Thin Lift Asphalt Overlays:
Project Selection, Design, and Construction

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This presentation was developed with support from the Federal Highway Administration

Outline

- Introduction
- Project Selection
- Thin Lift Asphalt Design
- Moisture Considerations
- Surface Preparation
- Construction
- Testing and QA
- Case Studies
- Conclusions

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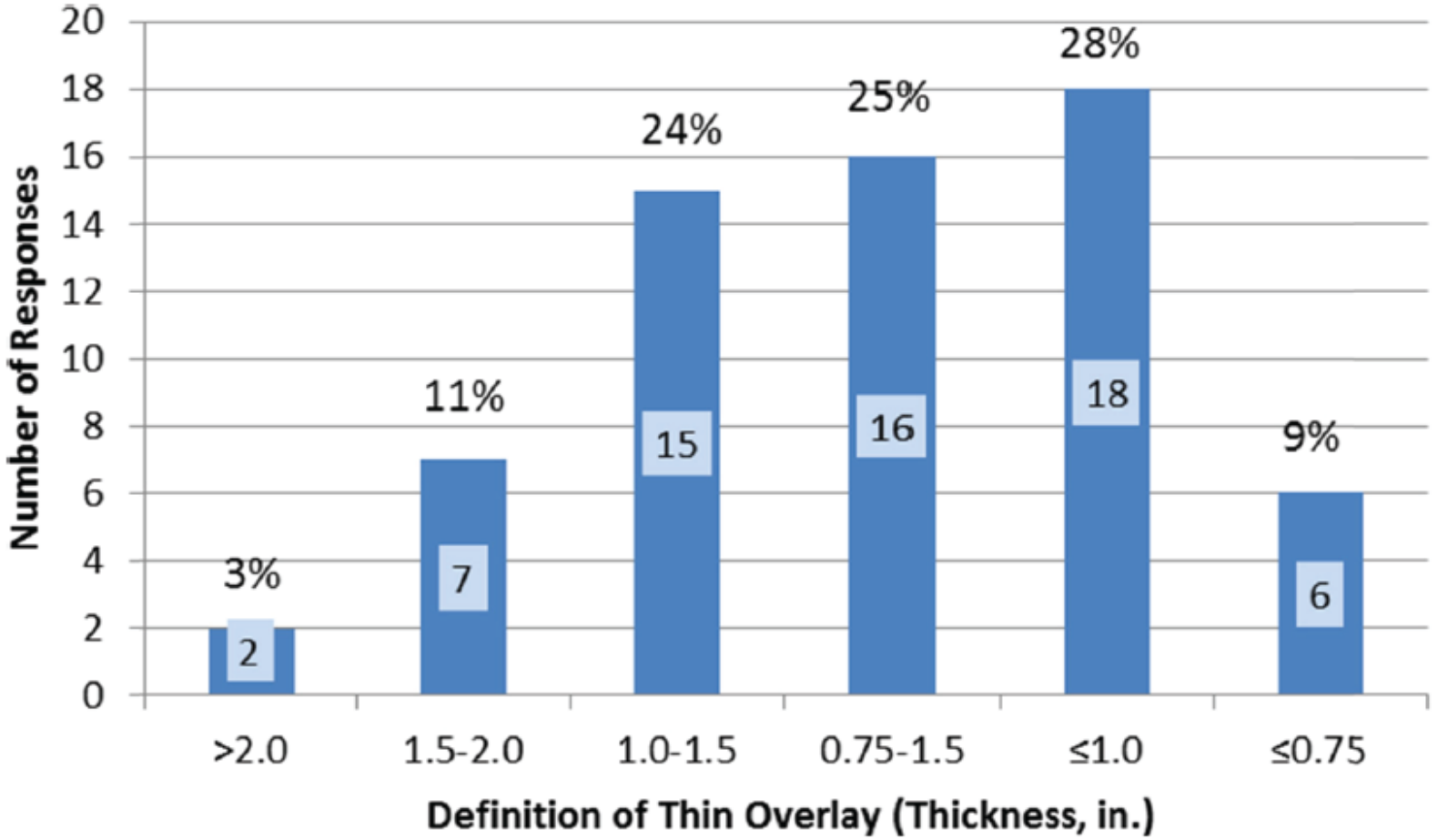
Introduction

How is “thin lift” asphalt defined?

