


**FHWA's Demonstration Project for Enhanced Durability Through Increased Density**



Courtesy Asphalt Institute

**TIM ASCHENBRENER, P.E.**  
SENIOR ASPHALT PAVEMENT ENGINEER  
PAVEMENT MATERIALS TEAM  
OFFICE OF PRECONSTRUCTION, CONSTRUCTION AND PAVEMENTS  
FHWA

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**Abbreviations & Acronyms**

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<ul style="list-style-type: none"><li>• AAD = absolute average deviation</li><li>• Avg. = average</li><li>• AVR = air void reduction</li><li>• Δ = delta = change</li><li>• DP = demonstration project</li><li>• G<sub>mm</sub> = maximum specific gravity of mixture</li><li>• Int. = interstate</li><li>• L.F. = linear foot</li><li>• LJS = longitudinal joint sealant</li><li>• mm = millimeter</li></ul>	<ul style="list-style-type: none"><li>• NCAT = National Center for Asphalt Technology</li><li>• NMAS = nominal maximum aggregate size</li><li>• PWL = percent within limits</li><li>• SHA = state highway administration</li><li>• Std. Dev. = standard deviation</li><li>• t/NMAS = thickness to NMAS</li><li>• USL = upper specification limit</li><li>• VMA = percent voids in the mineral aggregate</li><li>• WMA = warm mix asphalt</li></ul>
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**Disclaimer**

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- FHWA does not endorse any one particular entity and that any entity's name or mention of any proprietary product does not indicate FHWA endorsement and is merely shared for information exchange purposes only.

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Achieving Increased In-place Density

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- 1 • **Density is Important**
- 2 • **FHWA Density Demonstration Project**
- 3 • Gold Medal Examples
- 4 • How Higher Density Was Obtained
- 5 • Agency Specification Changes
- 6 • Overcoming Obstacles
- 7 • Wrap Up

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Remembering the Basics

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Hughes, C.S., "Comparison of Asphalt Pavements," NC18P Synthesis 134, Washington, DC, 1999.

- Compaction is the single most important factor that affects pavement performance in terms of durability, fatigue life, resistance to deformation, strength and moisture damage.



Gellier, M., Synthesis 137

- "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 19-19, 1999.

- "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."

- Even as technologies evolve, the basics remain relevant to the FHWA density demonstration project.
- Today's national experts continue to support fundamentals articulated decades ago.

Quotes and images used with permission.

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Reasons for Obtaining Density

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- 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



FHWA photo

**Density is important, but not a cure-all**

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National Center for Asphalt Technology (NCAT)  
Report 16-02 (2016) (Funded by FHWA)

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“A **1% decrease in air voids** was estimated to:

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



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

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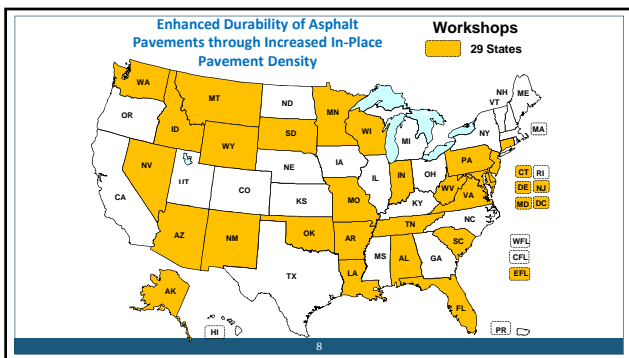
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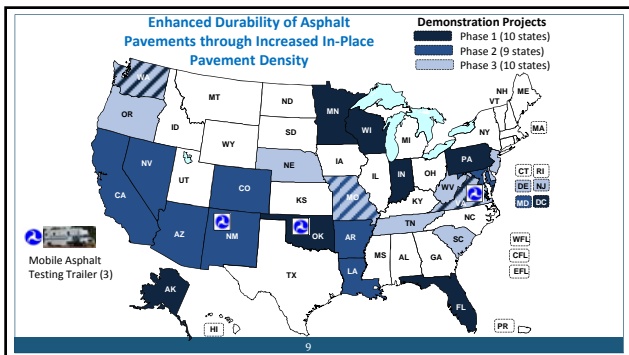
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### Demonstration Project Status

