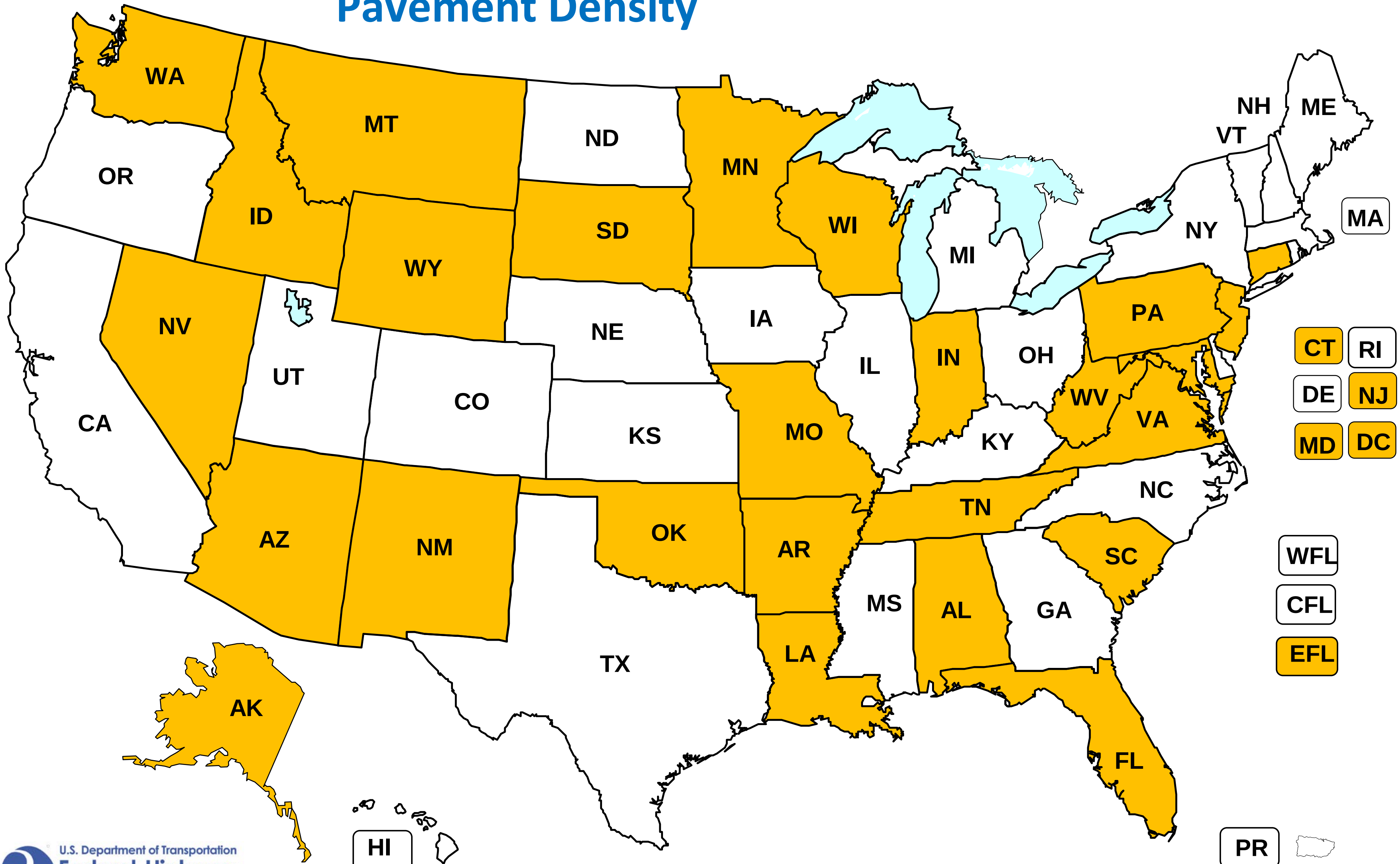
- Assumption – Pavement density can be increased with a minimum of additional cost
- Long-Term Objective – States will increase their in-place asphalt pavement density requirements resulting in increased pavement life



# Enhanced Durability of Asphalt Pavements through Increased In-Place Pavement Density

**Workshops**

28 States

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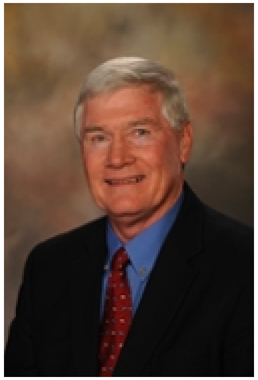
# Importance of Compaction

# Importance of Compaction

"Compaction is the single most important factor that affects pavement performance in terms of durability, fatigue life, resistance to deformation, strength and moisture damage." – C. S. Hughes, NCHRP Synthesis 152, *Compaction of Asphalt Pavement*, (1989)



"The amount of air voids in an asphalt mixture is probably the single most important factor that affects performance throughout the life of an asphalt pavement. The voids are primarily controlled by asphalt content, compactive effort during construction, and additional compaction under traffic." – E. R. Brown, NCAT Report No. 90-03, *Density of Asphalt Concrete—How Much is Needed?* (1990)

# Four Million Miles of Roads in US

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Federal = 3%

State = 20%

Local = 77%

2/3 are Paved (1/3 Unpaved)

94% of Paved have an Asphalt Surface

**+2.5 Million Miles of Asphalt Roads!**

Source: FHWA 2011

# Budgets vs. Needs

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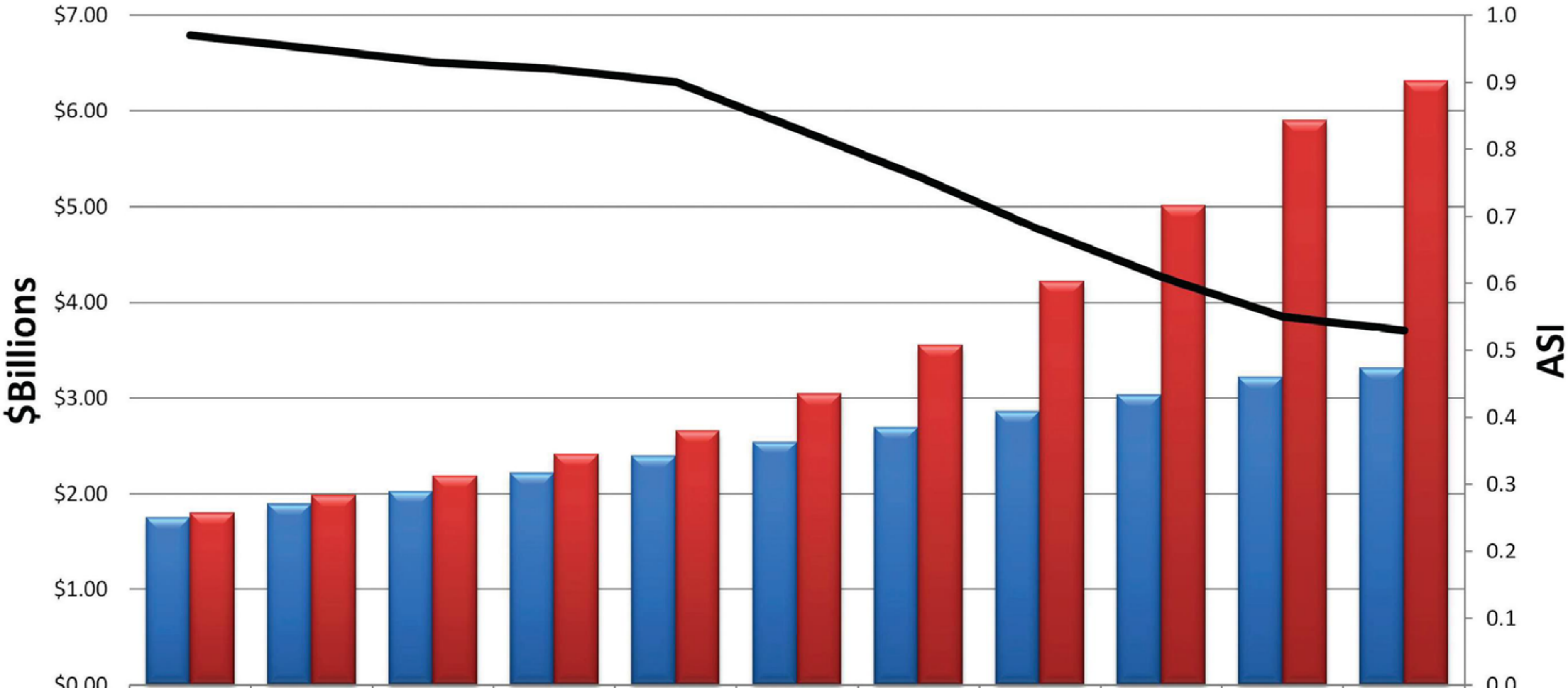
## Simplified Asset Sustainability Index




| | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | 2014 | 2016 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Budget | $1.75 | $1.89 | $2.03 | $2.21 | $2.39 | $2.54 | $2.70 | $2.86 | $3.03 | $3.22 | $3.31 |
| Need | $1.80 | $1.98 | $2.19 | $2.41 | $2.66 | $3.04 | $3.55 | $4.22 | $5.01 | $5.90 | $6.31 |
| ASI | 0.97 | 0.95 | 0.93 | 0.92 | 0.90 | 0.83 | 0.76 | 0.68 | 0.61 | 0.55 | 0.53 |

Budget  Need  ASI

Source: FHWA 2013

# Durability Concerns

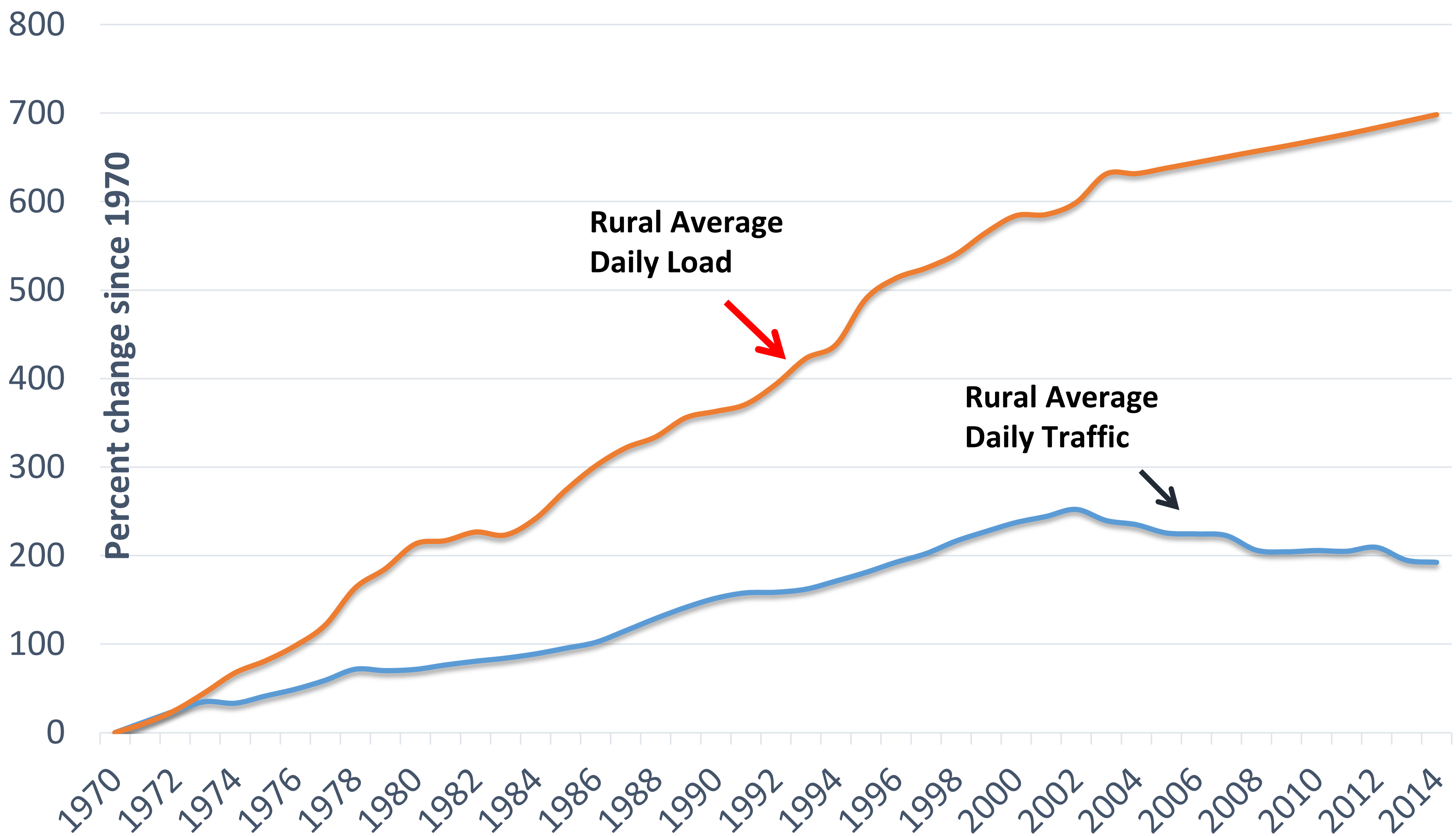
- SAPA's, AI, and NAPA all concerned with durability
  - Need for more binder in the mix
- Many DOT's looking for ways to improve durability
  - Minimum binder contents
  - Optimize mix designs
  - Balance rutting with fatigue

Improved density typically not considered

# Evolution of Traffic


- Interstate highways - 1956
- AASHO Road Test - 1958-62
  - still widely used for pavement design
  - legal truck load - 73,280 lbs.
- Legal load limit to 80,000 lbs. - 1982
  - 10% load increase
  - 40-50% greater stress to pavement
- Radial tires, higher contact pressure
- FAST Act raising load limit to 120,000 lbs. (in select locations)

# Growth in Traffic Volumes and Loadings on the Rural Interstate System




Source: FHWA Highway Statistics 2014

# Led to Rutting in 1980s

# Which led to…Superpave

- Fixed the rutting problem
- Gyratory compaction lowered binder contents
- Add in higher and higher recycled materials?

