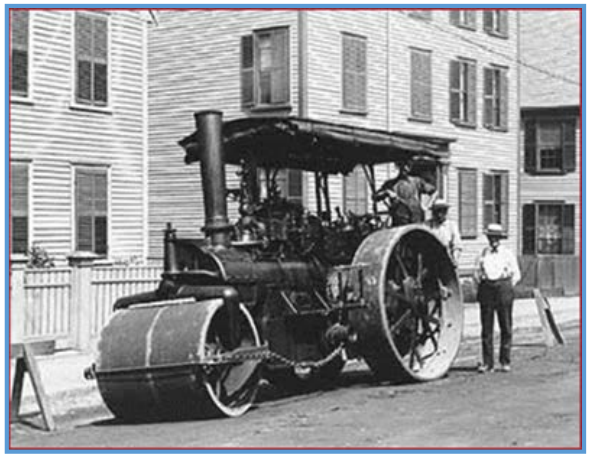
Enhanced Durability of Asphalt Pavements Through Increased In-Place Density



PAPA Annual Conference

18 January 2017

Overall Objective

Ultimately, achieving the in-place asphalt pavement density that results in the highest asphalt pavement performance.

1. The Importance of Density
2. FHWA – AI Compaction Workshop
3. Field Demonstration Projects
4. Summary

Compaction is Important

- Hughes, C.S., "Compaction of Asphalt Pavement." NCHRP Synthesis 152, Washington, D.C., 1989.
  - Compaction is the **single most important factor** that affects pavement performance in terms of durability, fatigue life, resistance to deformation, strength and moisture damage.
- Geller, M. Synthesis 152
  - "Compaction is the **most economical** alternative for achieving an increase in the life expectancy of new and rehabilitated pavement."

- Brown, E.R., "Density of Asphalt Concrete – How Much is Needed?" NCAT Report 90-03. 1990.
  - "The amount of 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."

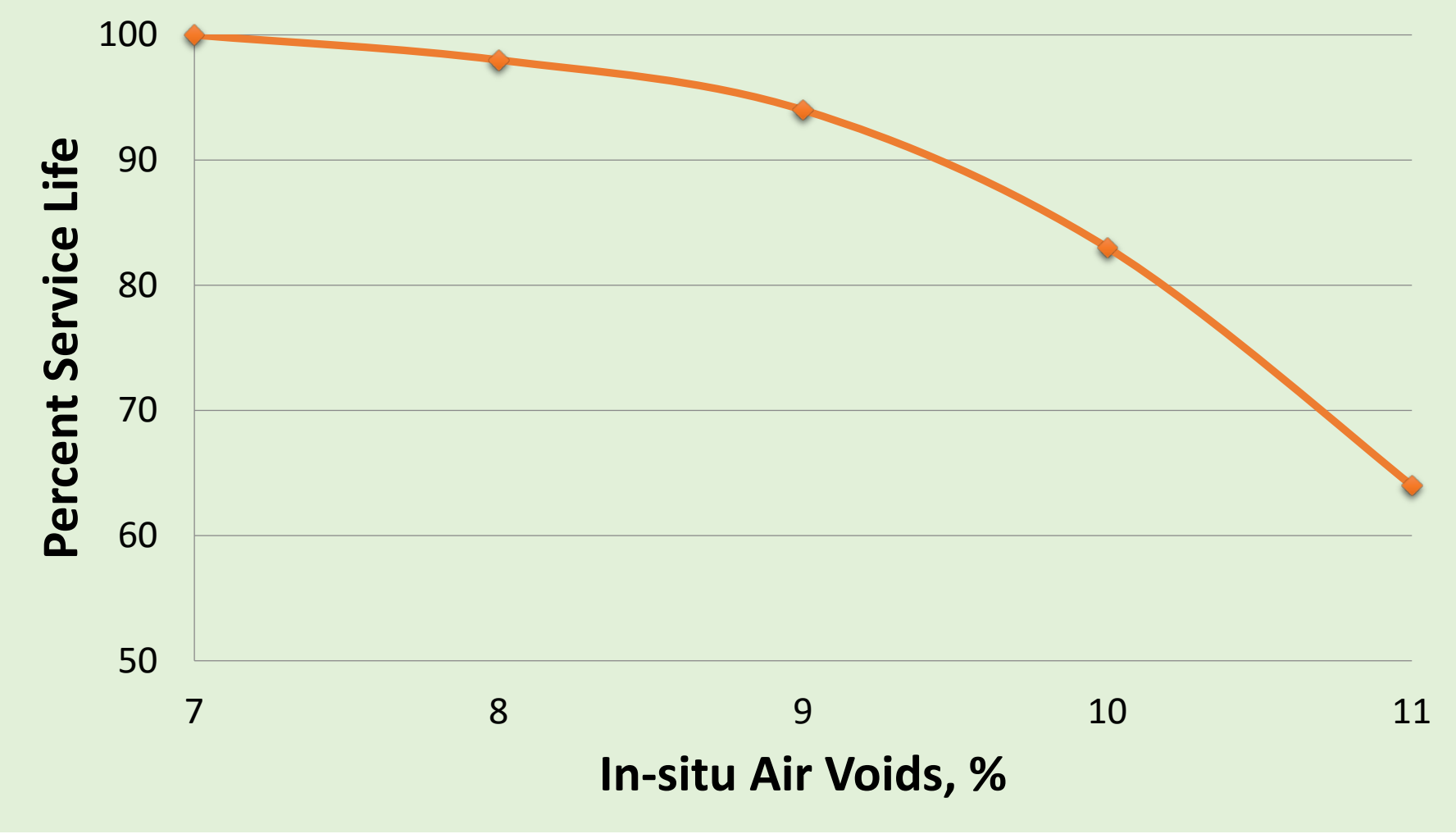
Improved Compaction = Improved Performance