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Phase	Year	States	Constructed	State Reports Completed	FHWA Summary Report	Additional Information
1	2016	10	10	10	July 2017	Literature Review
2	2017-2018	8	8 (2 re-do's)	7	July 2019	Gold Medal Specifications
3	2018-2019	11	11	8		Contractor Techniques & SHA Changes

Updated: July 16, 2019

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### Summary Reports

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**Phase 1**
**Phase 2**

- NCAT Report 17-05
- July 2017




Report Phase 1:  
<https://eng.auburn.edu/research/centers/ncat/files/technical-reports/rep17-05.pdf>

Report Phase 2:  
<https://www.fhwa.dot.gov/pavement/pubs/hif19052.pdf>

FHWA density website:  
<https://www.fhwa.dot.gov/pavement/asphalt/density/index.cfm>

- FHWA Report HIF-19-052
- NCAT Report 19-02
- July 2019



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### Achieving Increased In-place Density

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Some "Gold Medal" Density (% G<sub>mm</sub>) Specifications

Purpose

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- Identify density (% G<sub>mm</sub>) specifications that are success stories.
- Considering the Olympics, these success stories are considered "gold medal" examples.



*Image Pixabay*

Note: There are likely more. Contact me if you think you have one.

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Some "Gold Medal" Density (%G<sub>mm</sub>) Specifications

- Alaska DOT&PF
- Indiana DOT
- Maine DOT
- Maryland DOT SHA
- Michigan DOT
- Missouri DOT
- Montana DOT
- New Jersey DOT
- New York State DOT
- Pennsylvania DOT
- Puerto Rico HTA
- Tennessee DOT

Note: There are likely more. Contact me if you think you have one.

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Missouri DOT  
Statewide Results from 2018

**Avg. = 93.7%**

**5.0% below 92%**

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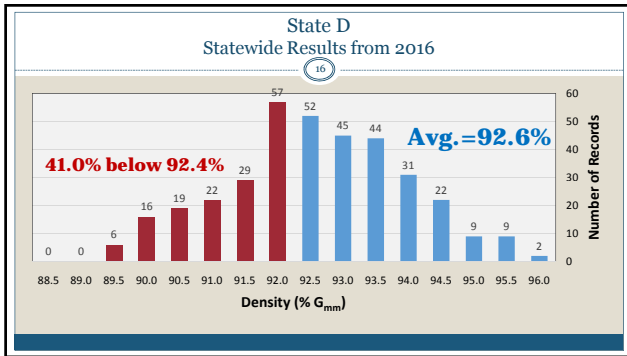
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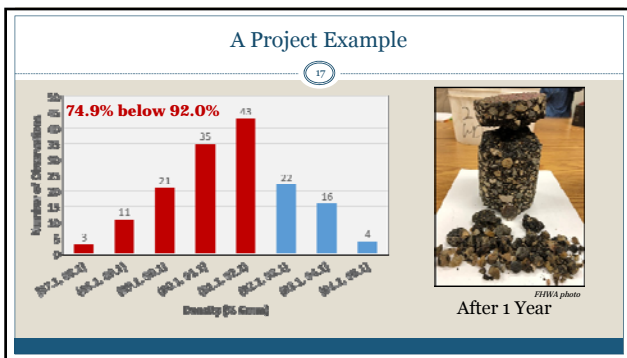
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### "Gold Medal" Density (%G<sub>mm</sub>) Specifications Specification / Criteria / Results

	Example State	MD	MT	TN
Type of Specification	Lot Avg.	Lot Avg. & Ind. Sublot	Lot Avg. & Range	Lot Avg.
Limits (% G <sub>mm</sub> )	91.5 to 95.0	92.0 to 97.0	93.0 to 100.0	92.0 to 97.0
Incentive for Only Density	1.5%	5.0%	8.0% (AC sep.)	2.0%
Max. Incent. (% G <sub>mm</sub> )	92.75	94.0	94.0 to 95.0	94.0
Avg. (% G <sub>mm</sub> )	92.6	94.0	94.3	93.9
Std. Dev. of Lots	N/A	1.03	N/A	N/A
< 92% G <sub>mm</sub>	25-3%	5-3%	6.6%	11.0%