# Reasons for Compaction

- To minimize prevent further consolidation
- To provide shear strength and resistance to rutting
- To improve fatigue cracking resistance
- To improve thermal cracking resistance
- To ensure the mixture is waterproof (impermeable)
- To minimize oxidation of the asphalt binder

**Compaction also provides a smooth, quiet driving surface**

**All are elements of durability**

# Improved Compaction = Improved Performance

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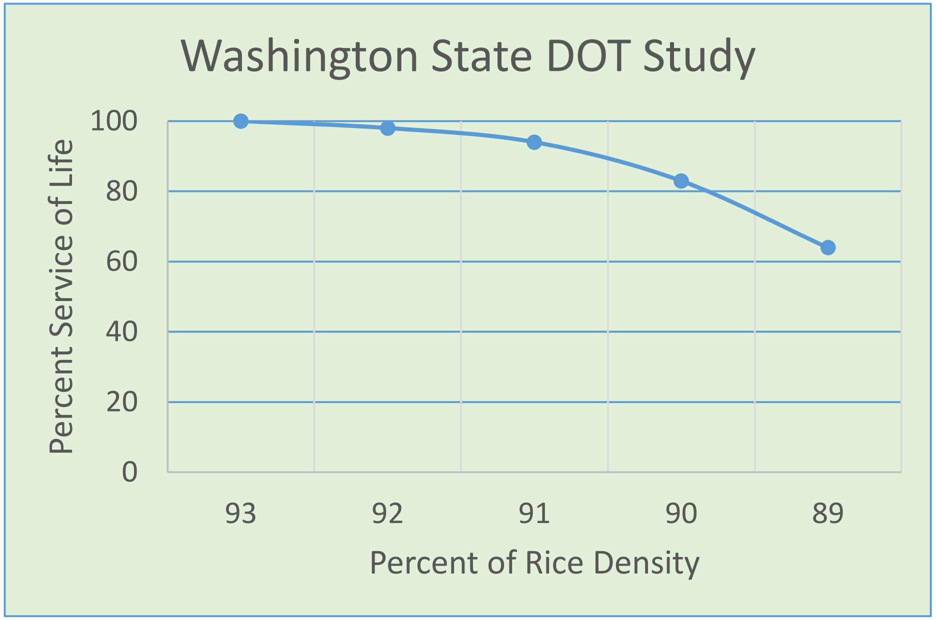
A BAD mix with GOOD density out-performed a GOOD mix with POOR density for ride and rutting.

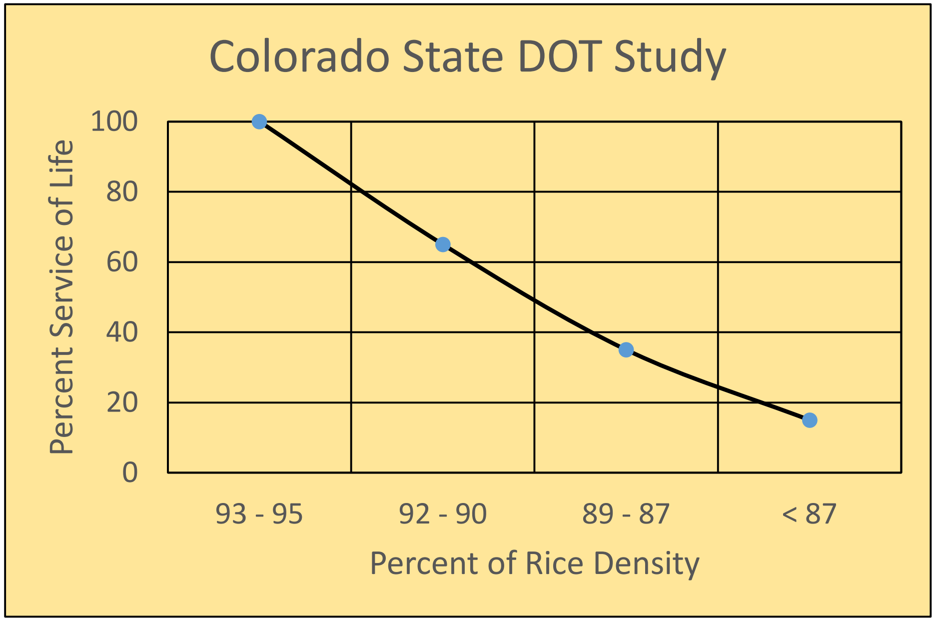

WesTrack Experiment

# Density vs. Loss of Pavement Service Life




Thicker Pavements

TRR 1217, 1989

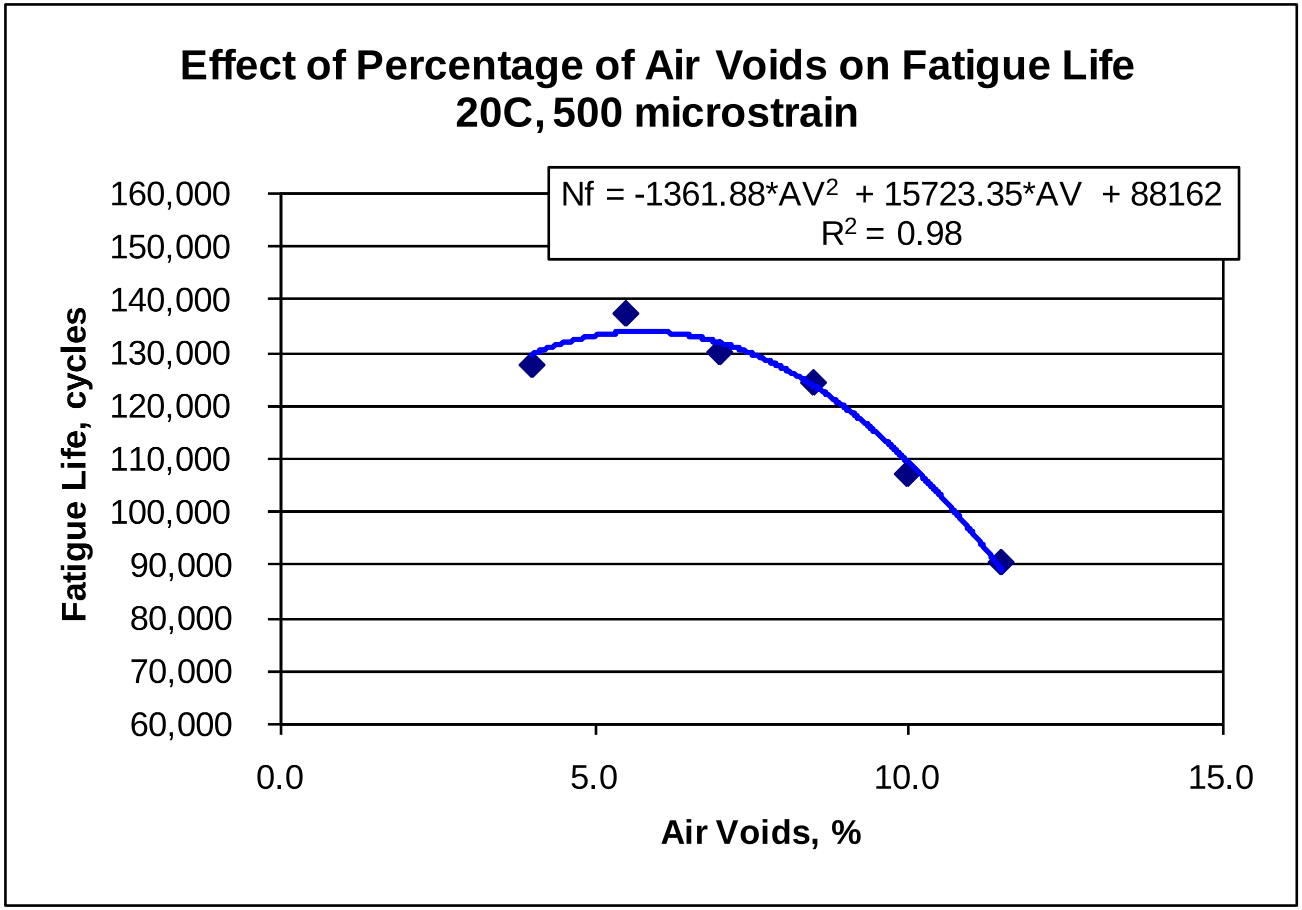



Typical Pavements

CDOT 2013-4, 2013

For both thicker and thinner, reduced in-place density at the time of construction results in significant loss of Service Life!

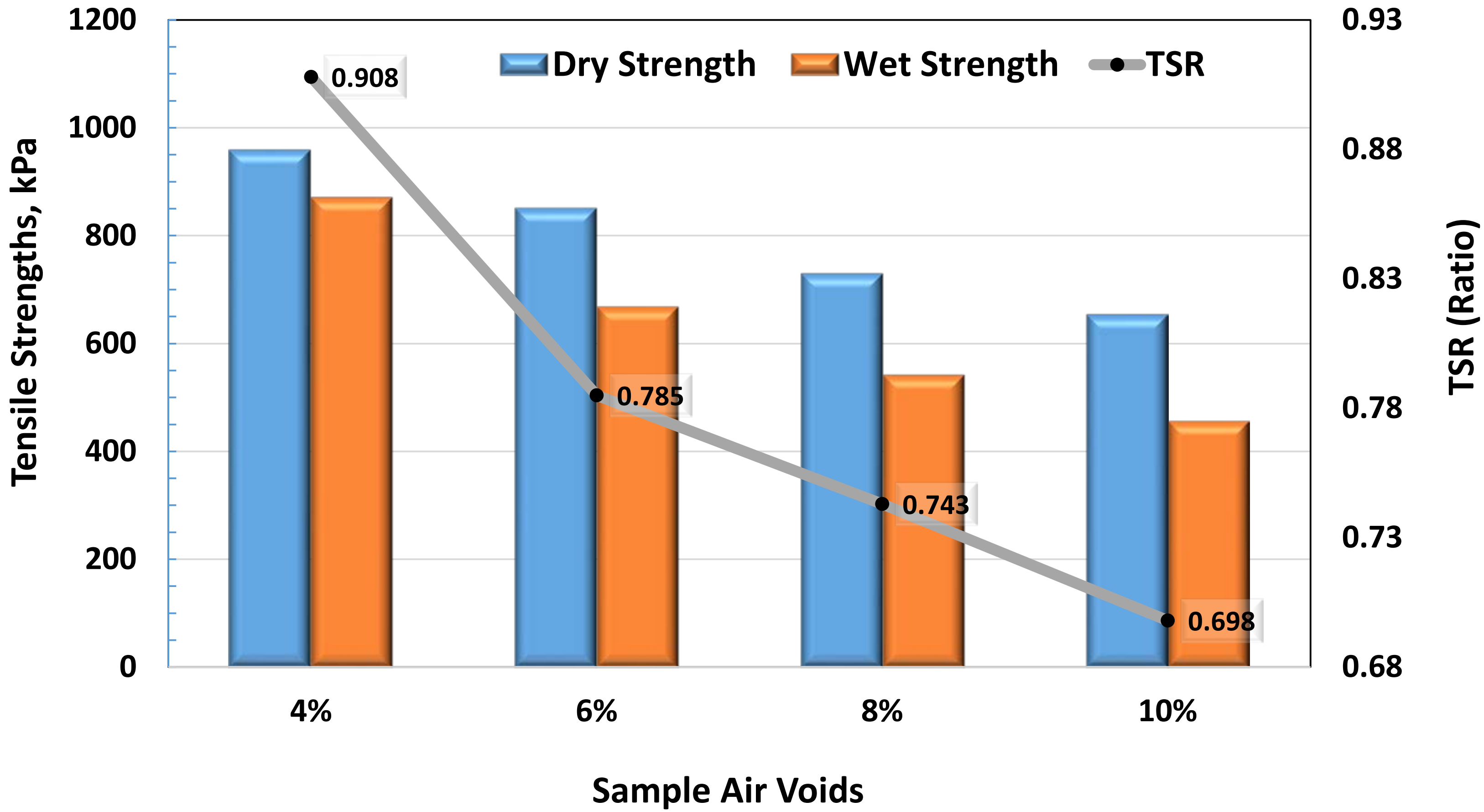
# In-Place Voids vs Fatigue Life




**<u>UK-AI Study</u>**

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

# Tensile Strength & Moisture Susceptibility vs. Air Voids
# AASHTO T 283



# NCAT Report 16-02 (2016)

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## Literature Review on connecting in-place density to performance