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

WesTrack Experiment

Effect of In-Place Voids on Life

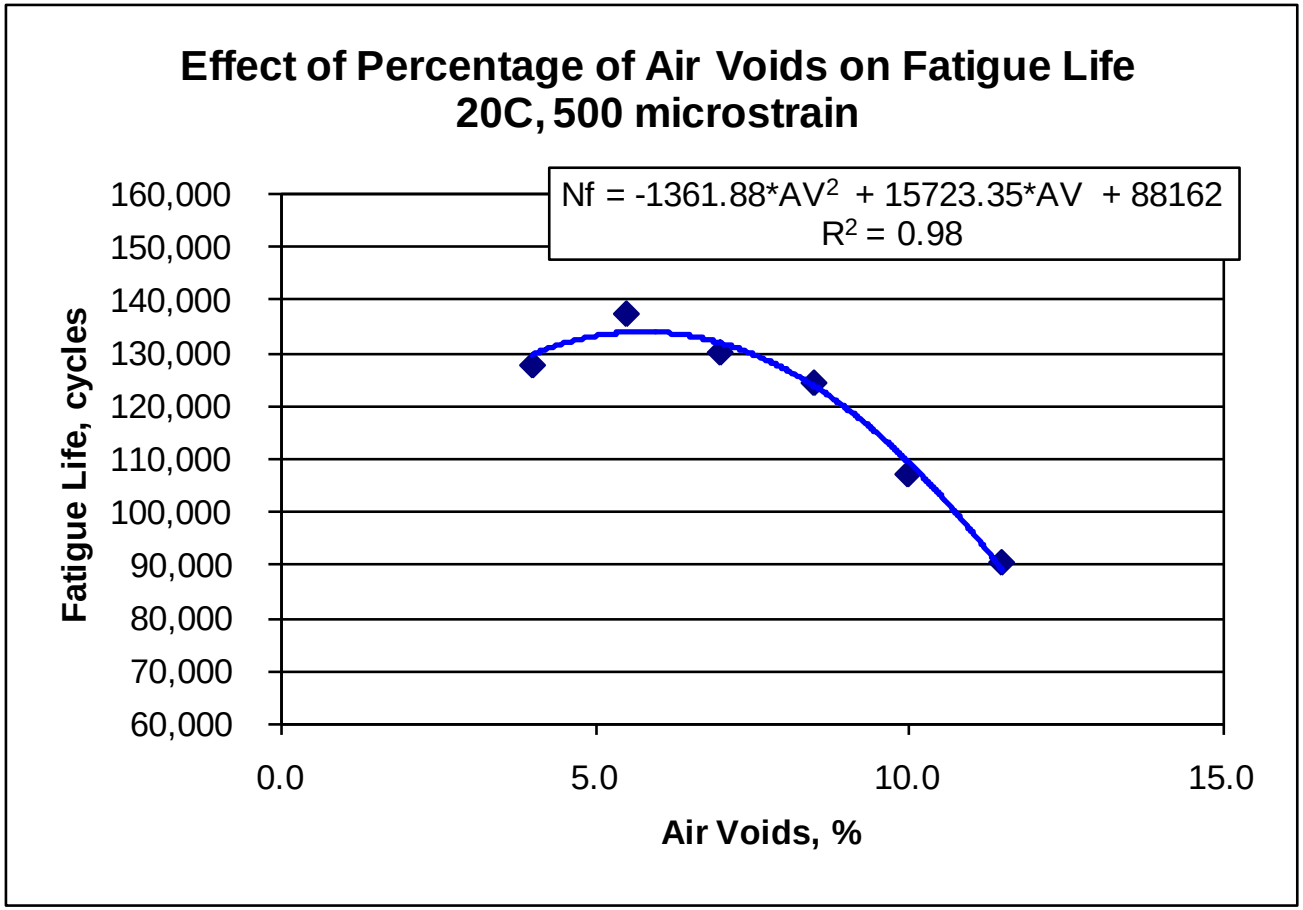
Washington State DOT Study



93% 92% 91% 90% 89%

Compaction Level

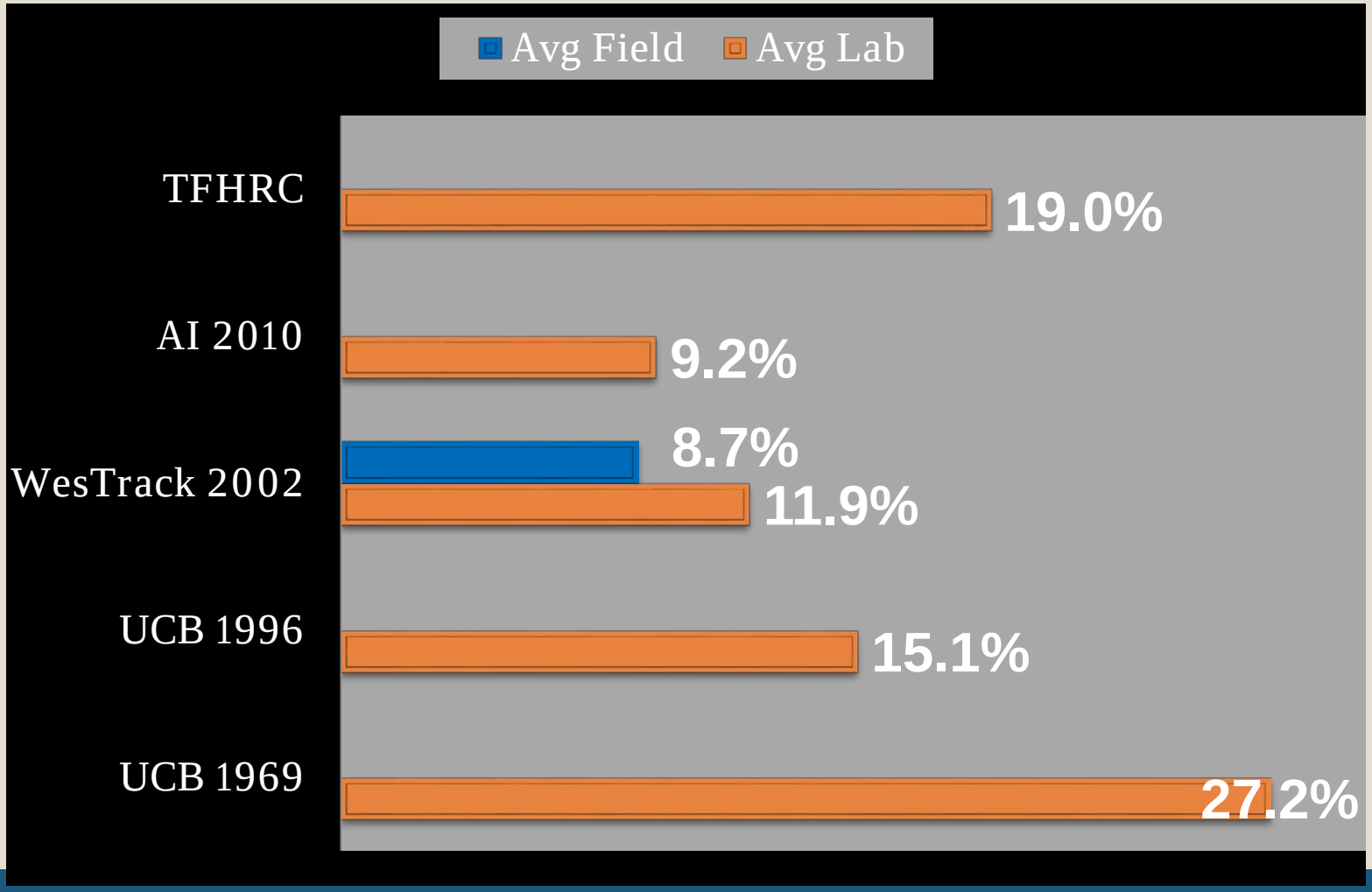
In-Place Voids vs Fatigue Life