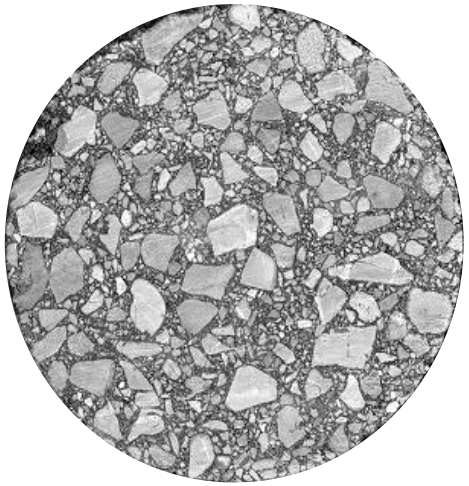


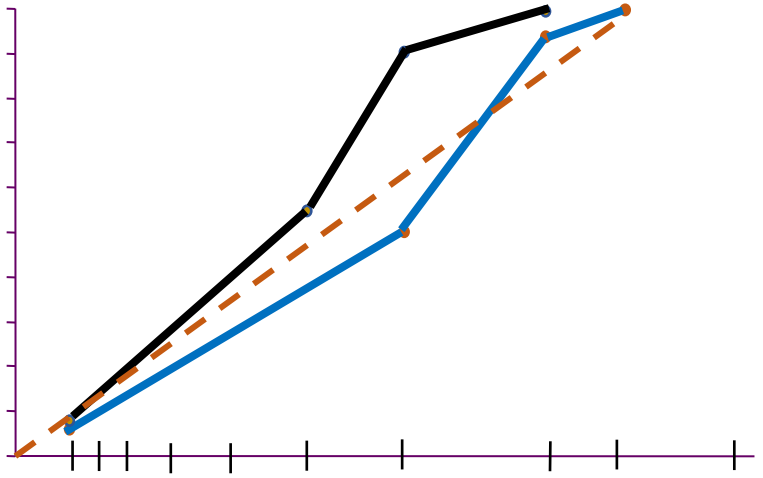
State survey responses - **NCHRP Synthesis 464: Thin Asphalt Concrete Overlays**

Thin Lift Mix Types

***Dense-Graded* :** has a well-distributed aggregate gradation throughout the entire range of sieves used.

- It is by far the most commonly-specified type of mix for all lifts within a pavement structure, including thin surface lifts.

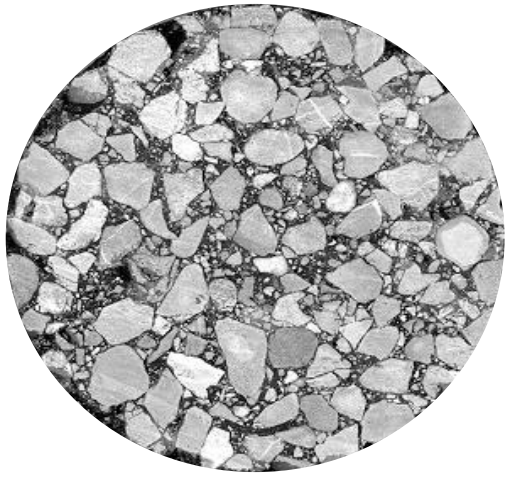


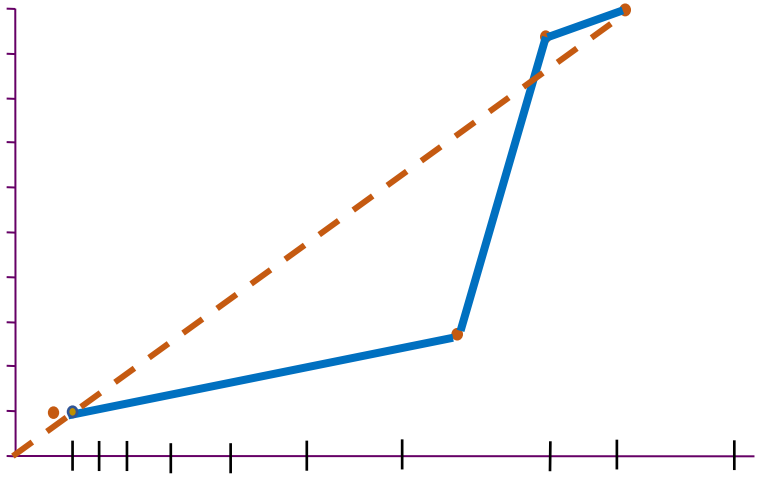


Thin Lift Mix Types

***Gap-Graded* :** has a high coarse-aggregate content (typically 70 - 80%), a high binder content (typically > 6%), and a high mineral filler content (typically > 8%), but few intermediate-sized particles.

- The high binder and filler content make it durable and the stone-on-stone contact makes it rut resistant.

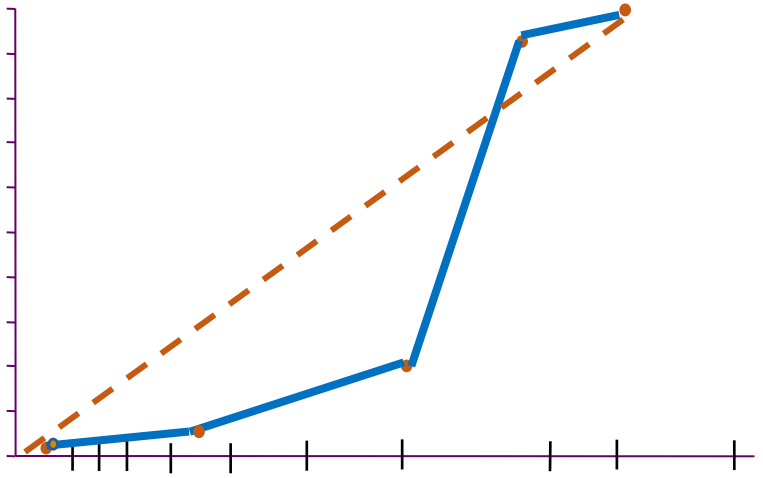




Mix Design - Dense-Graded Mixes

***Open-Graded* :** are designed to have a high percentage of air voids (typically 18-22%) by using uniformly-graded aggregates with minimal fines.