- 5 studies cited for fatigue life
- 7 studies cited for rutting
- "A **1% decrease in air voids** was estimated to improve the fatigue performance of asphalt pavements between 8.2 and 43.8%, to improve the rutting resistance by 7.3 to 66.3%, and to **extend the service life by conservatively 10%**."

# Average Decrease in Rut Depth for 1% Decrease in Air Voids

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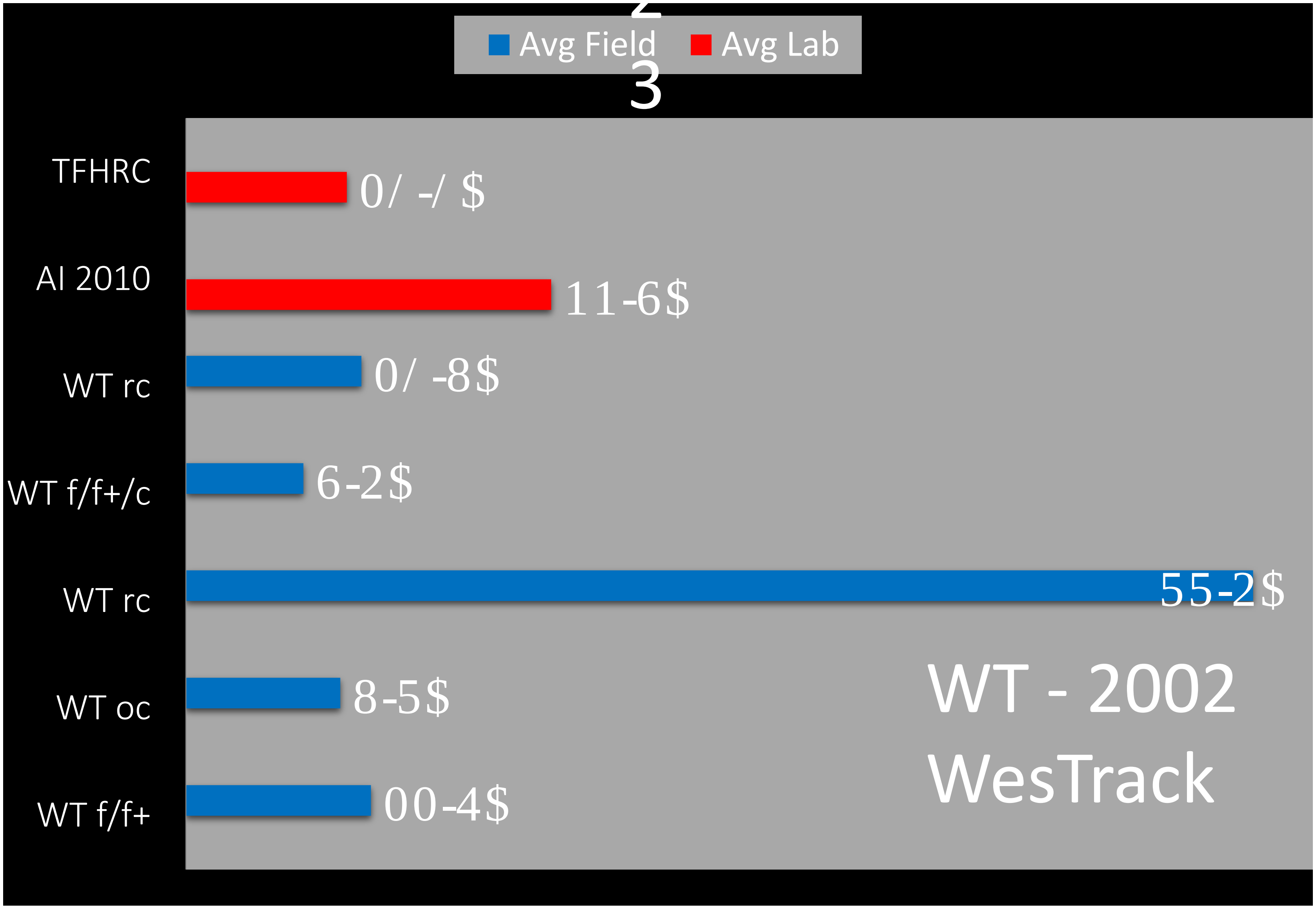
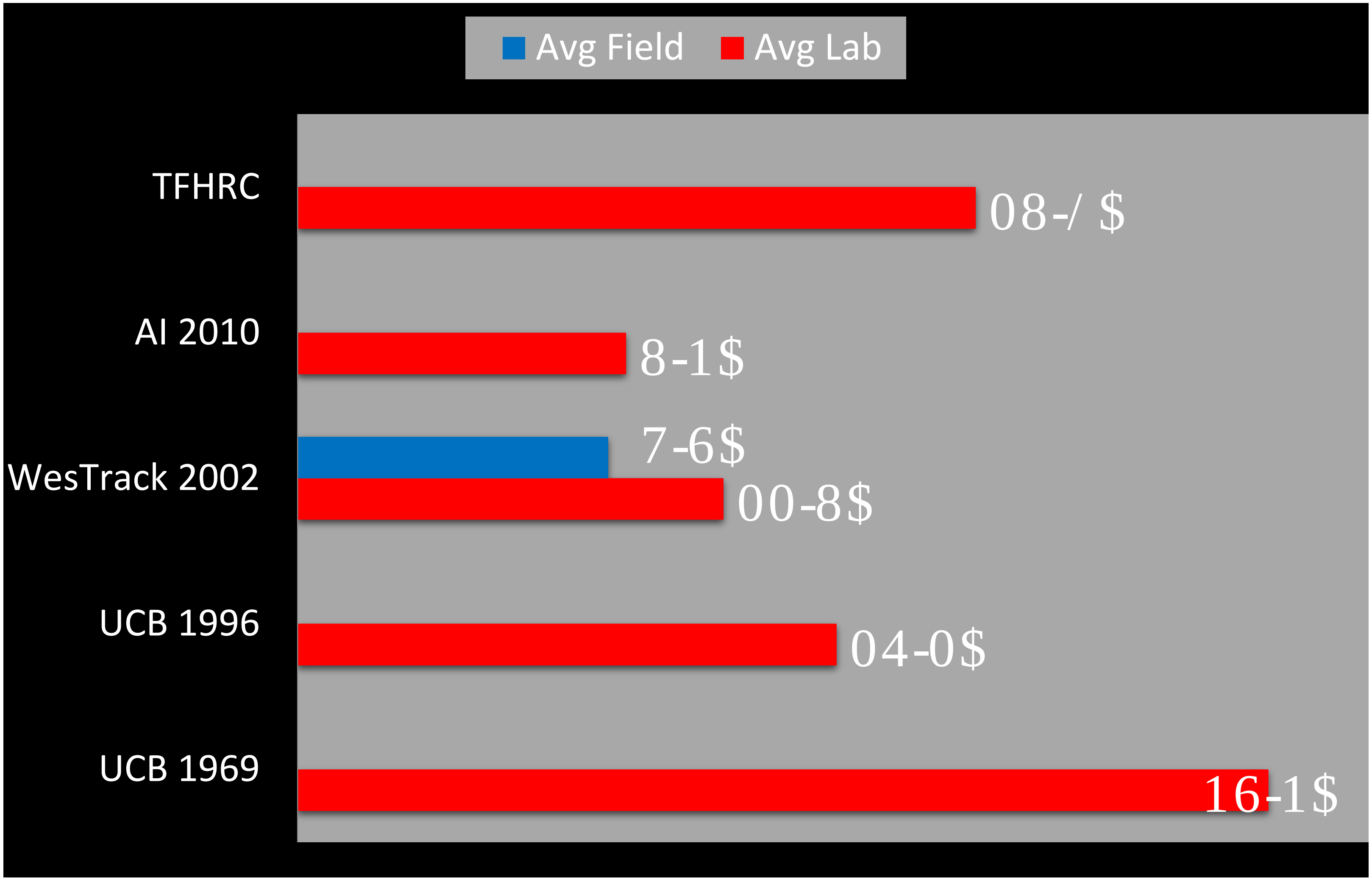
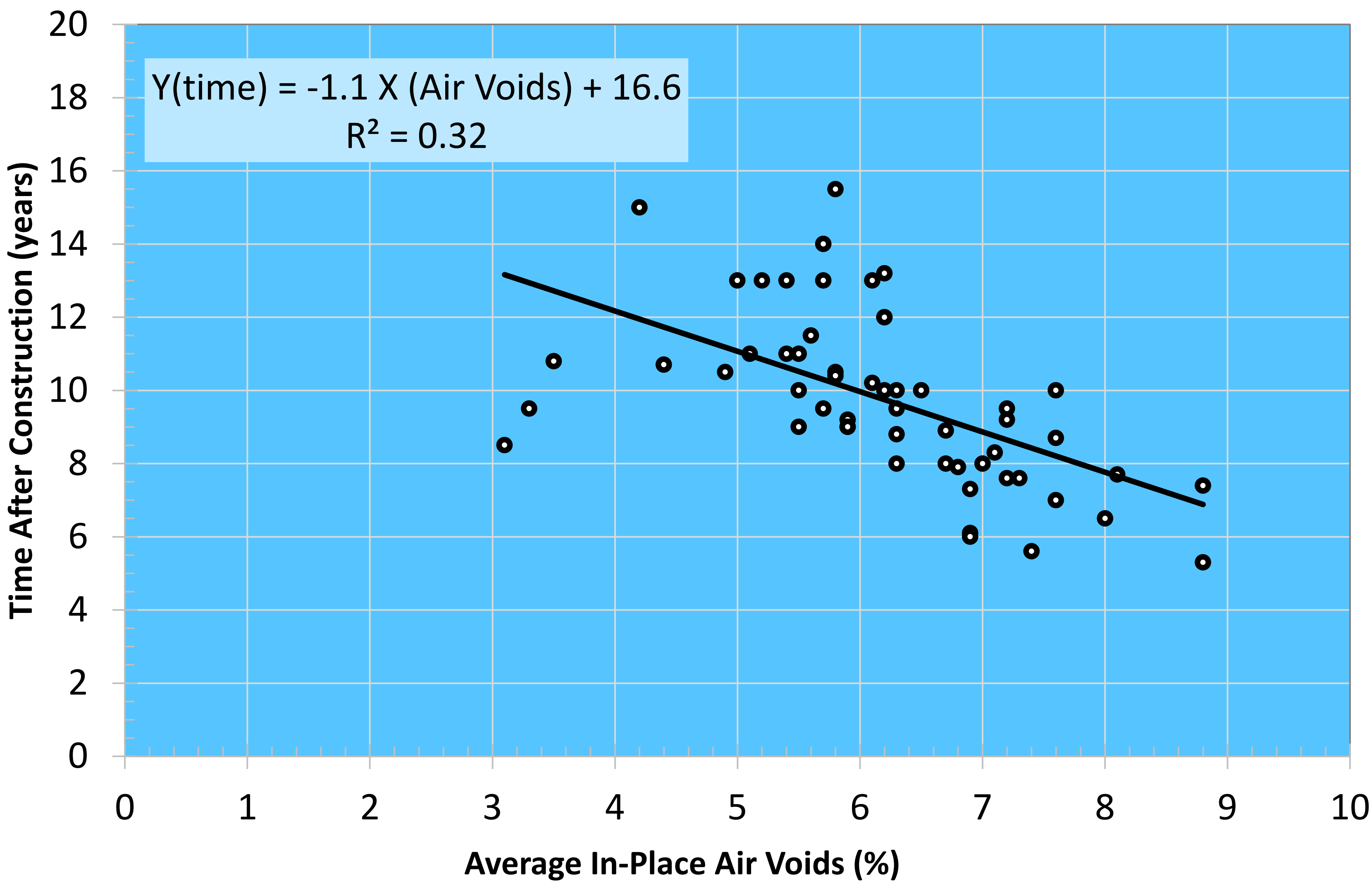