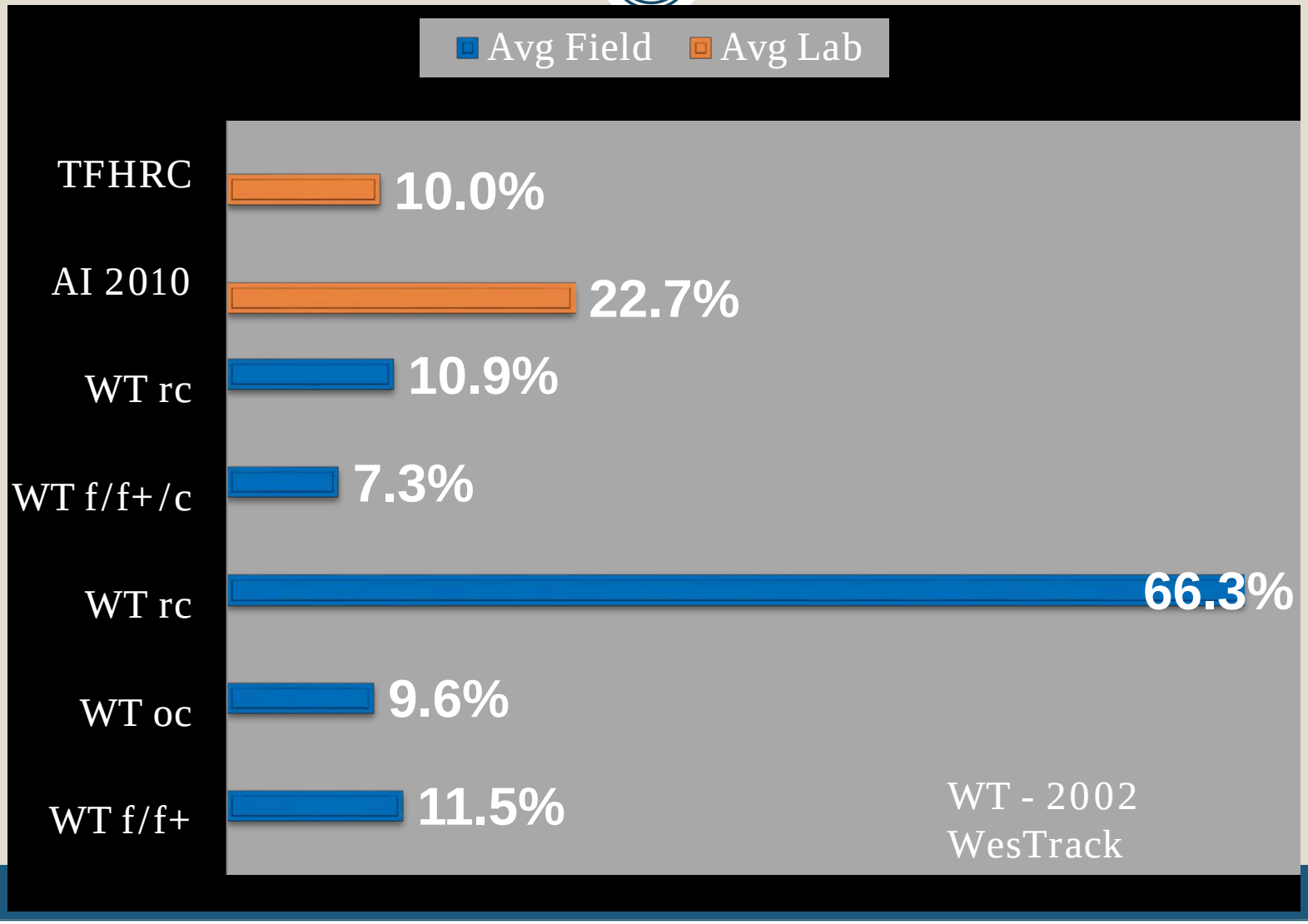
<u>UK-AI Study</u>

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

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



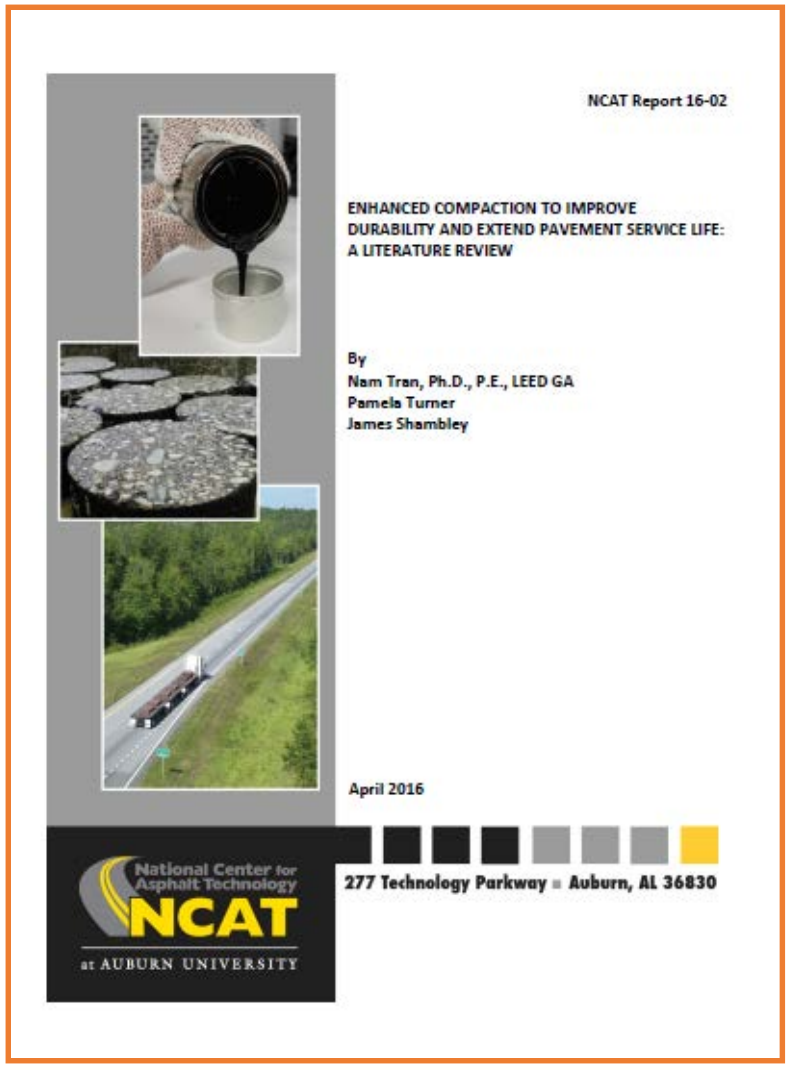
Average Decrease in Rut Depth for 1% Decrease in Air Voids