- These mixes drain readily to reduce surface spray and glare for enhanced safety and also reduce road noise.



How is “thin lift” asphalt used?

Benefits of Thin Asphalt Overlays (Dense-Graded and Gap-Graded Mixtures)

- Long service life, low life-cycle cost
- Can handle heavy traffic
- Can be constructed quickly, minimizing traffic delays
- Protects existing pavement
- Seals the surface
- Reduces rate of pavement deterioration
- Corrects surface deficiencies
- Restores skid resistance
- Can be recycled
- Aesthetically pleasing
- Safe
- Quiet
- Smooth
- *Looks and feels new to the traveling public*

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Benefits of Thin Asphalt Overlays (Open-Graded Mixtures)

- Reduces road spray in wet weather
- Reduces nighttime glare in wet weather
- Reduces potential for hydroplaning
- Can handle heavy traffic
- Can be constructed quickly, minimizing traffic delays
- Restores skid resistance
- Can be recycled
- Aesthetically pleasing
- Safe
- Quiet
- Smooth
- *Looks and feels new to the traveling public*

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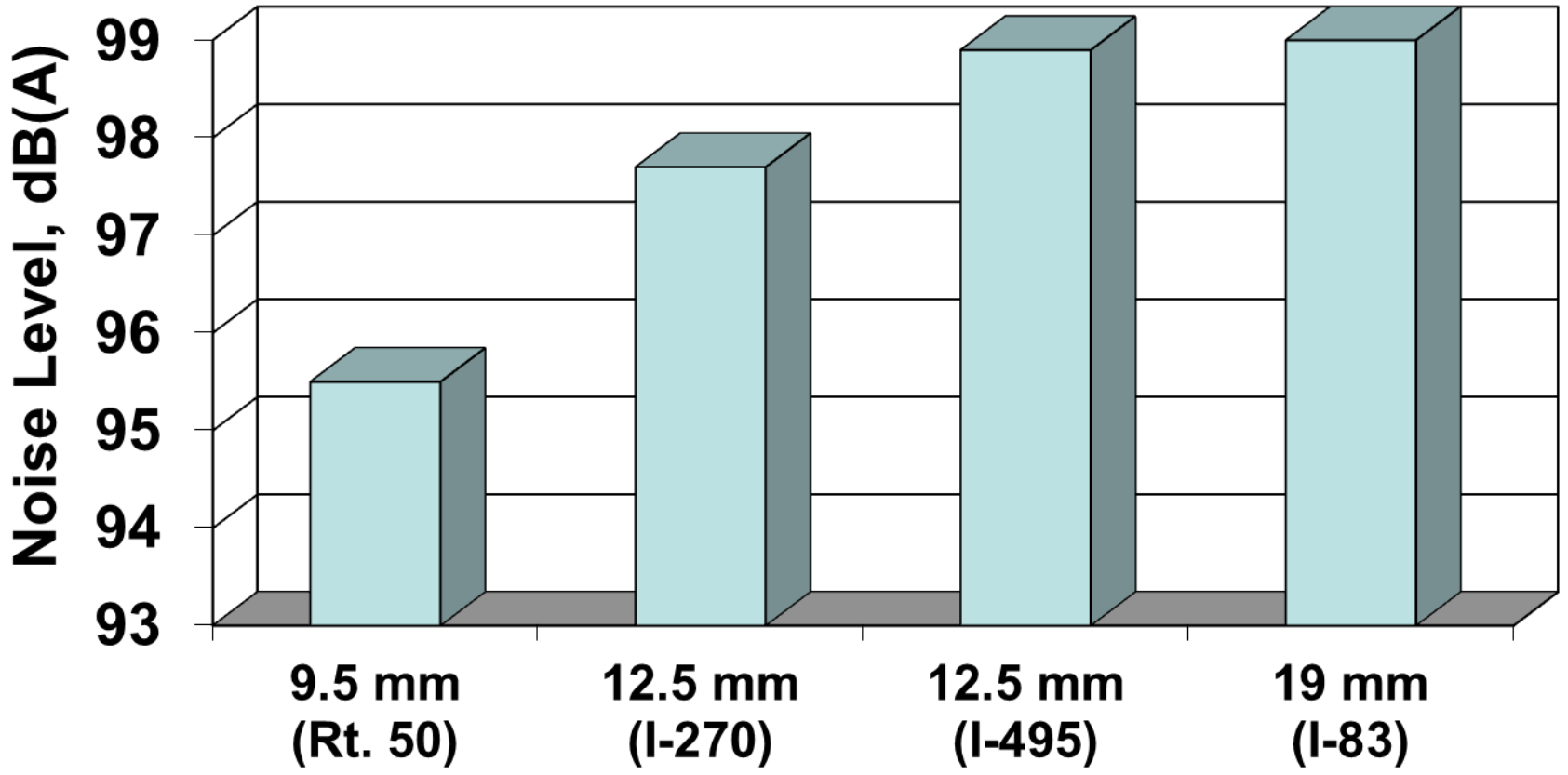
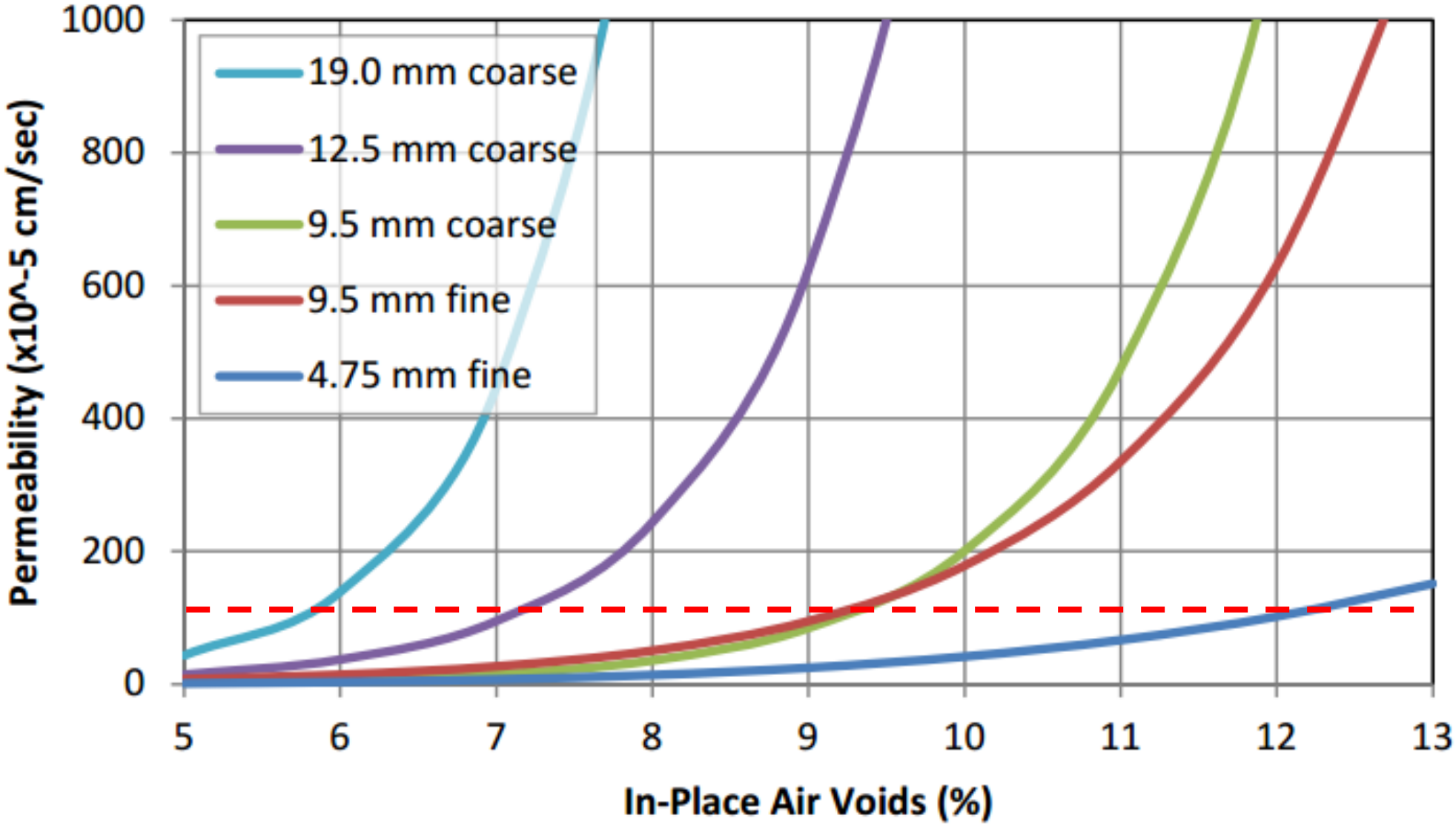
Noise Reduction