# Average Increase in Fatigue Life for 1% Decrease in Air Voids



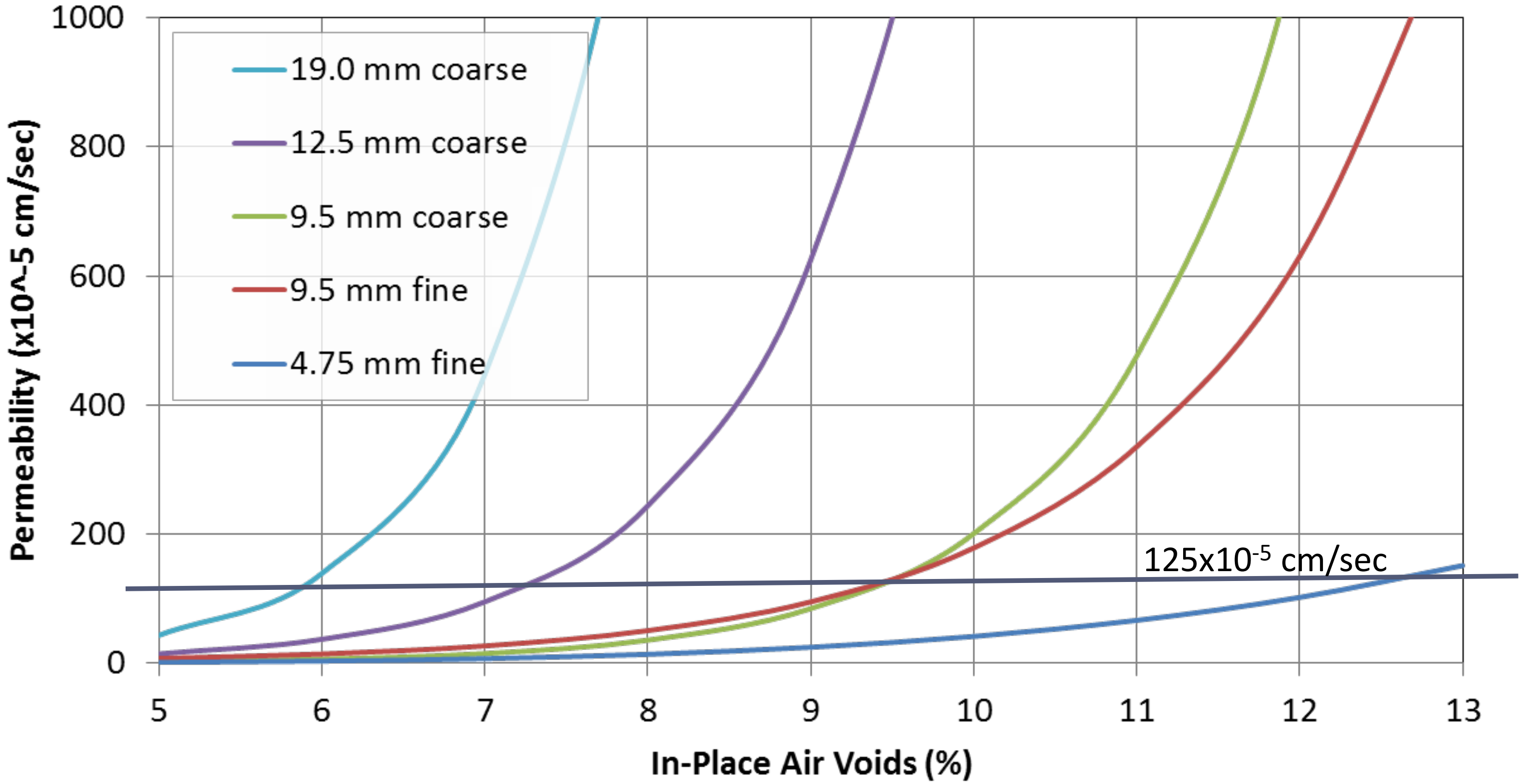
# Research from New Jersey



# …and then there's permeability

# Permeability can be Catastrophic

# NCAT Permeability Study



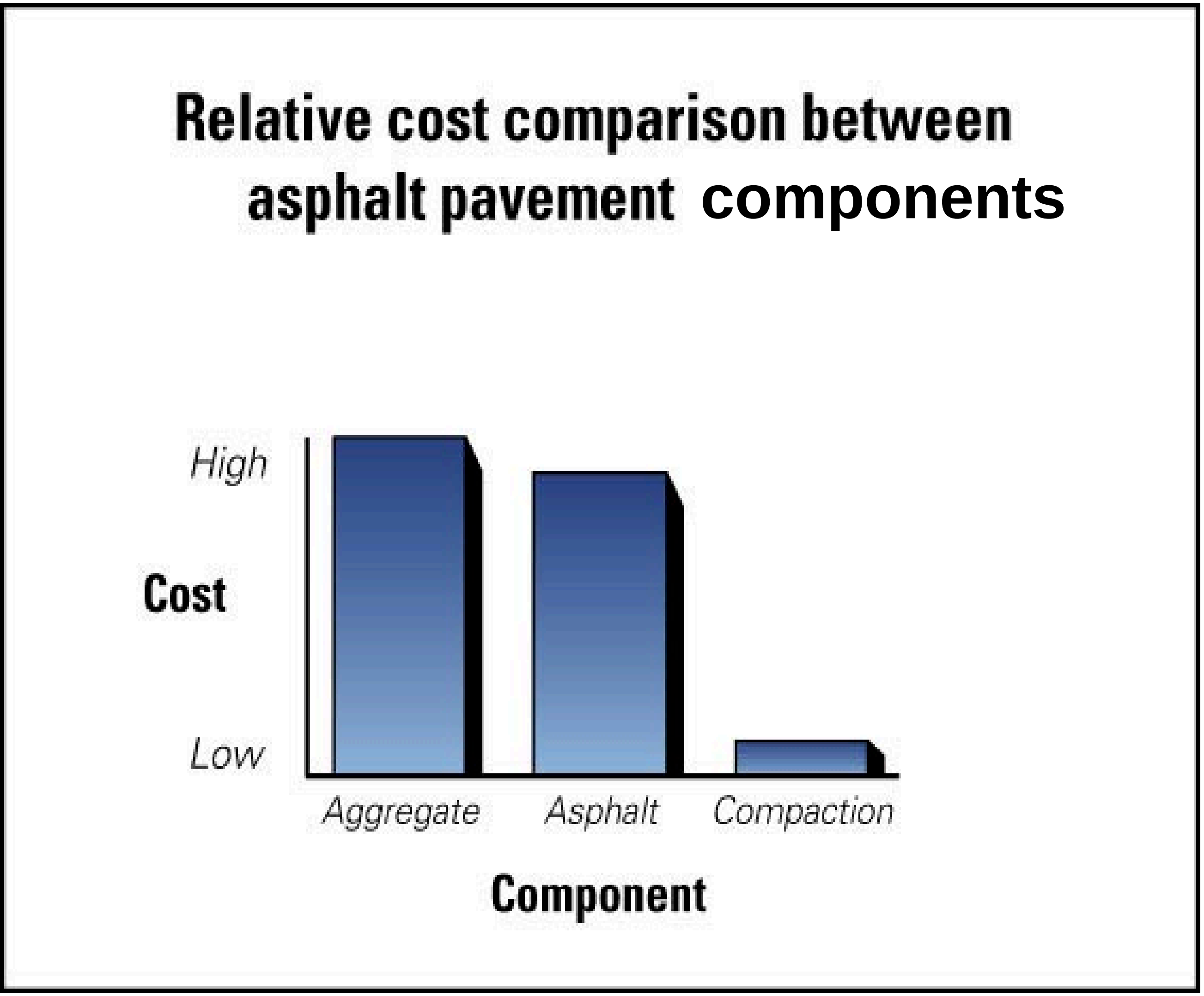

Finer NMAS mixes generally less permeable at equivalent air void levels!

From NCAT Report 03-02

# Research on Critical Air Void Level for Impermeability

**"…to ensure that permeability is not a problem, the in-place air voids should be between 6 and 7 percent or lower. This appears to be true for a wide range of mixtures regardless of NMAS and grading." – NCHRP 531**

# Cost of Compaction




- Least expensive part of the paving process
- Aggregates and binders are expensive in comparison
- Compaction adds little to the cost of a ton of asphalt