NCAT Report 16-02 (Oct 2016)

"A **1% decrease in air voids** was estimated to…

- improve fatigue performance between 8.2 and 43.8%,
- improve rutting resistance between 7.3 to 66.3%,
- **extend the service life by conservatively 10%**"


NCAT Report 16-02

ENHANCED COMPACTION TO IMPROVE DURABILITY AND EXTEND PAVEMENT SERVICE LIFE: A LITERATURE REVIEW

By
Nam Tran, Ph.D., P.E., LEED GA
Pamela Turner
James Shambley

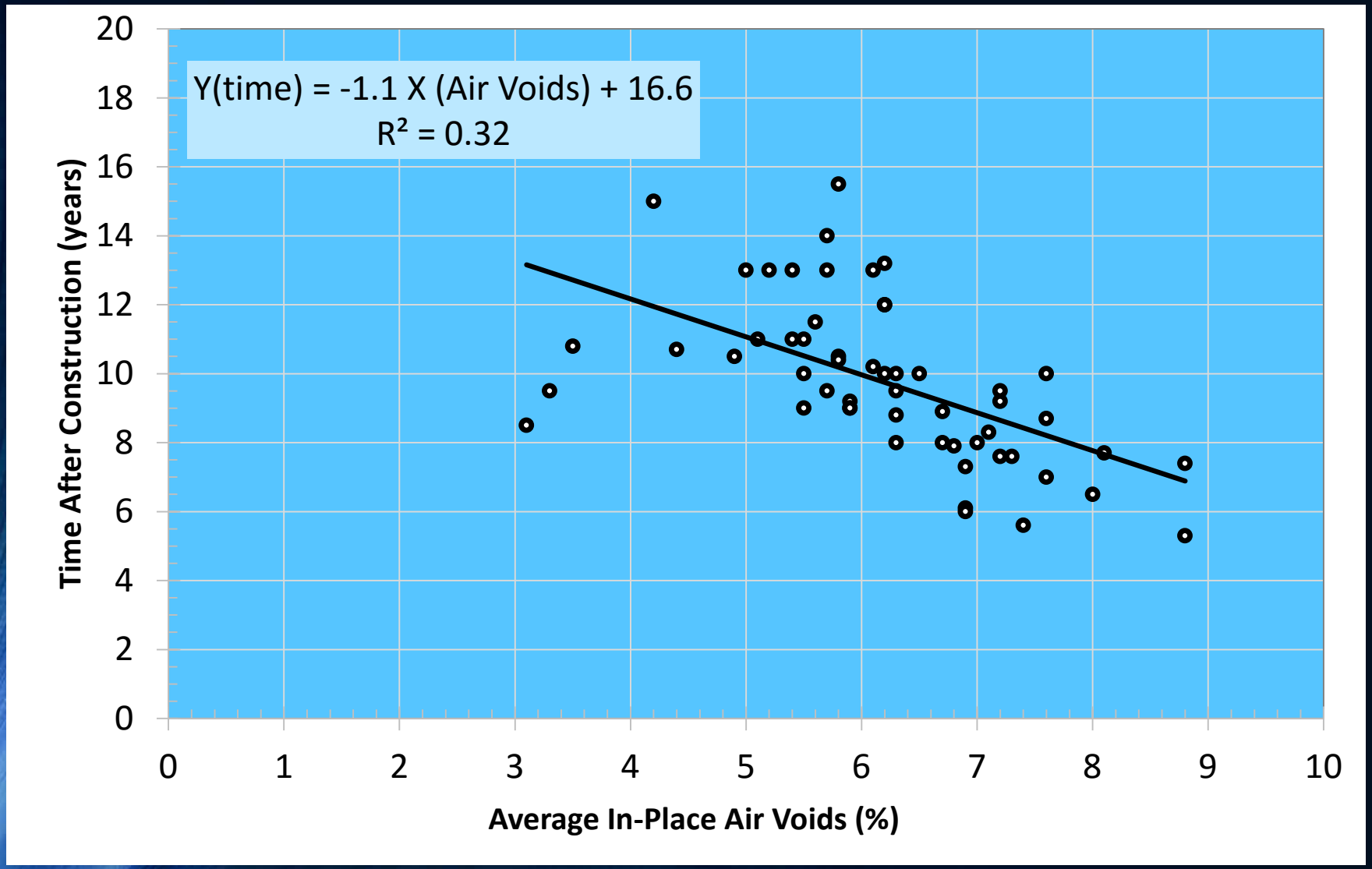
April 2016

National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY

277 Technology Parkway ■ Auburn, AL 36830

http://eng.auburn.edu/research/centers/ncat/files/technical-reports/rep16-02.pdf

Research from New Jersey



Reasons for Compaction

Cracking

- To improve fatigue cracking resistance
- To improve thermal cracking resistance

Rutting

- To minimize prevent further consolidation
- To provide shear strength and resistance to rutting

Moisture Damage

- To ensure the mixture is waterproof (impermeable)

Aging

- To minimize oxidation of the asphalt binder

Although not a "cure-all remedy", compaction is important!!