NCAT Noise Trailer on SMA Mixtures



NCAT - Hanson, James and NeSmith 2002

Permeability - Dense Graded Mixtures



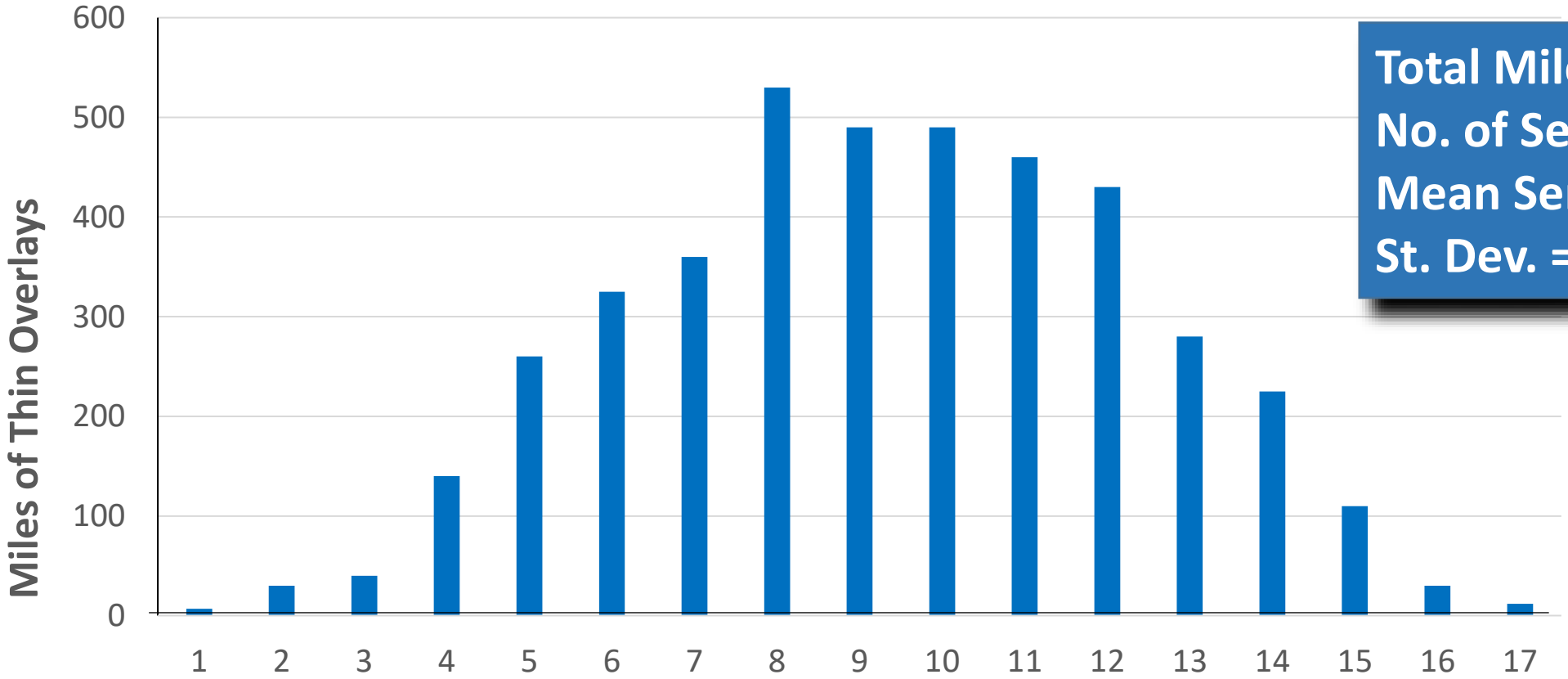
NCAT - Brown and Heitzman 2013

Permeability - Dense Graded Mixtures

Permeability in a coarse dense-graded 12.5mm Superpave surface mix.

Expected Longevity

Service Life of Dense-Graded Thin Asphalt Overlays in Ohio



Total Miles = 4075
No. of Sections = 1923
Mean Service Life = 9.1 yrs
St. Dev. = 3.0 yrs

FHWA/OH-2008/4
Effectiveness of Thin Hot Mix Asphalt Overlay on Pavement Ride and Condition Performance
Chou, Datta, Pulugurta

Project Selection for Thin Lifts

Project Selection - Thin Asphalt Overlays

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Versatile - Materials and Mix Types for All Roads

Components of a Basic Evaluation

- Visual Survey
- Structural Assessment
- Drainage Evaluation
- Functional Evaluation
- Maintenance Personnel
- PMS