# Mixture Factors Affecting Compaction

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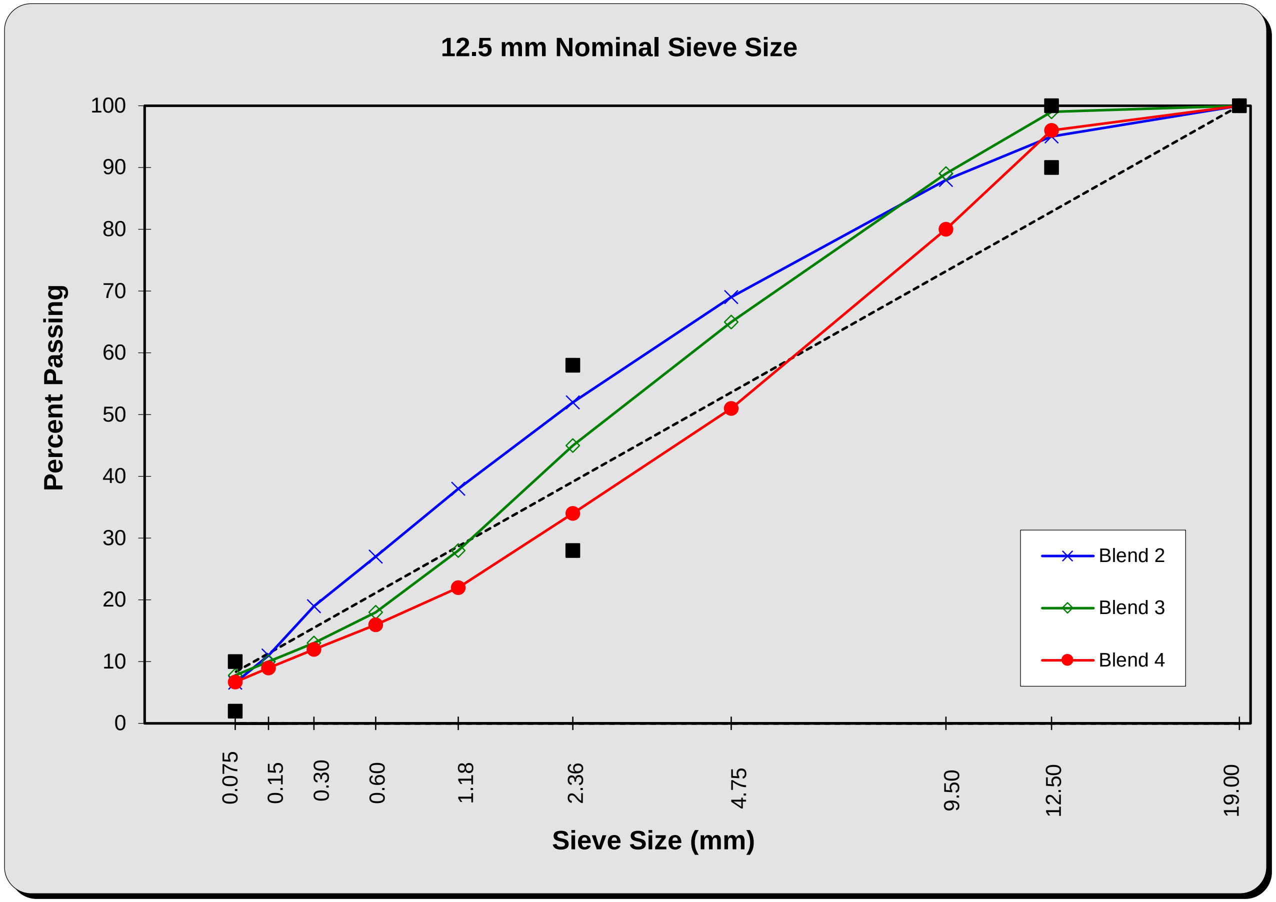
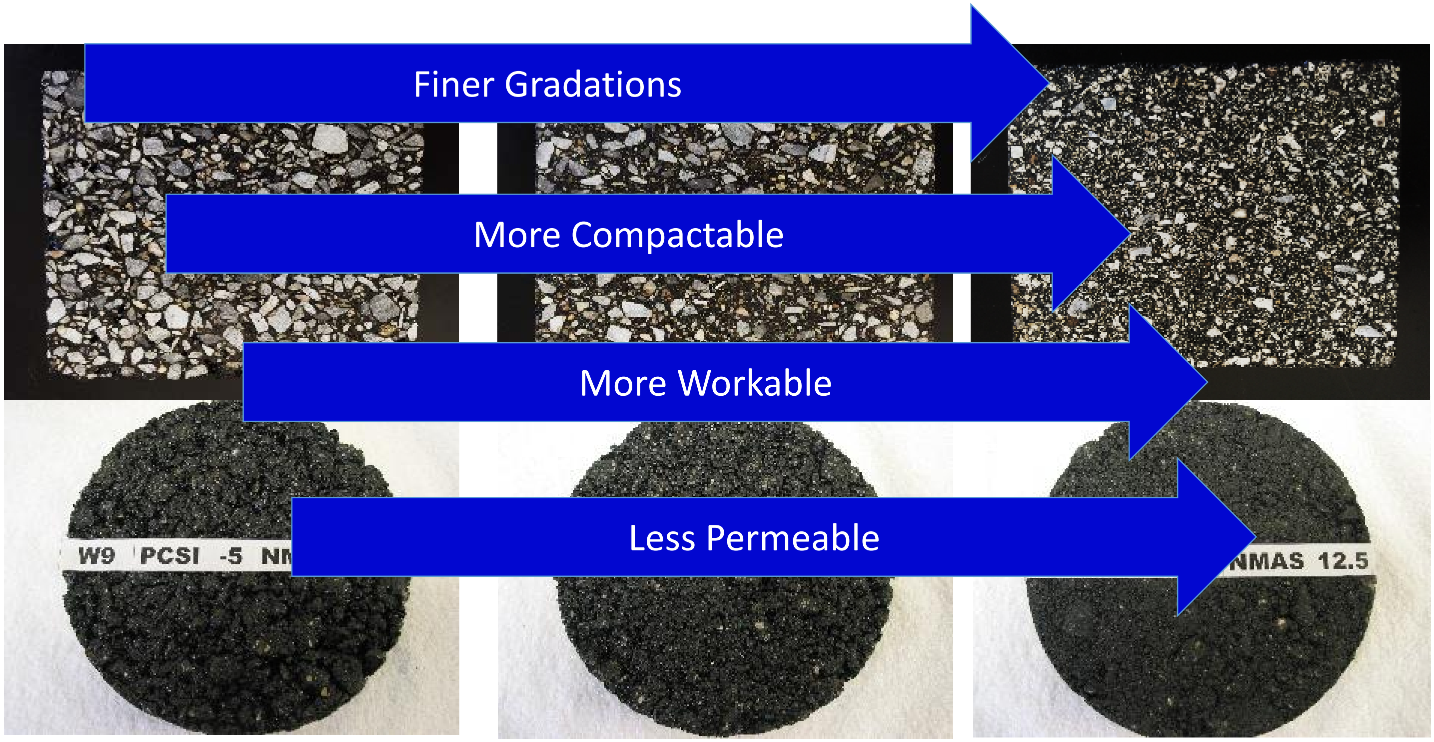
- Mix Properties
  - Aggregate
    - Gradation
    - Angularity
  - Asphalt Cement
    - Grade
    - Quantity
  - Volumetrics
    - Air Voids
    - VMA
    - VFA
  - Balancing a Mix

# Choosing a Gradation




Courtesy of NCAT

# Choosing a Gradation




Courtesy of NCAT

# NCAT Test Track 1st Cycle


Coarse, intermediate, and fine gradations. No differences in rutting performance!

Courtesy of NCAT

# Effect of Aggregate on Compaction

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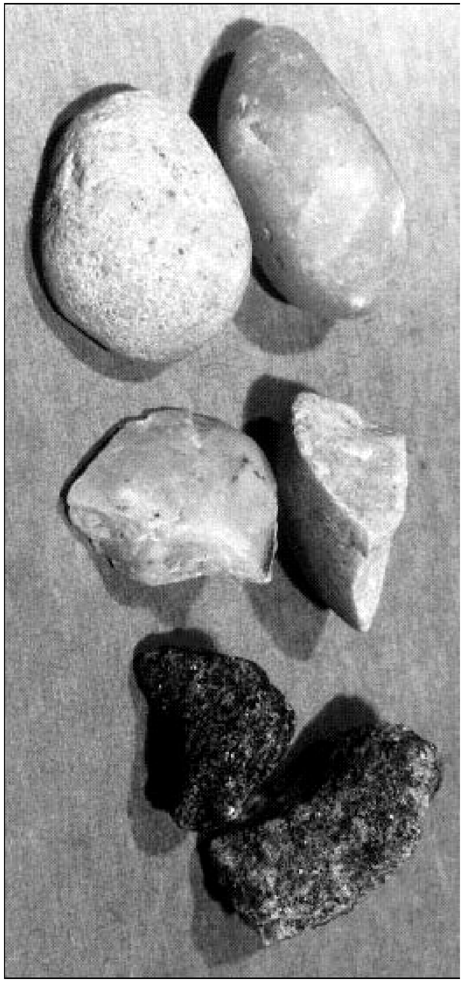
- **GRADATION**
  - continuously-graded, gap-graded, etc.
- **SHAPE**
  - flat & elongated, cubical, round
- **SURFACE TEXTURE**
  - smooth, rough
- **STRENGTH**
  - resistance to breaking, abrasion, etc.



# Effect of Binder on Compaction

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- **PERFORMANCE GRADE**
  - Binder grades that are "stiffer" at paving temperatures can make the mix more difficult to compact

- **MODIFIED BINDERS**
  - In general, the grades with modifier added tend to be stiffer and more difficult to compact.
  - The time available for compaction tends to decrease as the amount of modifier increases.

# Mix Design – Balancing Act

Smooth Quiet Ride
Skid Resistance

Strength/ Stability

Rut Resistance

Shoving

Flushing Resistant

Durability

Crack Resistance

Raveling

Permeability

# Balanced Mix Design

***ETG Definition*****: *“Asphalt mix design using performance tests on appropriately conditioned specimens that address multiple modes of distress taking into consideration mix aging, traffic, climate and location within the pavement structure.”***

***A mix design that is balanced for rutting and cracking resistance.***

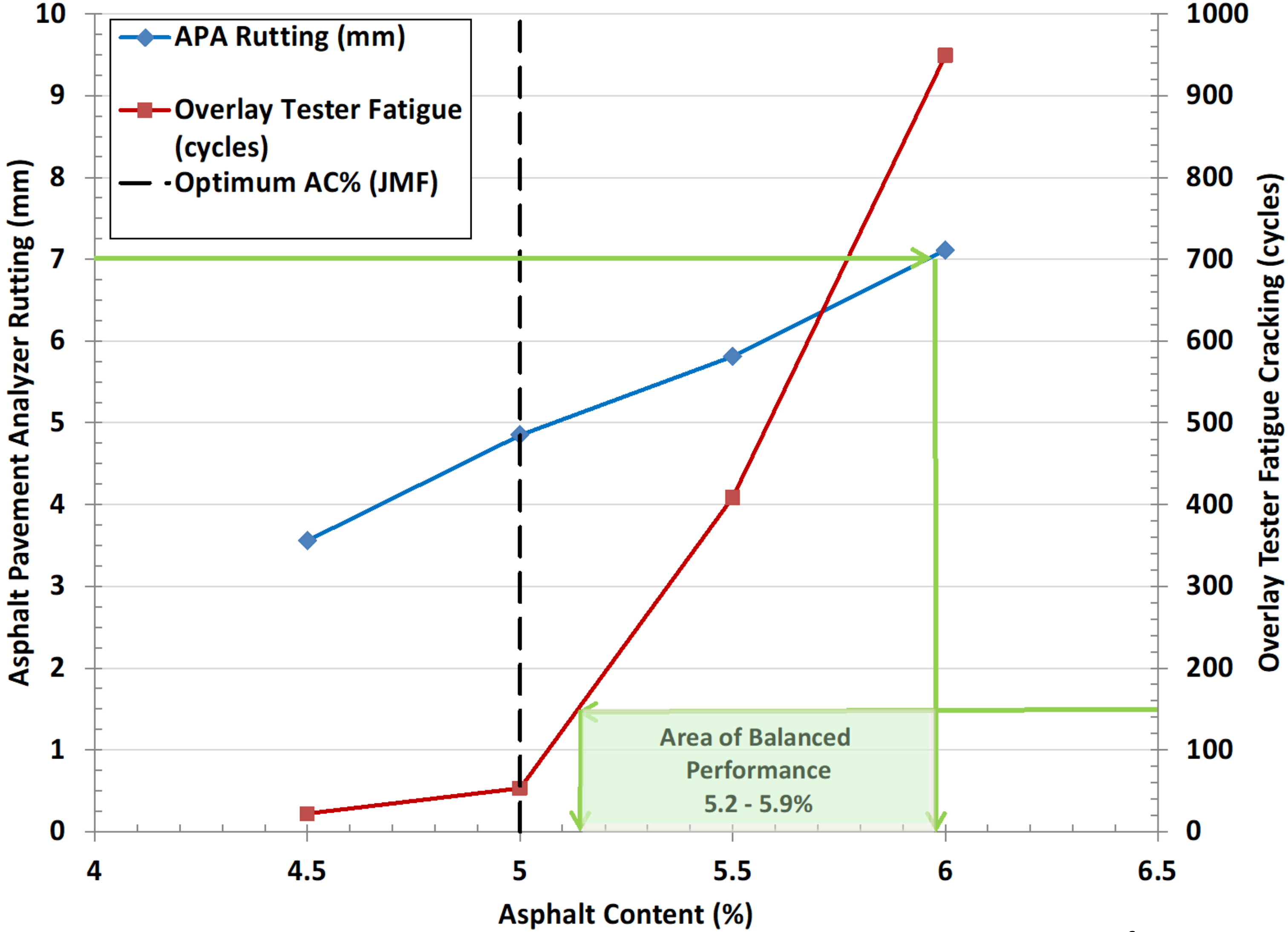
# Balanced Mix Design Approach

- General Procedure
  - Design and test mix for Rutting
  - Test mix for Cracking and/or Durability
  - Performance Testing
- States that are using this approach
  - Texas
  - Louisiana
  - New Jersey
  - Illinois
  - California
  - Wisconsin

# NJDOT/Rutgers

- Balanced Mixture Design Concept
- Mixes are designed to optimize performance
  - Not around a target air void content
- Take an existing mix design
  - Start at a "dry" binder content
  - Add binder at 0.5% increments – measure rutting and cracking
  - Determine range where rutting and cracking are optimized
  - Conduct volumetric work
- Performance criteria (limits) already determined

# New Jersey Balanced Design




Courtesy of Tom Bennert

# Balanced Mix Design Research – New Jersey

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- Most NJ mixes found to be below (dry) of the balanced area
- Plant QC air voids requirements need to be re-evaluated to account for the added binder
- Changes in production volumetrics are likely required to move the mixes in the right direction

# FHWA Performance Based Mix Design

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| | Fatigue Cracking | Rutting |
|---|---|---|
| **Design Air Voids**<br><br>For every 1% increase | 40% increase | 22% decrease |
| **Design VMA**<br><br>For every 1% increase | 73% decrease | 32% increase |
| **Compaction Density**<br><br>For every 1% lower in-place Air Voids<br>**(Increasing Density Improved Both!)** | 19% decrease | 10% decrease |

Courtesy of Nelson Gibson

# Superpave 5 – Purdue Research

- Design at 5% air voids and compact to 5% voids in field (95% $G_{mm}$)
- Lower design gyration to increase in-place density
  - No change in rutting resistance
  - No change in stiffness
  - Improve pavement life
    - Reduced aging
- Maintained Volume of Eff. Binder ($V_{be}$)
  - Increased VMA by 1%