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**“Gold Medal” Density (%G<sub>mm</sub>) Specifications**  
Specification / Criteria / Results



	AK	IN	ME	MI	NJ	MO	NY	PA	PRHTA
Type of Specification	PWL	PWL	PWL	PWL	PD	PWL	PWL	PWL	PWL
Limits (% G <sub>mm</sub> )	93.0 to 100.0	93.0 to 100.0	92.5 to 97.5	92.5 to 100.0	92.0 to 98.0	92.0 to 97.0	92.0 to 97.0	92.0 to 98.0	92.0 to 99.0
Incentive for Only Density	5.0%	1.75%	2.5%	2.0%	4.0%	1.25%	5.0%	2.0%	2.5%
Max. Incent. (% G <sub>mm</sub> )	≈96.0		≈93.5	≈94.5		≈94.5	≈94.0	≈94.0	≈94.0
Avg. (% G <sub>mm</sub> )	94.9	93.9	94.5	94.4	94.9	93.7	94.2	94.4	94.6
Std. Dev. of Lots	1.76		1.20	1.03			1.01	1.46	
< 92% G <sub>mm</sub>	5.6%	8.4%	5.8%	5.5%	5.4%	5.0%	5.0%	3.1%	3.6%

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**Gold Medal Density (% G<sub>mm</sub>) Specifications**  
Specification/Criteria/Results



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**Longitudinal Joint**

	AK	IN	ME	MI	MT	NY	PA	TN
Type of Specification	Lot Avg.	Method	PWL	Lot Avg.	Lot Avg.	Under Development	PWL	Lot Avg.
Limits (% G <sub>mm</sub> )	>91.0	Long Joint Sealant (LJS) and fog seal	>91.0	>90.5	>91.0 >92.0 for incentive		>90.0	>91.0
Incentive for Only Joint Density	\$1.50 per L.F. (≈6.25%)		2.0%	\$1.00 per L.F. (≈4.0%)	\$4.50 per L.F.		\$5000 per Lot (≈2.5%)	1.25%

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- Achieving Increased In-place Density**
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Can We Achieve Increased In-place Density?

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**YES!**

- Test sections had increased density (% Gmm):
- 17 of 29 demonstration projects achieved  $\geq 1.0\%$  increase
- 23 of 29 demonstration projects achieved  $\geq 94.0\%$  Gmm
- 24 of 29 had either/or

Of 26 states, will there be changes?

- 24 of 26 states are changing specifications

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What Changes Were Made to Increase Density?

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• Contractor Changes

- More passes / more rollers / type / location
  - "Roll until you meet density requirements"
  - Some were using 1 roller
  - Pneumatic / Oscillation / Combination
  - Echelon



Courtesy Miguel Montoya

• Agency Changes

- Adjusting optimum asphalt content
- Larger t/NMAS
- Smaller NMAS
- Innovative materials / techniques

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State 4:  
Cost / Benefit of Best Practices

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- Benefit of 1% Density Increase  
10 percent of \$60 / ton mix = \$\$\$\$\$

• Cost of 1 Percent Density Increase

- Additional rollers  $\leq \$$
- Additional binder  $\leq \$\$$   
(AVR to 3%)
- WMA Additive  $\leq \$$
- 9.5mm vs. 12.5mm  $\approx \$\$$



Image: Pixabay, text added

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Achieving Increased In-place Density

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Acknowledgements

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- Adam Hand, University of Nevada Reno
- Tim Kowalski, Wirtgen-Group
- Todd Mansell, Caterpillar Paving Products

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Additional Resources

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- Asphalt Institute (2007). The Asphalt Handbook, Manual Series No. 4 (MS-4), Seventh Edition
- Brown, E.R., et al. (2009). Hot Mix Asphalt Materials, Mixture Design and Construction, Third Edition, NAPA Research and Education Foundation
- U.S. Army Corps of Engineers (2000). Hot-Mix Asphalt Paving Handbook 2000