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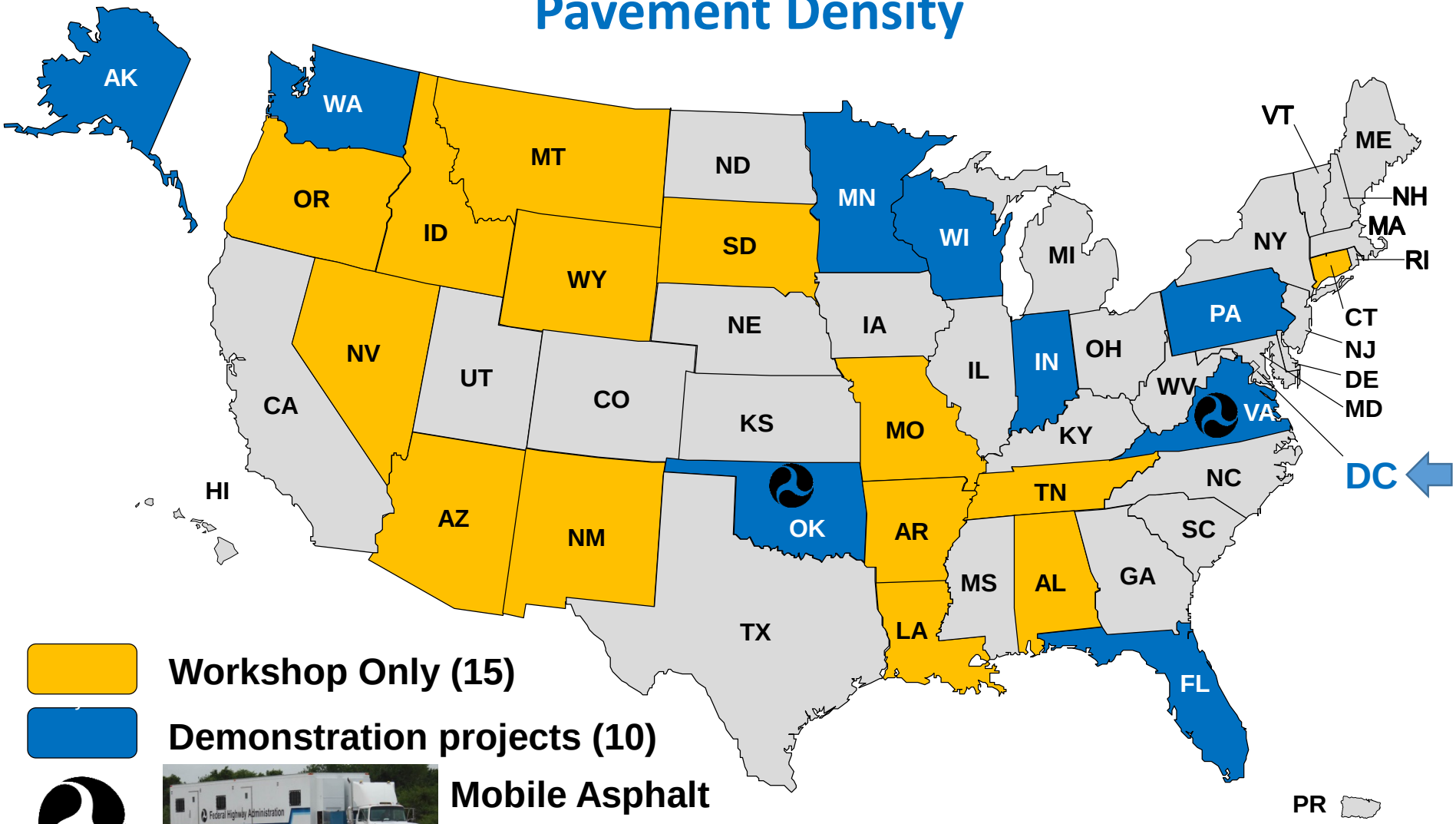
4. Summary

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



Workshop Only (15)

Demonstration projects (10)

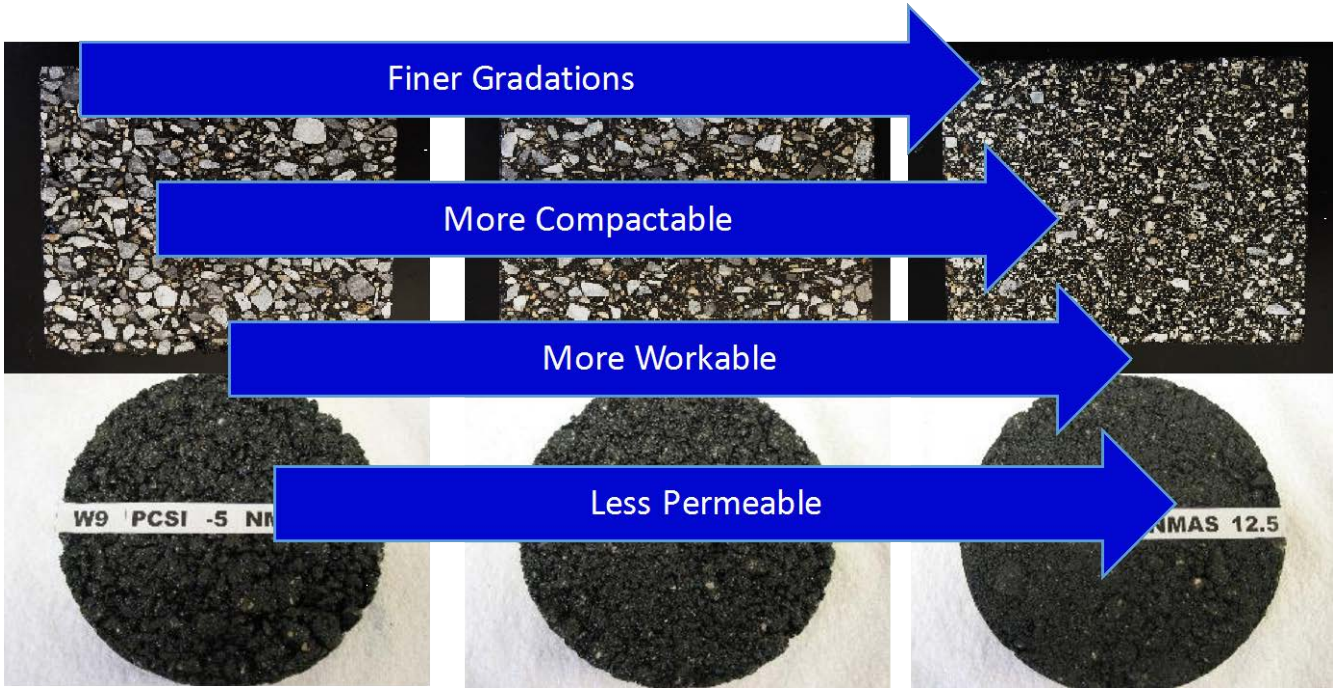
Mobile Asphalt Testing Trailer (2)