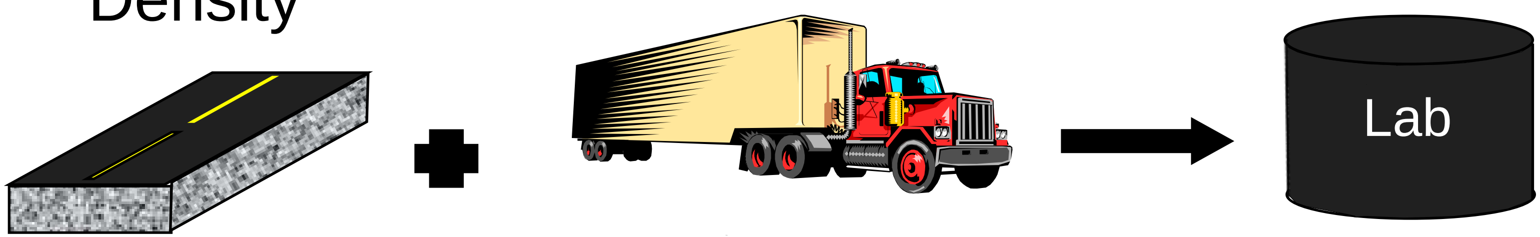
Courtesy of Gerald Huber

# Lab-Molded / Roadway Air Voids

**Why are the target values for lab-molded air voids and roadway air voids different? Lab-molded air voids simulate the in-place density of HMA after it has endured several years of traffic in the roadway.**

In-place Density

Lab-Molded Density




Future Traffic

<u>Air Voids</u>

≈15-25% Before Rolling

6 - 8 % After Rolling

<u>Air Voids</u>

4%  Superpave

# Lab Screening

- Flow Number (rutting evaluation)
  - N100/4/7 840 cycles
  - N30/5/5 1180 cycles ↑
- Stiffness
  - N100/4/7 2,072 MPa
  - N30/5/5 2,645 Mpa ↑

Note: gradations had to be altered to maintain Effective Asphalt Contents

Courtesy of Gerald Huber

# Question?

Does lowering gyration level - i.e. compactive effort in the lab - always increase percent binder in the mix?

NO!

Why – Because the gradation can be changed to lower the binder content back to where it began.

# Question?

Will lowering the gyration levels always increase field densities?

NO!

Why – Because specifications will often dictate final density

# Compaction Factors

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- Outside The Roller Operator’s Control
  - Factors Affecting Compaction
  - Forces of Compaction and Roller Types

- Within The Roller Operator’s Control
  - Roller Operations and Rolling Procedures

# Items Outside the Roller Operator's Control

# Factors in Affecting Compaction

- Base Condition
- Lift Thickness vs. NMAS
- Laydown Temperature
- Ambient Conditions
- Cooling Rates
- Balancing Production Through Compaction
- Paver Operations

# Lift Thickness' Effect on Compaction

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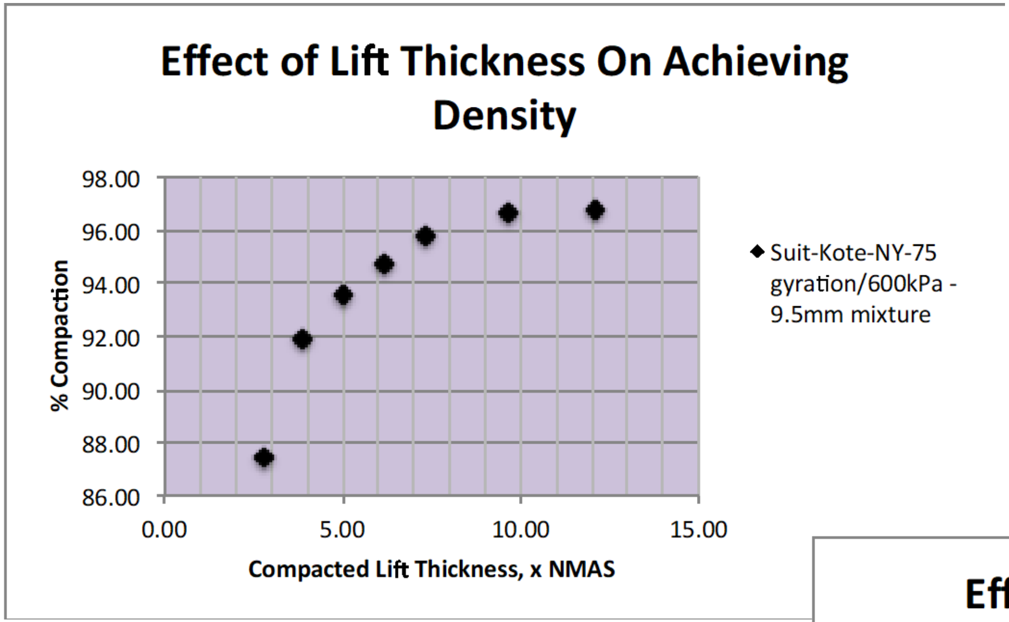
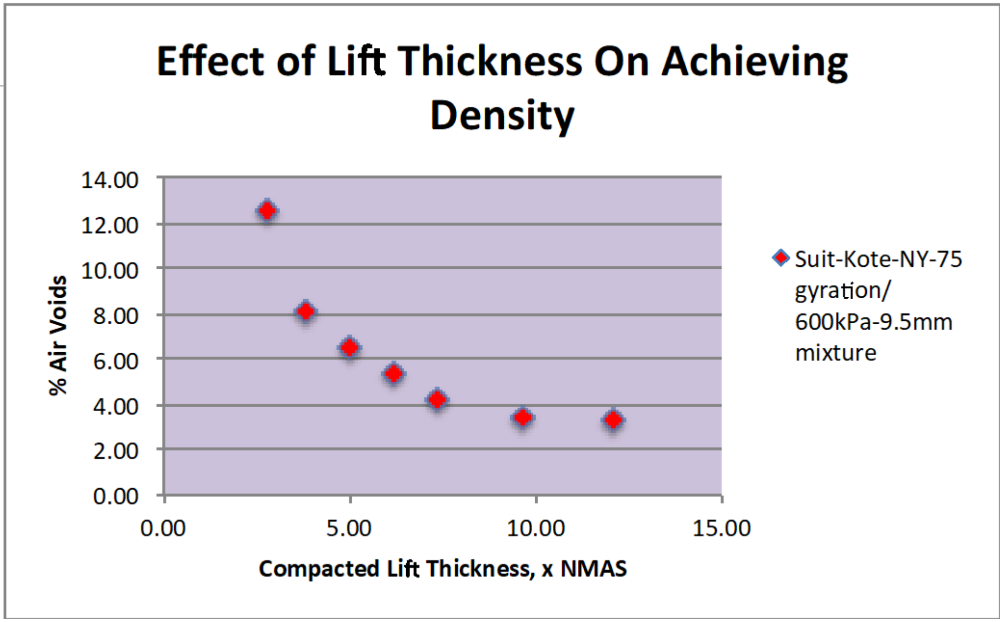
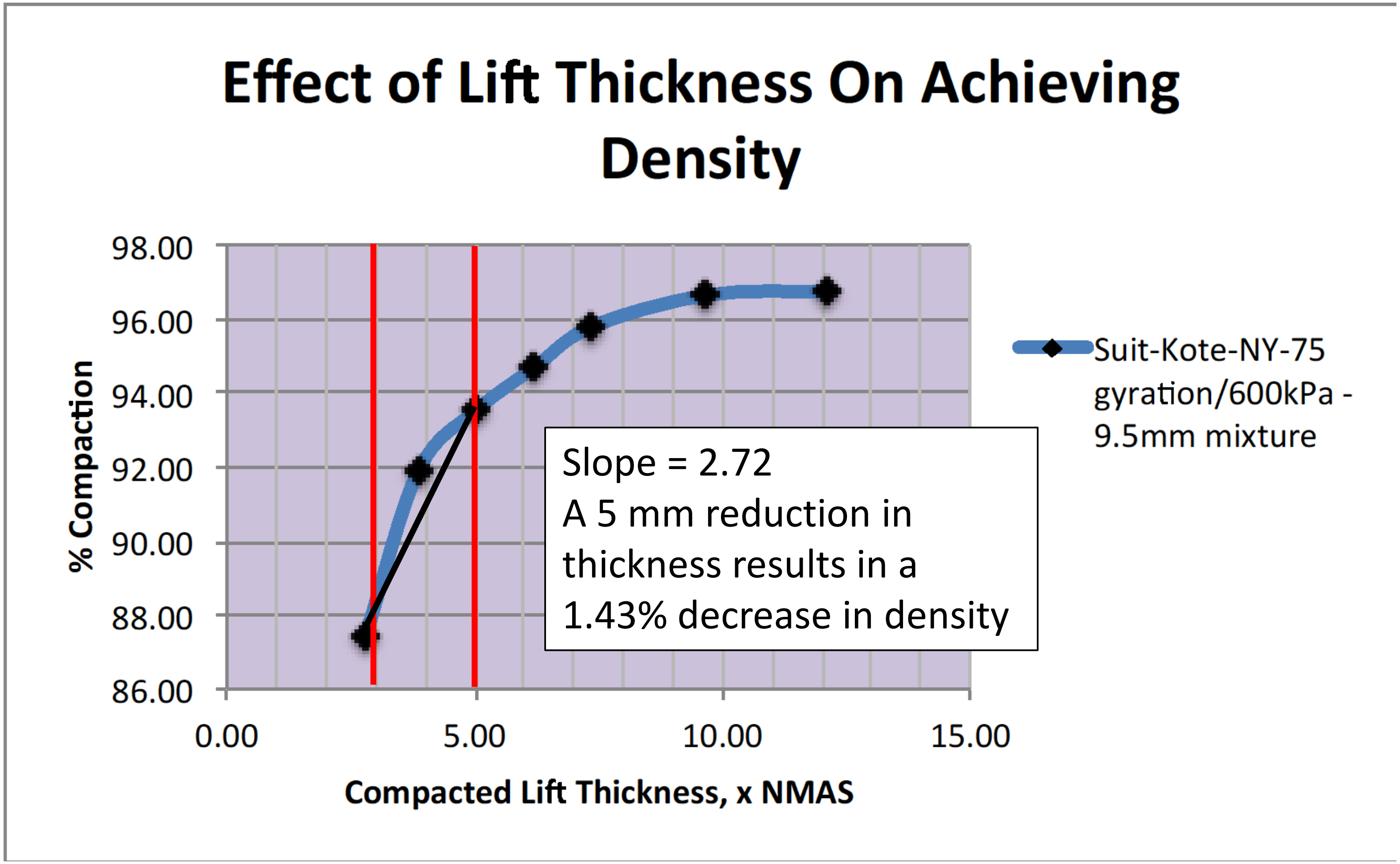
- Aggregates need room to densify
- Too thin vs. NMAS leads to:
  - Roller bridging
  - Aggregate lockup
  - Aggregate breakage
  - **Compaction Difficulties**
- NCHRP Report 531 (2004)
  - Fine Graded Mix—Minimum Thickness = 3 X NMAS
  - Coarse Graded Mix—Minimum Thickness = 4 X NMAS
  - SMA Mix—Minimum Thickness = 4 X NMAS

# Superpave Mix Designations

| Superpave Mix Designations | Maximum Size | Minimum Compacted Lift Thickness (Fine) | Minimum Compacted Lift Thickness (Coarse) |
|---|---|---|---|
| 37.5 mm (1-1/2 inch) | 50.0 mm (2 inch) | 112.5 mm (4-1/2 inch) | 150 mm (6 inch) |
| 25.0 mm (1 inch) | 37.5 mm (1-1/2 inch) | 75 mm (3 inch) | 100 mm (4 inch) |
| 19.0 mm (3/4 inch) | 25.0 mm (1 inch) | 57 mm (2-1/4 inch) | 76 mm (3 inch) |
| 12.5 mm (1/2 inch) | 19.0 mm (3/4 inch) | 37.5 mm (1-1/2 inch) | 50 mm (2 inch) |
| 9.5 mm (3/8 inch) | 12.5 mm (1/2 inch) | 28.5 mm (1-1/8 inch) | 38 mm (1-1/2 inch) |
| 4.75 mm (3/16 inch) | 9.5 mm (3/8 inch) | 14.25 mm (9/16 inch) | 19 mm (3/4 inch) |