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### Stiff Mixture

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- Tips:
  - Breakdown rollers in echelon
  - Intermediate rollers in echelon
  - Tight roller pattern



2 Photos Courtesy: Lee Gallivan

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### Tender Mixture

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- Causes:
  - Additional fluids
    - Moisture (aggregates, reclaimed materials, etc.)
    - Additives (anti-stripping, WMA, etc.)
  - Soft binder
- Tips:
  - Address the cause
  - Echelon rolling (before “tender zone” occurs)
  - Larger diameter roller drum
  - Should density be obtained “tomorrow”?



2 Photos Courtesy: University of Nevada Reno

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### Soft Aggregate

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- Tips:
  - **Add pneumatic roller**
  - Pneumatic roller in echelon
  - Roller set-up: amplitude, frequency and speed



2 Photos Courtesy: NCAT

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Soft Aggregate 31

- **Tips:**
  - Add pneumatic roller
  - **Pneumatic roller in echelon**
  - Roller set-up: amplitude, frequency and speed



*Photo Courtesy University Nevada Reno*

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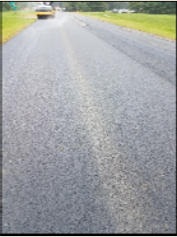
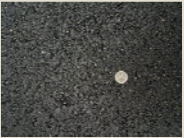
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Soft Aggregate 32

- **Tips:**
  - Add pneumatic roller
  - Pneumatic roller in echelon
  - **Roller set-up: amplitude, frequency and speed**



*Photo Courtesy NCAT*

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Weak Base / Subbase / Subgrade 33

- **Tips:**
  - Lower density requirement in lowest lift
  - Properly compacted base, subbase and subgrade
    - Good specification
    - Proof rolling
    - Intelligent compaction
    - Correct deficiencies
  - Treat lowest lift as a fatigue-resistant layer
    - Asphalt mixture design requirements (e.g., increased asphalt content, etc.)

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### Density Curve

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- Tips:
  - Good information
  - Strict adherence can pose issues
  - Density curve weaknesses include:
    - Mixture changes with time: temperature, moisture, etc.
    - May encourage "lazy" roller pattern
  - May not encourage:
    - Echelon rollers
    - Type of roller
  - False peaks
  - Test strip vs. production is often different

Roller Pattern

High Density

Low Density

Roller Passes: 1, 2, 3, 4, 5, 6, 7

Passing Density

False Peak

*Graphic Courtesy National Highway Institute*

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### Smoothness

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- Tips:
  - Agency's control
    - Number of lifts
    - Thickness of lifts
  - Contractor's control
    - Paver operation
    - Mixture delivery
  - Rollers play a minor role: this can be easily fixed

*FHWA Photo*

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### Achieving Increased In-place Density

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### Key Findings

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- Level of field compactive effort varies greatly
- No extraordinary field compactive effort needed
  - Specification (quality measure, limits, incentives, etc.)
  - Smaller NMAS
  - Larger t/NMAS
  - Adequate binder content
- All Together:
  - Mixture design with appropriate asphalt content
  - Performance testing
  - Acceptance
  - In-place density

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### Next Steps

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- Field experiment – Phase 3 Report
  - 11 of 11 states completed construction
  - 8 of 11 states completed reports
- FHWA's best practices communication
  - Tech Brief
  - Focused visits in 2020
  - Additional workshops (funding dependent)



Image: Pixabay

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# Thank you

QUESTIONS / COMMENTS:

**TIM ASCHENBRENER, P. E.**  
FHWA

SENIOR ASPHALT PAVEMENT ENGINEER  
PAVEMENT MATERIALS TEAM  
OFFICE OF PRECONSTRUCTION, CONSTRUCTION AND PAVEMENTS  
LAKEWOOD, COLORADO

(720) 963-3247  
TIMOTHY.ASCHENBRENER@DOT.GOV



Image: Pixabay

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