Workshop Outline

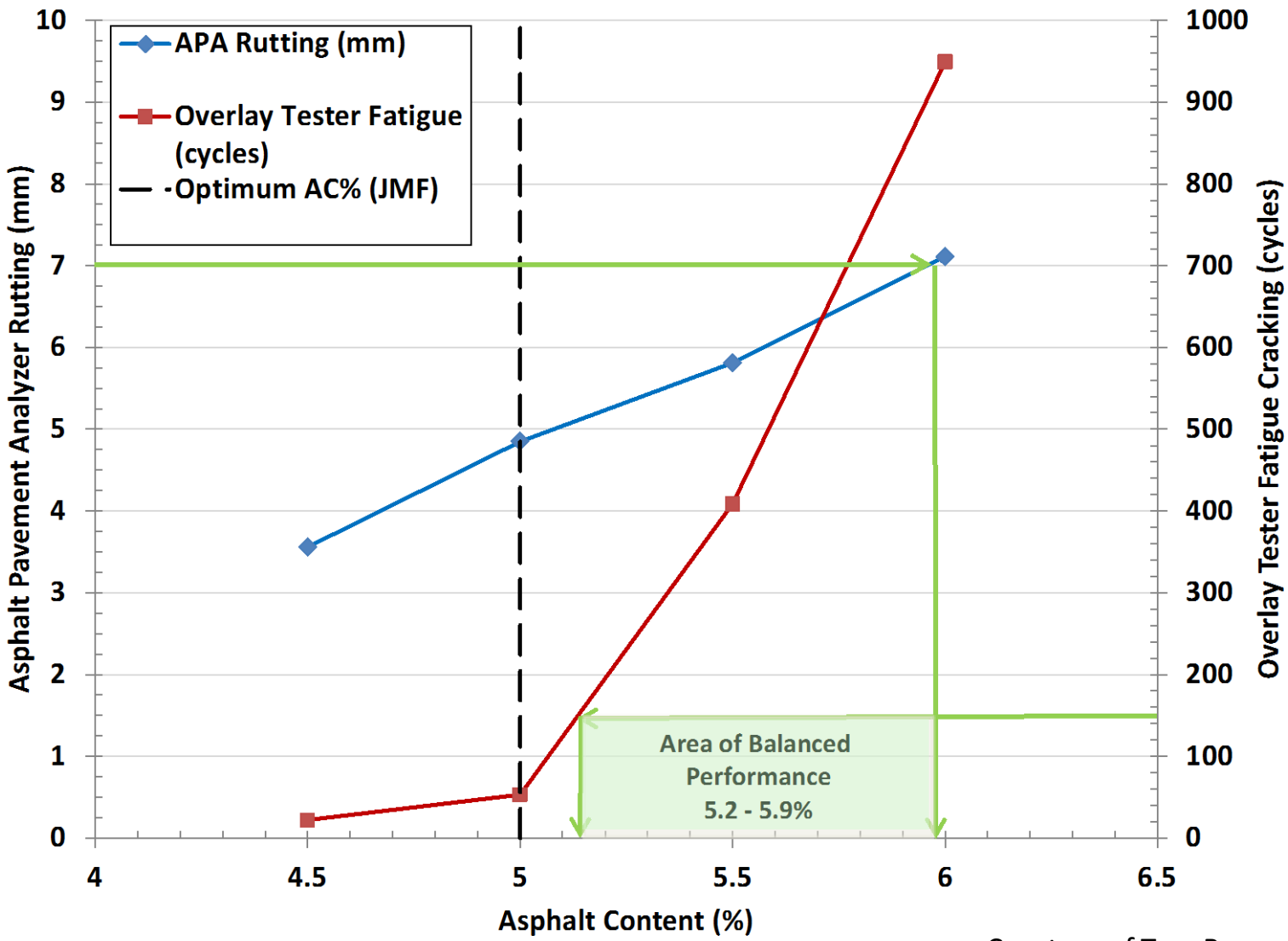
1. Introduction
2. Mixture Factors Effecting Compaction
3. Compaction Best Practices
4. Other Best Practices
5. Measurement & Payment
6. New Technologies
7. Wrap Up

Mix Design

- Fine graded
- Lower gyrations
- Increase Vbe
  - Balanced mix design
  - Superpave 5