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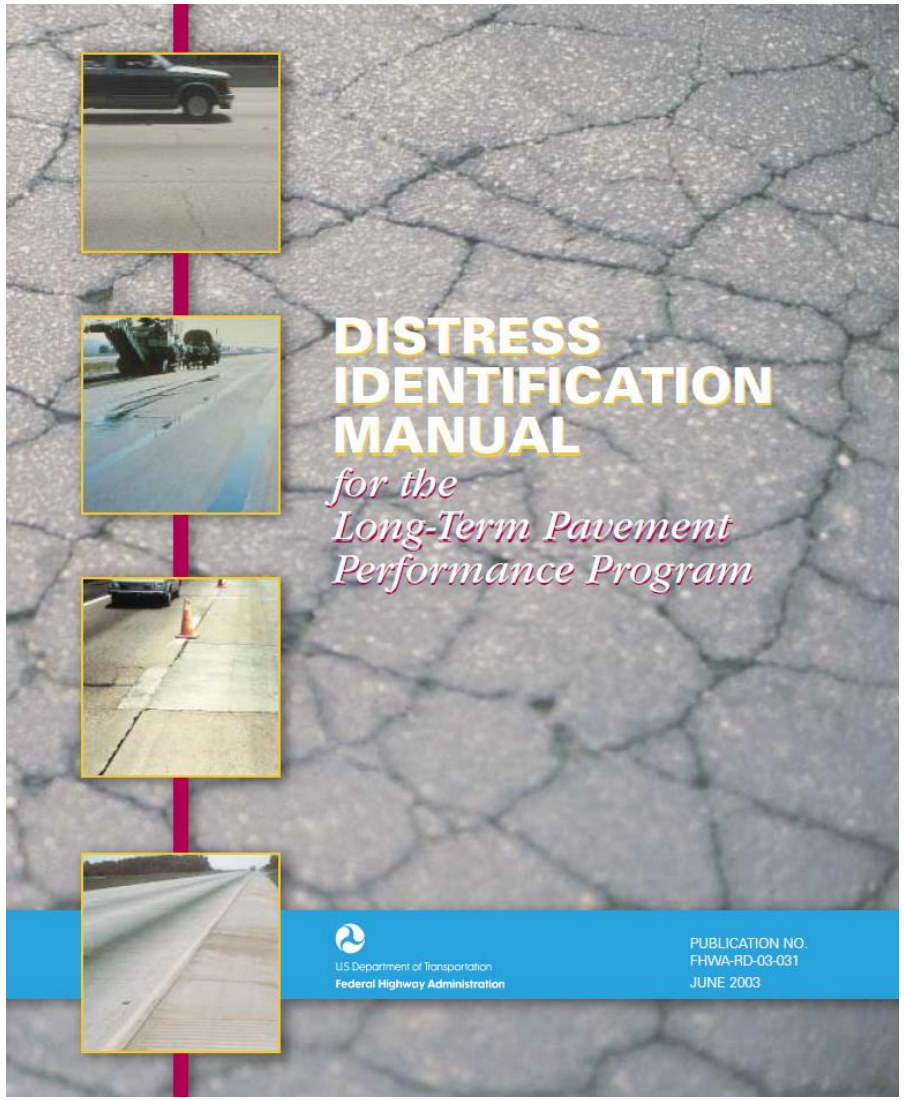
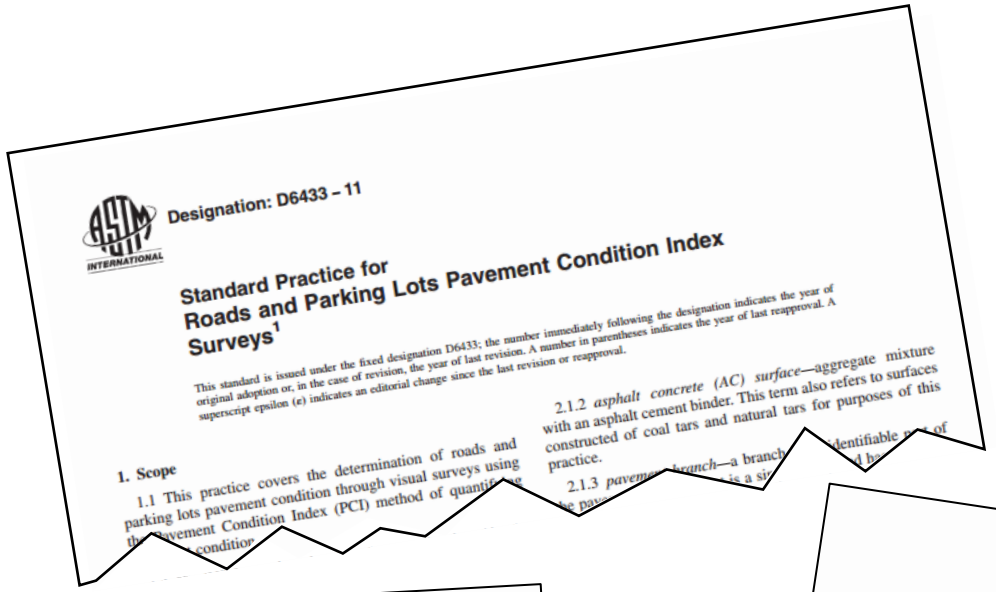
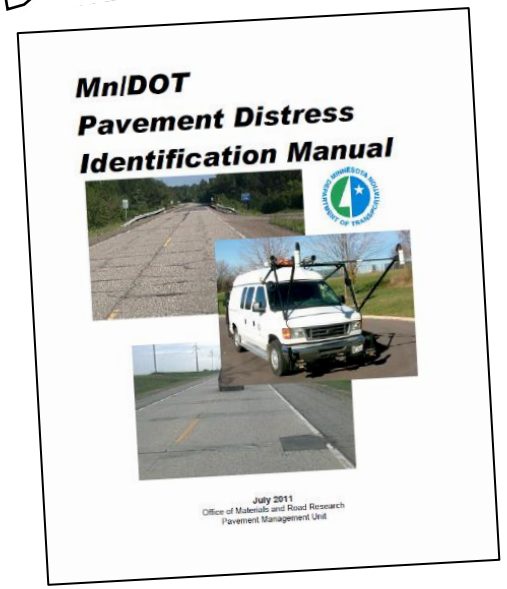
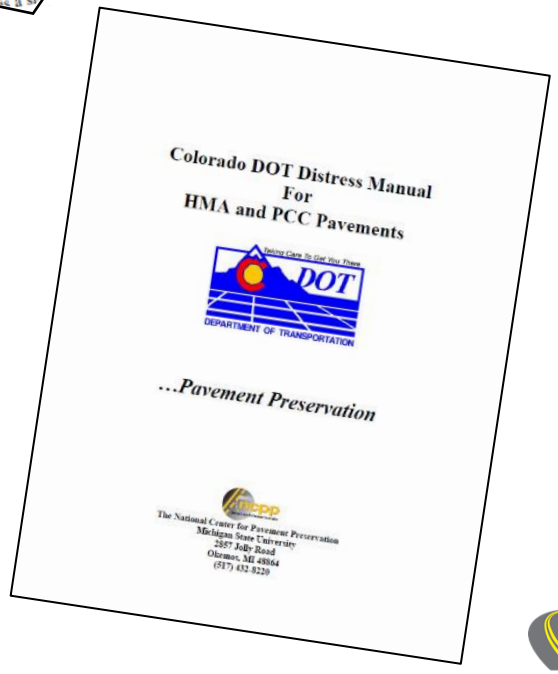
Identifying/Classifying Distresses in Existing Pavement