Effect of Lift Thickness On Achieving Density
98.00
96.00
94.00
92.00
90.00
88.00
86.00
% Compaction
0.00
5.00
10.00
15.00
Compacted Lift Thickness, x NMAS
Suit-Kote-NY-75 gyration/600kPa - 9.5mm mixture


Effect of Lift Thickness On Achieving Density
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
% Air Voids
0.00
5.00
10.00
15.00
Compacted Lift Thickness, x NMAS
Suit-Kote-NY-75 gyration/ 600kPa-9.5mm mixture



Effect of Lift Thickness On Achieving Density
98.00
96.00
94.00
92.00
90.00
88.00
86.00
% Compaction
0.00
5.00
10.00
15.00
Compacted Lift Thickness, x NMAS
Suit-Kote-NY-75 gyration/600kPa - 9.5mm mixture
Slope = 2.72
A 5 mm reduction in thickness results in a 1.43% decrease in density

# Thickness Matters

- Based on the NY 9.5mm NMAS (75 gyrations) mixture data:
  - From 5x NMAS to 4x NMAS (47.5 mm ↓ to 38.0 mm), there is 1.5% decrease in density.
  - From 4x NMAS to 3x NMAS (38.0 mm ↓ to 28.5 mm), there is a further 4.1% decrease in density.
- Ideal – consider placing thicker mats – increasing the thickness to nominal maximum aggregate size ratio
- Realistical – lift thickness likely may not be increased due to geometric and/or budgetary limitations
- Solution - consider using smaller nominal maximum aggregate size mixtures for a given lift thickness (increasing the thickness to nominal maximum aggregate size ratio)

- **Best Practices for Specifying and Constructing HMA Longitudinal Joints**

- **Tack Coat Best Practices**

- **Both these sub-sections built directly from the two 4-hr workshops developed on each of these critical topics. Those workshops, and related info, can be viewed at:**

www.asphaltinstitute.org/engineering

- **Both topics directly relate to better in-place density**

# Newer Technologies to Enhance Compaction

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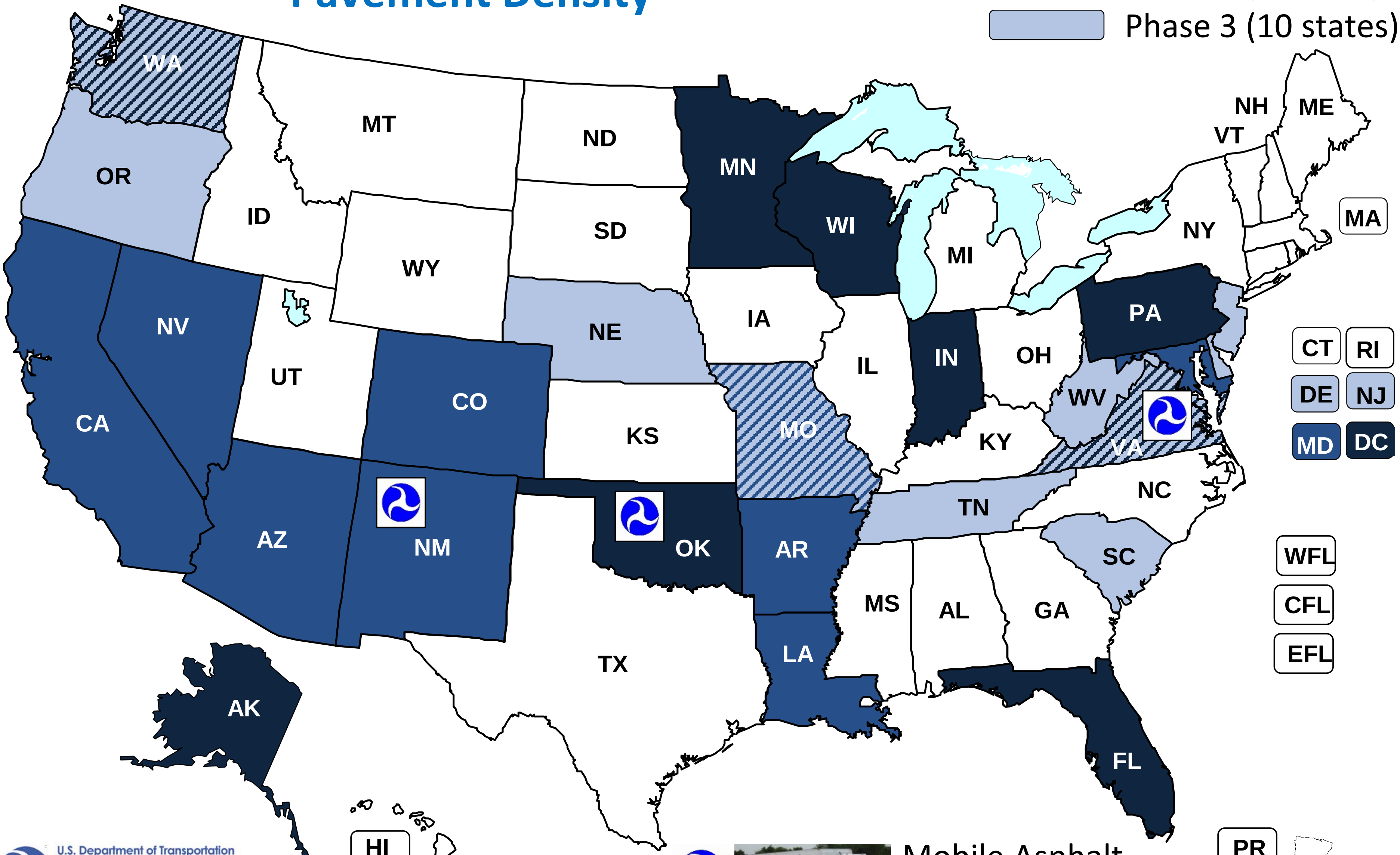
- Warm Mix Asphalt (WMA)
- SHRP2 Infrared (IR)
- Intelligent Compaction (IC)

# Enhanced Durability of Asphalt Pavements through Increased In-Place Pavement Density

**Demonstration Projects**

- Phase 1 (10 states)
- Phase 2 (9 states)
- Phase 3 (10 states)




Mobile Asphalt Testing Trailer (3)

U.S. Department of Transportation
Federal Highway Administration

# Achieving Increased In-place Density

1. • Density (%$G_{mm}$) Requirement
2. • Optimum Asphalt Content
3. • Consistency
4. • Best Practices
5. • New Technology

# State #1

| | Location | Mode | Passes | Equipment |
|---|---|---|---|---|
| | Delivery | MTV | | Roadtec SB-2500 |
| Control | Breakdown | Static | 9 | CAT CB54 |
| | | Static | 9 | CAT CB54 |

*Courtesy Ray Brown*

# State #1

| Experiment | Contractor's Compactive Effort |
|---|---|
| Test Section 1 | **Added 1 to 2 vibratory passes** |
| Test Section 2 | **Added pneumatic** - CAT CW34 |


# State #1

| Experiment | Density Results (%$G_{mm}$) | Change |
| --- | --- | --- |
| Control | 93.5 | --- |
| Test Section 1 | 93.2 | Not significant |
| Test Section 2 | 95.4 | + 1.9 |

Average of 10 core densities each

- 2 static rollers achieved full incentive
- Using vibratory mode resulted in no change in density
- Adding pneumatic increased density

# State #2

| | Location | Mode | Passes | Equipment |
|---|---|---|---|---|
| | Delivery | | | End Dumps |
| Control | Breakdown | Vibratory | 7 | BW 161 AD-5 (10 ton) |
| Test Section | Breakdown | Vibratory | 9 | Same |

*Courtesy Ray Brown*

# State #2

| Experiment | Density Results (% $G_{mm}$) | Change |
|---|---|---|
| Control | 91.7 | --- |
| Test Section | 92.5 | ≈ + 1 |

Average of 6 cores each / Reference is $G_{mm}$

- Only 1 compaction roller needed to meet specification
- Adding 2 passes increased % density

# Achieving Increased In-place Density

1. Density (%$G_{mm}$) Requirement
2. Optimum Asphalt Content
3. Consistency
4. Best Practices
5. New Technology

# State #3

| | Location | Mode | Passes | Equipment |
|---|---|---|---|---|
| | Delivery | Bottom Dumps | | Cedar Rapids MS2 |
| Control | Breakdown | Vibratory | 5 | Dynapac CC 624 |
| | | Vibratory | 5 | Dynapac CC 624 |
| | Intermediate | Pneumatic | 7 | CAT CW35 |
| | | Pneumatic | 7 | Hamm GRW18 |

*Courtesy Lee Gallivan*

# State #3

| Experiment | Contractor's Compactive Effort |
| --- | --- |
| Test Section 1 | **Added 1 vibratory roller** – Hamm HD130 (5 total rollers) |
| Test Section 3 | **Added 0.3% asphalt** (5 total rollers) |

*Courtesy Lee Gallivan*

# State #3

| Experiment | Density Results (%$G_{mm}$) | Change |
| --- | --- | --- |
| Control | 92.9 | --- |
| Test Section 1 | 92.9 | No change |
| Test Section 3 | 94.1 | + 1.2 |

Average of 8 core densities each

- 4 compaction rollers needed to meet specification
- 1 additional roller did not change density
- Mixture design adjustment resulted in density increase

# State #4

| | Location | Mode | Passes | Equipment |
|---|---|---|---|---|
| | Delivery | MTV | | Weiler E2850 |
| Control | Breakdown | Vibratory | 5 | Dynapac CC 624 HF |
| | | Vibratory | 5 | Volvo DV 140B |
| | Intermediate | Pneumatic | 11 | Hamm GRW280 |