New Jersey Balanced Design



Courtesy of Tom Bennert

FHWA Performance Based Mix Design

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

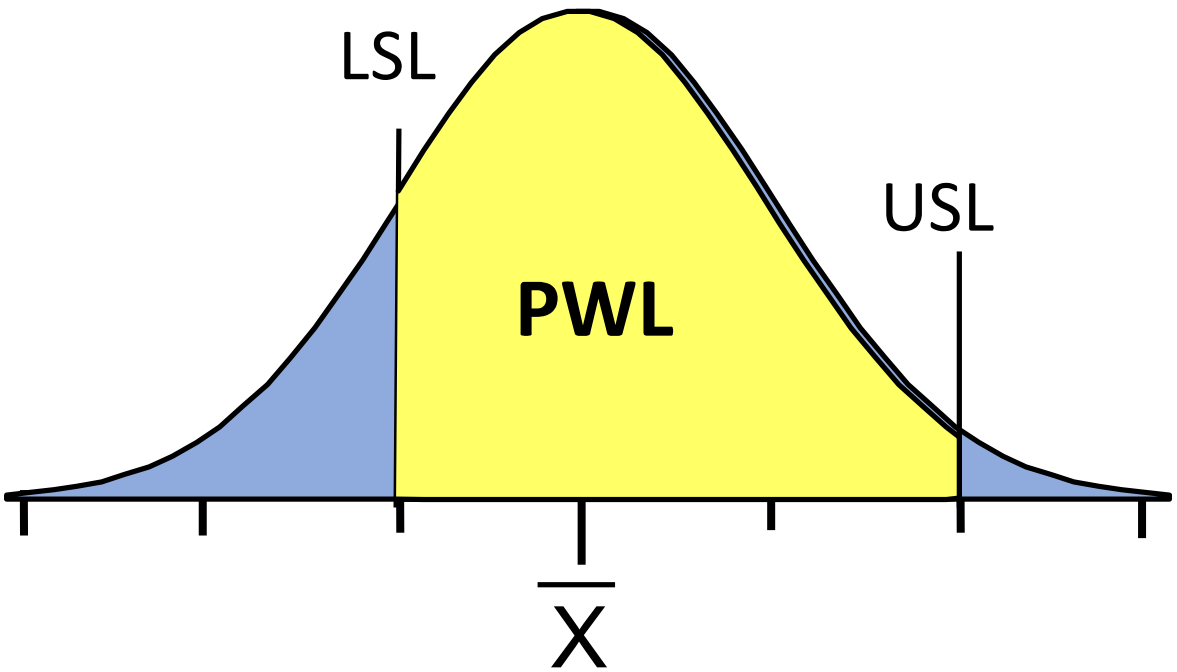
Courtesy of Nelson Gibson

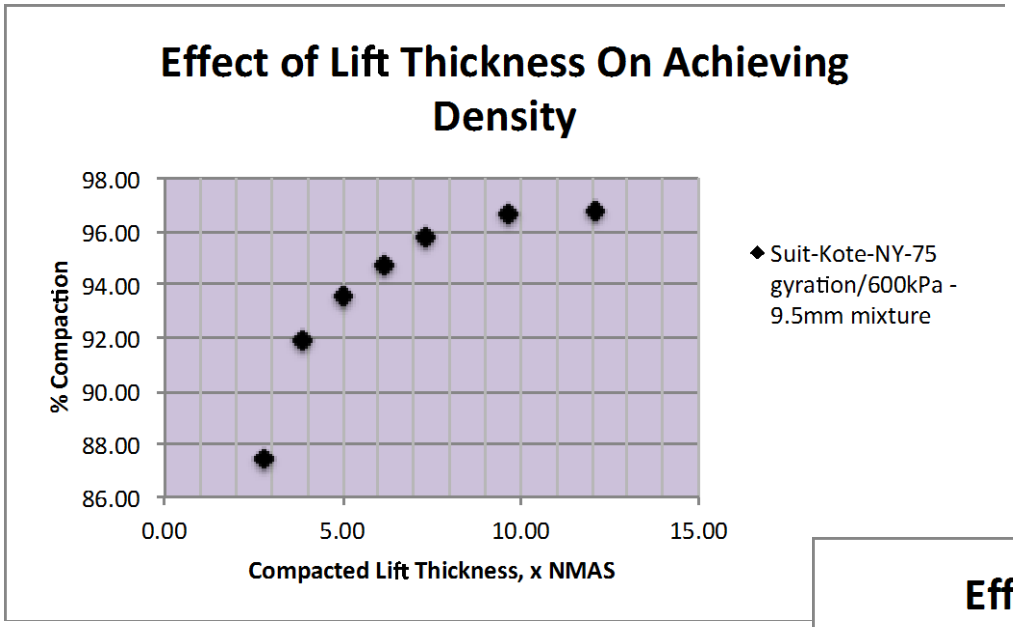
Best Practices

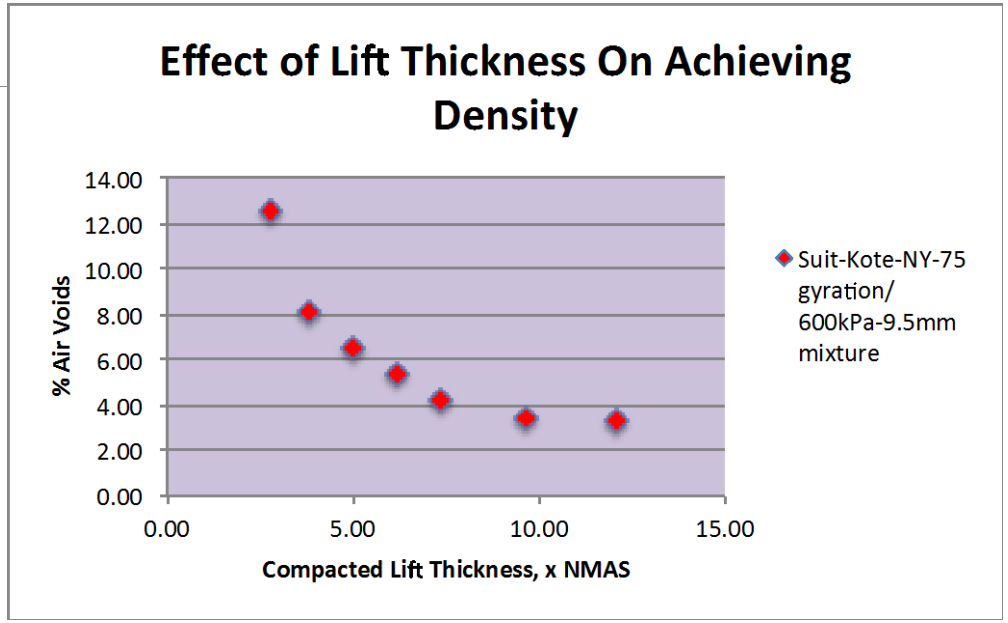
- Mix production
- Tack coat
- Paving operations
- Compaction
  - # of rollers
  - IC
- Pave IR
- Longitudinal Joints

Measurement and Payment

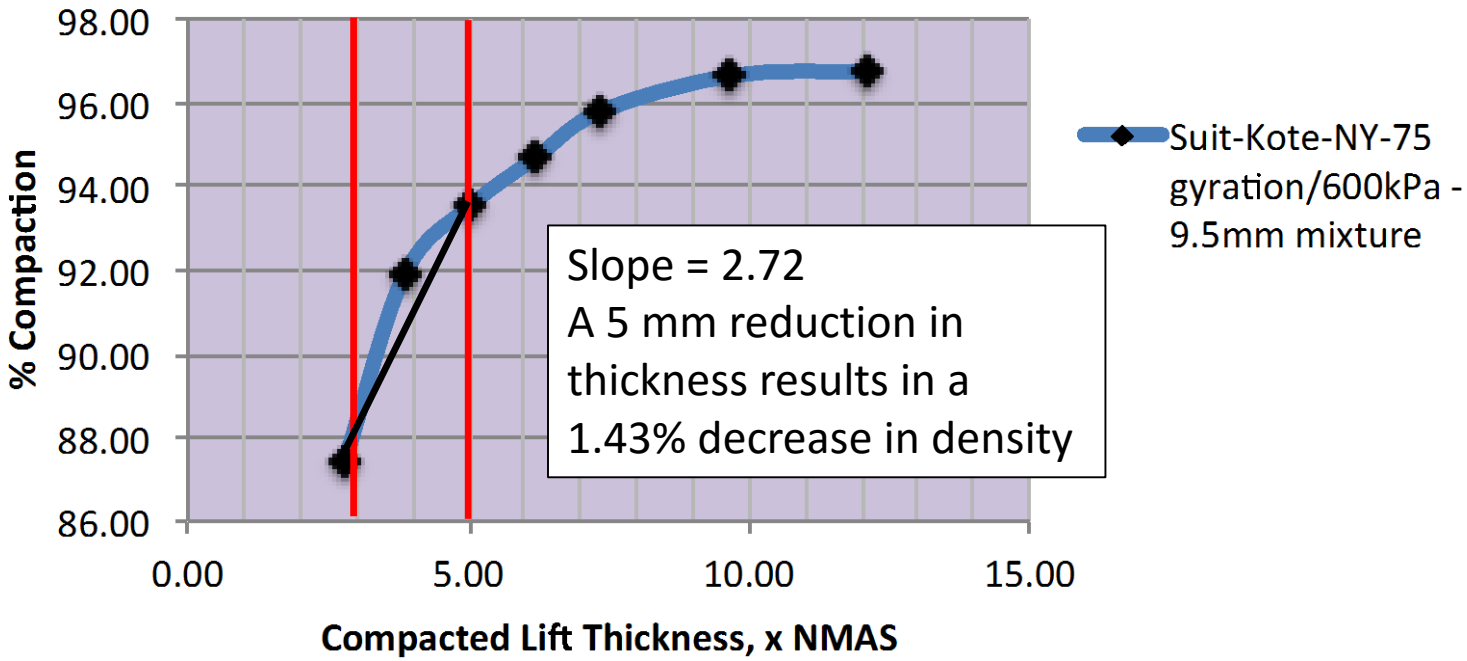
- Increase Limits
- PWL vs. Average
- One sided PWL