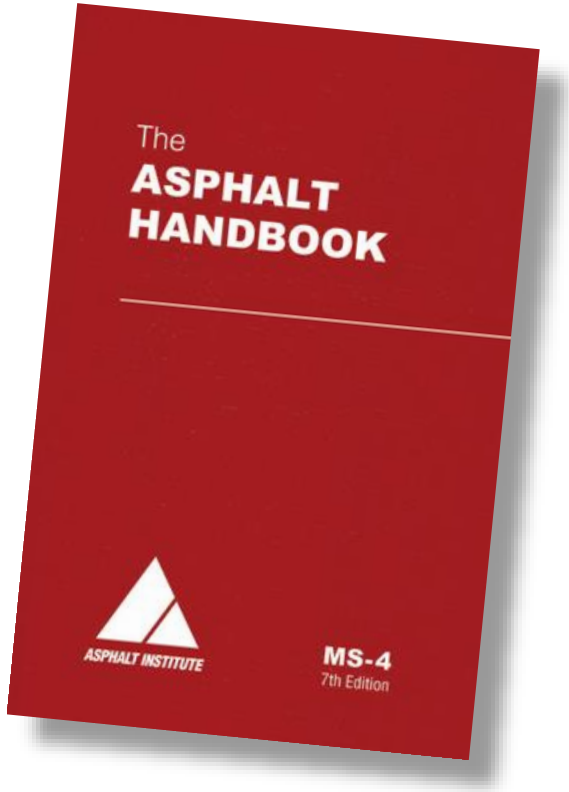




Categories of Distresses

The Asphalt Institute's MS-4 Asphalt Handbook categorizes the common types of asphalt pavement distress:

- **Cracking**
  - Fatigue Cracking
  - Block Cracking
  - Edge Cracking
  - Longitudinal Cracking
  - Slippage Cracking
  - Reflection Cracking
- **Distortion**
  - Rutting
  - Corrugations and Shoving
  - Settlement/Grade Depressions
  - Upheaval/Swell
- **Disintegration**
  - Potholes
  - Raveling/Weathering
- **Skid Hazards**
  - Bleeding/Flushing
  - Polished Aggregates



Cores as a Forensic Tool

Cores:

- determine crack depth
- bottom up or top down
- determine rut location
- other distress types

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Identify Movement of Cracking

Working Crack

- ≥ 3mm (1/8”) movement
- Thermal
- Jointed Concrete

Non-Working Crack

- < 3mm (1/8”) movement
- Longitudinal and Block
- Fatigue?