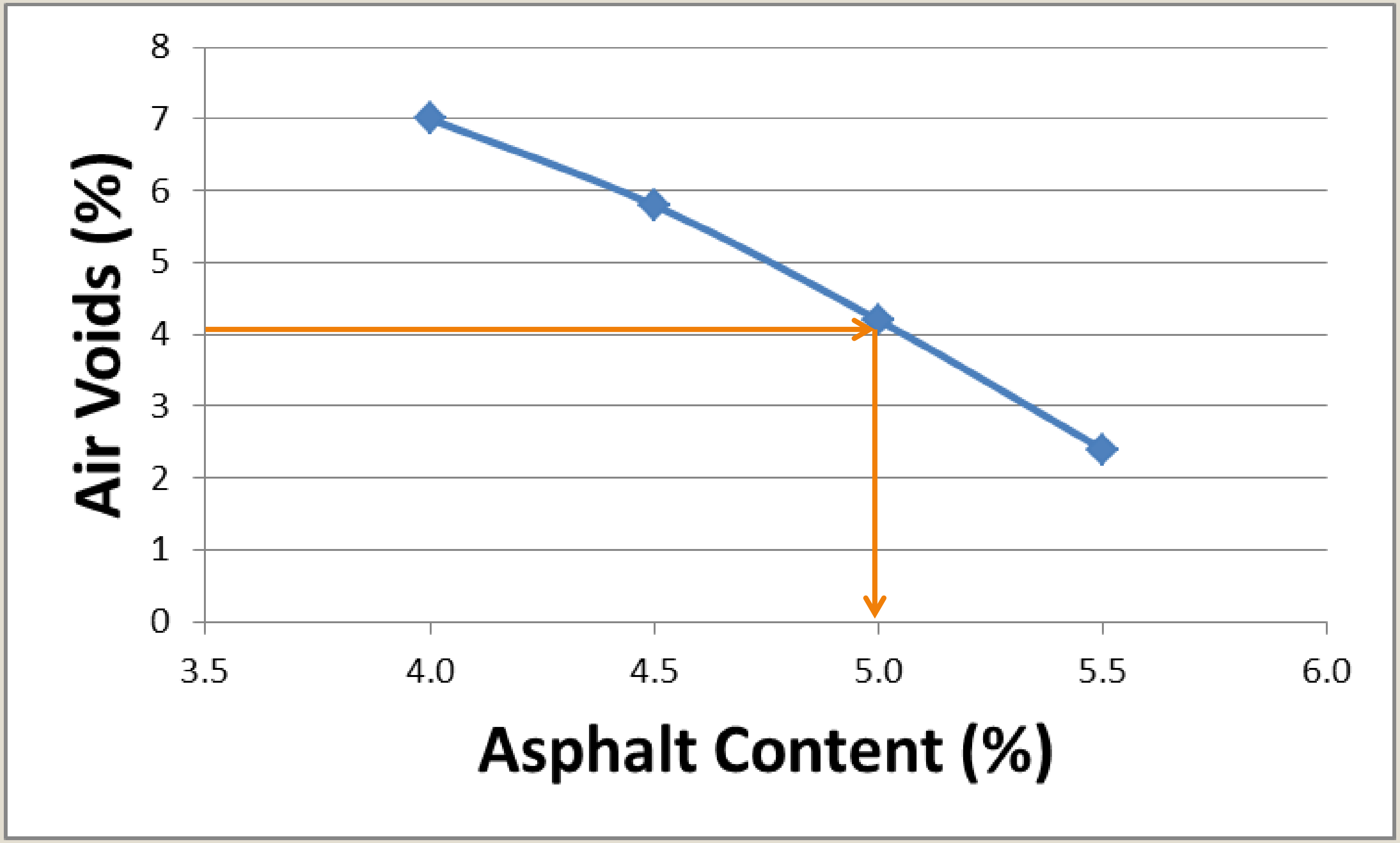
*Courtesy Lee Gallivan*

# State #4

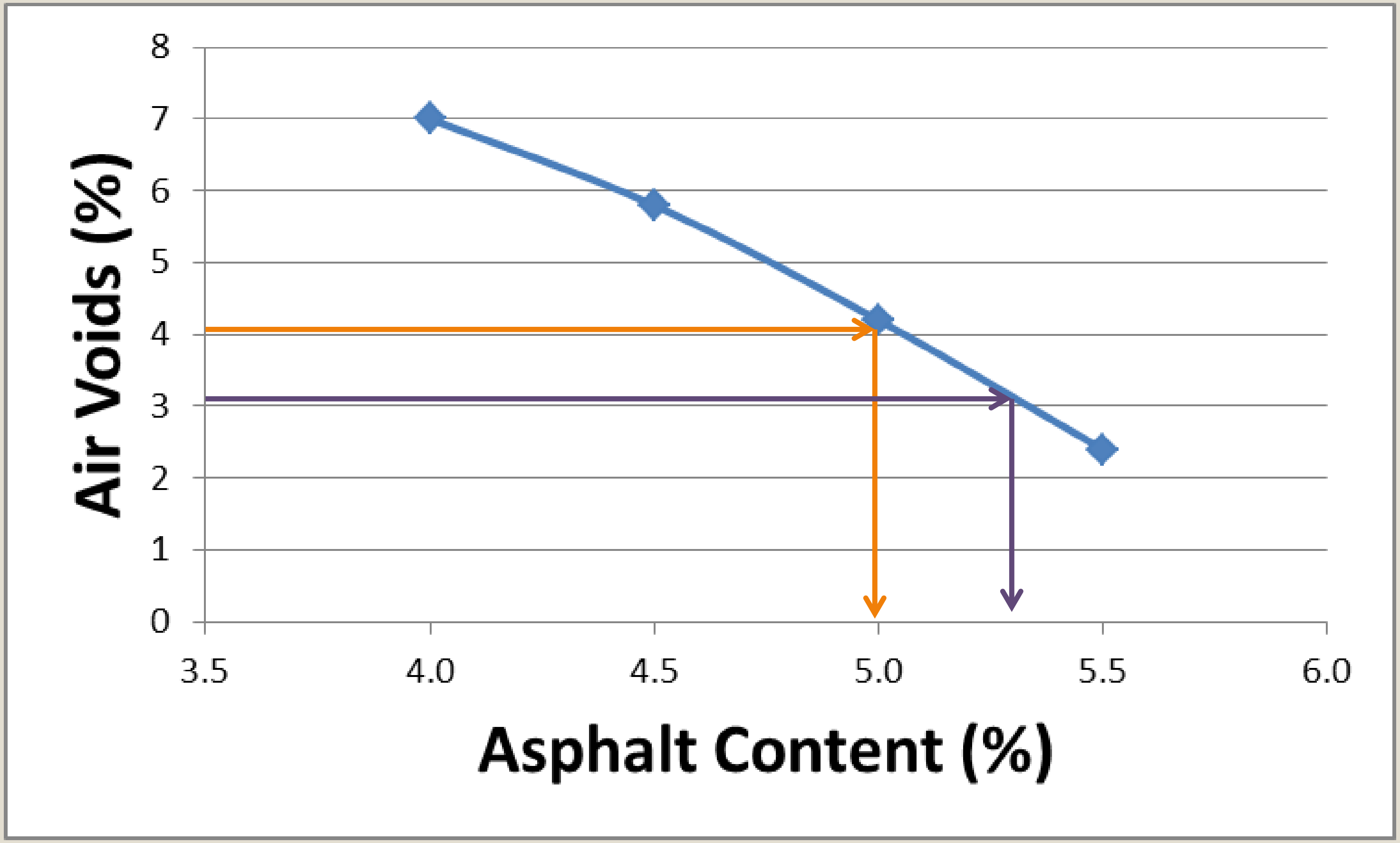
| Experiment | Contractor's Compactive Effort |
|---|---|
| Test Section 1 | **Added 1 vibratory roller** – Dynapac CC 524 HF (4 rollers) |
| Test Section 3 | **Added 0.3% asphalt** (4 rollers) |


*Courtesy Lee Gallivan*

# Selecting Optimum Asphalt Content with Air Void Regression



# Selecting Optimum Asphalt Content with Air Void Regression



# State #4

| Experiment | Density Results (% $G_{mm}$) | Change |
| --- | --- | --- |
| Control | 93.5 | --- |
| Test Section 1 | 95.0 | + 1.5 |
| Test Section 3 | 95.4 | + 1.9 |

Average of 12 nuclear gauge readings each

- Control achieved maximum incentive
- Additional roller and mix design adjustment resulted in density increase

# State #5

| | Location | Mode | Passes | Equipment |
|---|---|---|---|---|
| | Delivery | MTV | | Terex CR622RM |
| Control | Breakdown | Vibratory | 5 | Volvo DD 138 HFA |
| | | Vibratory | 5 | Volvo DD 138 HFA |
| | Intermediate | Pneumatic | 5 | Hypac C530 AH |

*Courtesy Ken Hobson*

# State #5

| | Location | Mode | Passes | Equipment |
|---|---|---|---|---|
| Test Section #1 | Breakdown | Oscillatory | 5 | Hamm HD+ 120i |
| | | Oscillatory | 5 | Bomag BW 190 ADO |
| Test Section #2 | Same rolling pattern as control<br>**Additional asphalt**: 0.3% more AC | | | |

*Courtesy Ken Hobson*

# State #5

| Experiment | Density Results (%$G_{mm}$) | Change |
|---|---|---|
| Control | 92.5 | --- |
| Test Section #1 | 93.2 | +0.7 |
| Test Section #2 | 95.2 | +2.7 |

Average of 3 cores each

# State #6

| | Location | Mode | Passes | Equipment |
|---|---|---|---|---|
| | Delivery | MTV | | Roadtec SB 2500 |
| Control and Test | Breakdown | Vibratory | 5V<br>2S | CAT CB 534 XW |
| | | Vibratory | 5V<br>2S | CAT CB 534 XW |

*Courtesy Miguel Montoya*

# State #6

- Optimum asphalt content
  - Modified asphalt mixture design procedure
    - Air voids, gyrations, and VMA
  - Additional asphalt content
    - 0.3% in the asphalt mixture design
    - 0.1% during field production

- Performance testing
  - Flow Number
  - Dynamic Modulus

# State #6

| Experiment | Density Results (%$G_{mm}$) | Change |
|---|---|---|
| Control | 93.3 | --- |
| Test Section | 95.4 | +2.1 |

Average of 10 cores each

# Achieving Increased In-place Density

1. Density (%$G_{mm}$) Requirement
2. Optimum Asphalt Content
3. Consistency
4. Best Practices
5. New Technology

# State #7

| | Construction Information |
|---|---|
| Delivery | MTV: Roadtec SB-1500 |
| Control | Current minimum sublot specification |
| Test Section | New PWL specification |

*Courtesy Lee Gallivan*

# State #7

| | Location | Mode | Passes | Equipment |
|---|---|---|---|---|
| Test Section | Breakdown | Vibratory | 4V 1S | CAT CB 54B |
| | | Vibratory | 4V 1S | Sakai WS800 |
| | | Vibratory | 4V 1S | CAT CB 54B |
| | Joints | Vibratory | | ?? |

*Courtesy Lee Gallivan*

# State #7

| Experiment | Density Results (%$G_{mm}$) | Change | Pay Factor | Std. Dev. (Statewide) |
|---|---|---|---|---|
| Statewide Avg. | 93.6 | --- | --- | --- |
| Control | 94.4 | --- | 0.97 | 1.55 |
| Test Section 1 | 96.1 | +1.7 | 1.04 | 0.95* |

Average of 5 cores each

*Implementing Percent Within Limits (PWL) specification

# State #8

| | Location | Mode | Passes | Equipment |
|---|---|---|---|---|
| | Delivery | MTV | | Weiler E2850 |
| Control | Breakdown | Vibratory | 8V 1S | CAT CB 68B |
| | Intermediate | Pneumatic | 15 | Dynapac CP30 |
| Test Section | Decrease roller spacing | | | Same |



*Courtesy Jim Huddleston*

# State #8

| Experiment | Density Results (% $G_{mm}$) | n | LSL | PWL |
|---|---|---|---|---|
| Control | 93.1 | 77 | **91.0** | 90.3 |
| Test Section | 93.0 | 11 | **92.0** | 93.3 |

Standard deviation changes from 1.58 to 0.67 from individual tests

- Additional effort by contractor was minimal
- Consistency improvements showed LSL could be 1% higher

# Achieving Increased In-place Density

1. • Density (%$G_{mm}$) Requirement
2. • Optimum Asphalt Content
3. • Consistency
4. • Best Practices
5. • New Technology

# State #9

| | Location | Mode | Passes | Equipment |
|---|---|---|---|---|
| | Delivery | MTV | | IR MC 330 |
| Control | Breakdown | Vibratory<br>Static | 3<br>6 | CAT CB 64B |
| | Intermediate | Static | 7 | Hamm HD+ 90 |

*Courtesy Ray Brown*

# State #9

| | Location | Mode | Passes | Equipment |
|---|---|---|---|---|
| Test Section #1 | Breakdown | Vibratory<br>Static | 5<br>2 | CAT CB 64B |
| | Intermediate | Static<br>Oscillatory | 2<br>3 | Hamm HD+ 90 |
| Test Section #2 | Breakdown | Vibratory | 7 | CAT CB 64B |
| | Intermediate | Static<br>Oscillatory | 2<br>3 | Hamm HD+ 90 |

*Courtesy Ray Brown*

# State #9

| Experiment | Density Results (%$G_{mm}$) | Change |
| --- | --- | --- |
| Control | 92.2 | --- |
| Test Section 1 | 92.0 | Not significant |
| Test Section 2 | 92.0 | Not significant |

Average of 10 cores each

- Density increase was not significant
- Density results exceeded current specification

# Achieving Increased In-place Density

1. • Density (%$G_{mm}$) Requirement
2. • Optimum Asphalt Content
3. • Consistency
4. • Best Practices
5. • New Technology

# QC Tools
# SHRP2 Products

## Rolling Density Meter (RDM)

- Density from dielectric constant

## Thermal Temperature Scanner (IR Scan)

- Paver speed
- Temperature

*Courtesy Lee Gallivan*

# Can We Achieve Increased In-place Density?

**YES!**

Test sections had increased density (% $G_{mm}$):

- 8 of 10 States achieved > 1.0% increase
- 7 of 10 States achieved > 94.0% $G_{mm}$
- 6 of 10 States achieved > 95.0% $G_{mm}$

Will there be changes?

- 8 of 10 States are changing specifications

# How Do We Achieve Increased In-place Density?

- Measuring density (1)
- Reference density (1)
- Density of pavement to meet requirements (4)
  - Some at 90 to 91% $G_{mm}$
  - Others at 94% $G_{mm}$
- Type of specification (2)
  - 22 states use minimum lot average
  - 25 states use PWL
    - Impacts contractors' target and consistency
- Consistency (2)
  - Standard deviations <1.00 were achievable

(#) – Number of States making changes or in the process

# How Do We Achieve Increased In-place Density?

## Incentives (3)

- 37 states have incentives: range from 1 to 10%
- Average 2.9%

## Mixture design changes (5)

- Many states changing Superpave to get more asphalt
- Must also look at density specification

## New technologies (2)

- Did not help improve density, but were a good trouble-shooting tool

(#) – Number of States making changes or in the process

# Bottom Line

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**Increased compaction = Increased Performance**

**Better "Return on Investment" for the taxpayers**

**More Successful Pavements = More Tonnage for the HMA Industry !!!**

**Thank you for your time!!!**

# Thank you

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