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



FHWA & Asphalt Institute Workshop

- Feedback Very Positive
  - Formal training
  - Comprehensive:
    - Mix design to
    - Finish roller to
    - Measurement and Acceptance
  - Back to the basics focus
  - Learned new topics and reinforced others
  - over 450 participants

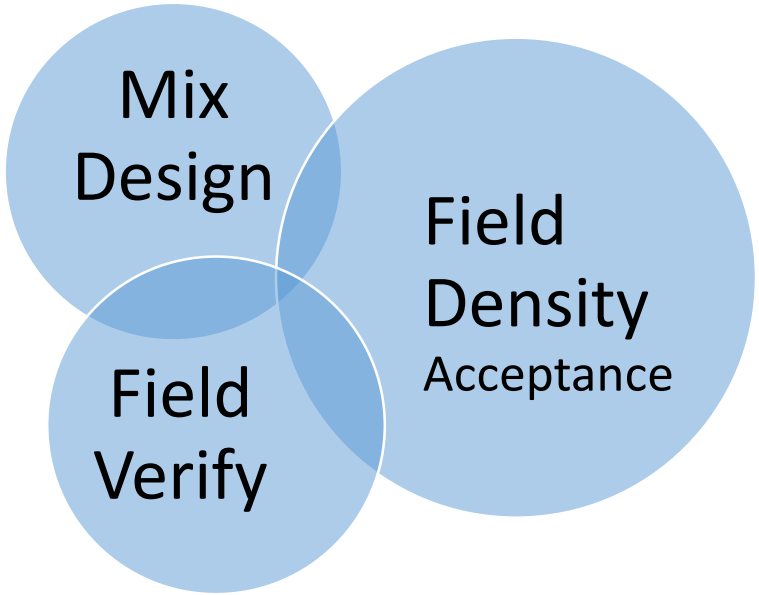
U.S.Department of Transportation
Federal Highway Administration

Our Visit

1. The Importance of Density
2. FHWA – AI Compaction Workshop
3. Field Demonstration Projects
4. Summary

FHWA Demonstration Project
Field Project Results

- 8 of 10 projects constructed to date
- Three Key Lessons:
  1. Follow best practices
  2. Inter-relationship between:
  3. Higher density is achievable



State #1

Experiment	Contractor's Compactive Effort
Control	2 static rollers in echelon (≈10 passes each)
Test Section 1	**Added 1 to 2 vibratory passes**
Test Section 2	3 rollers – **added pneumatic**

State #1

Experiment	Density Results (%)	Change
Control	93.5	---
Test Section 1	93.2	Not significant
Test Section 2	95.4	+ 1.9

Average of 10 core densities each / Reference is G_{mm}

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

State #2

Experiment	Contractor's Compactive Effort
Control	10-ton vibratory roller **(8 passes)** 4-ton vibratory roller (7 passes)
Test Section	10-ton vibratory roller **(10 passes)** 4-ton vibratory roller (7 passes)

State #2

Experiment	Density Results (%)	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

State #3

Experiment	Contractor's Compactive Effort
Control	4 rollers - 2 vibratory in echelon (5 to 7 passes each) - 2 pneumatic in echelon (5 to 7 passes each)
Test Section 1	5 rollers – **added 1 vibratory roller**
Test Section 2	5 rollers – **added 0.3% asphalt**

State #3

Experiment	Density Results (%)	Change
Control	92.9	---
Test Section 1	92.9	No change
Test Section 2	94.1	+ 1.2

Average of 8 core densities each / Reference is G_{mm}

- 4 compaction rollers needed to meet specification
- 1 additional roller did not change % density
- Mix design adjustment resulted in % density increase
- Added new technology: IC, IR, and RDM

State #4

Experiment	Contractor's Compactive Effort
Control	2 vibratory rollers in echelon (5 passes each) 1 pneumatic roller (11 passes)
Test Section 1	**Added 1 vibratory roller**
Test Section 2	4 rollers **Added 0.3% asphalt**

State #4

Experiment	Density Results (%)	Change
Control	94.1	---
Test Section 1	94.4	+ 0.3
Test Section 2	95.3	+ 1.2

Average of 12 nuclear gauge readings each / Reference is G_{mm}

- Control achieved maximum incentive
- Additional roller did not change % density
- Mix design adjustment resulted in % density increase

State #5

Experiment	Contractor's Compactive Effort
Control	Current minimum sublot specification
Test Section 1	New PWL specification 4 rollers – **3 vibratory rollers in echelon** 1 vibratory on joint (4 vibratory & 1 static pass)

State #5

Experiment	Density Results (%)	Change	Pay Factor	Std. Dev.
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 / Reference is G_{mm}
* Statewide averages

- Implementing PWL specification
- Control and test section both obtained maximum incentive

FHWA Demonstration Project
Field Project Results

- 8 of 10 projects constructed
- Key Lessons:
  1. Follow best practices
     - 6 of 8 increased density from control
     - 4 of 8 had equipment issues
  2. Inter-relationship between:
     - Mix design / Field mix verification / Density specification
     - 2 of 8 had “dry” mixtures
  3. Higher density is achievable:
     - Optimistically: higher density with best practices only (8 of 8)
     - Pessimistically: higher density with additional roller (4 of 8)

Our Visit

1. The Importance of Density
2. FHWA – AI Compaction Workshop
3. Field Demonstration Projects
4. Summary

Summary

- Density is critical to performance
- Improving density is possible
  - Mix design changes
    - Fine gradation
    - Lower gyrations
    - Increased Vbe
  - Best practices
    - Mix production
    - Tack coat
    - Paving
    - Compaction
  - Specification changes
  - Lift thickness
- *Changes are likely*

Next Steps…

- State's summary reports on all 10 projects
  - follow-up activities on field performance
- FHWA's best practices communication
  - Summary document
  - Tech Brief
  - Additional workshops
- Extend field experiment
  - Dependent on FY17 funding
  - Dependent on State interest

Thank you

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