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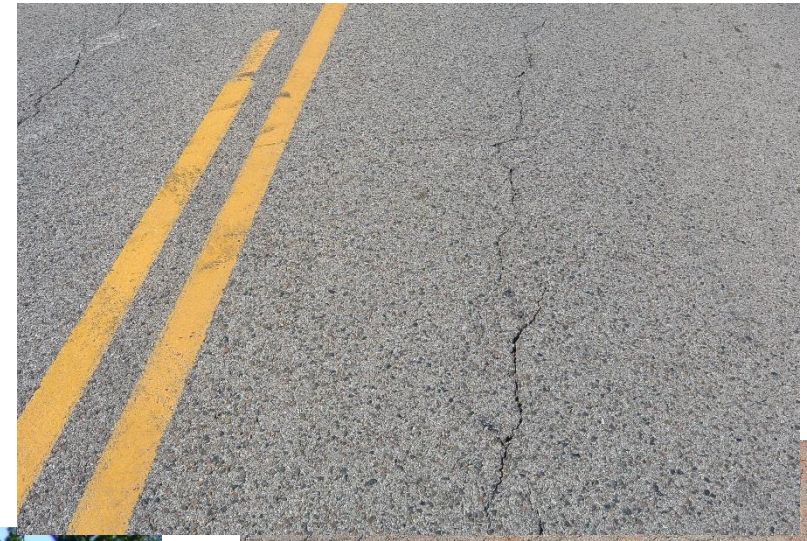
Identify Percentage and Severity of Cracking

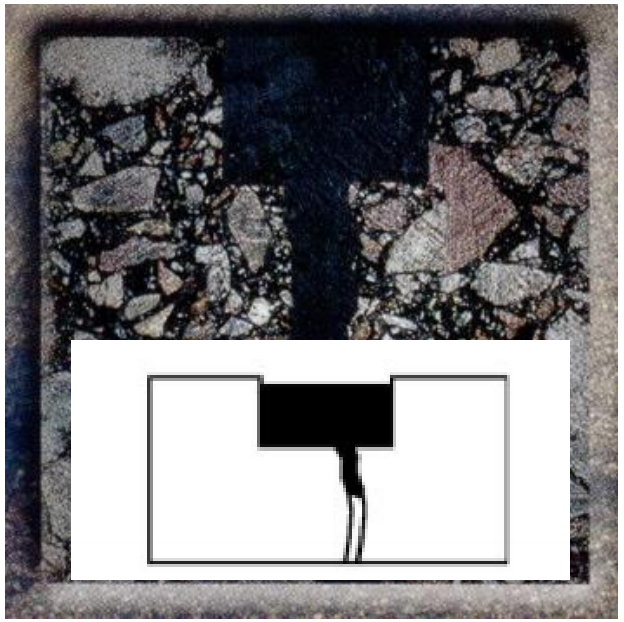
- percentage in length or area
- severity?
  - low
  - moderate
  - high



Crack Sealing Before a Thin Asphalt Overlay

Route

Clean



Seal
Reservoir and Recessed

Thin Asphalt Overlays on Pavements with Distortion

Rutting due to unstable subgrade

Rutting due to unstable plastic mix

Thin Asphalt Overlays on Pavements with Distortion

Low rutting due to normal traffic consolidation

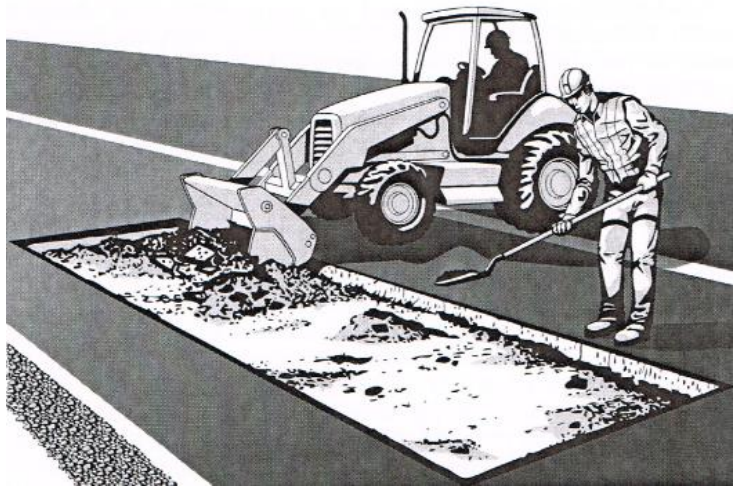
Thin Asphalt Overlays on Pavements with Distortion

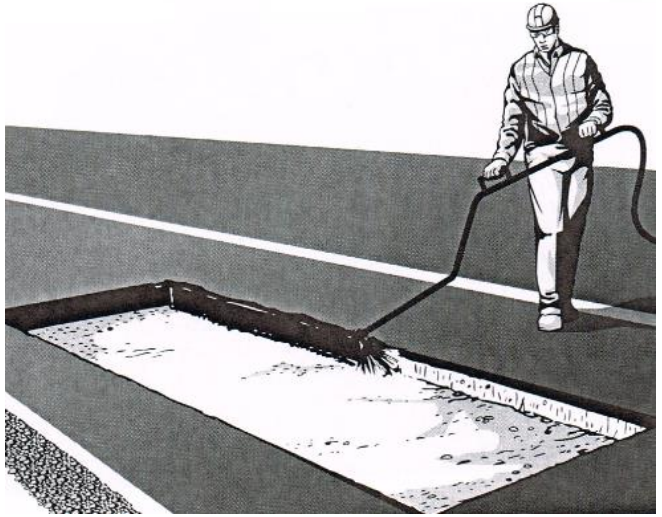
Corrugations and shoving

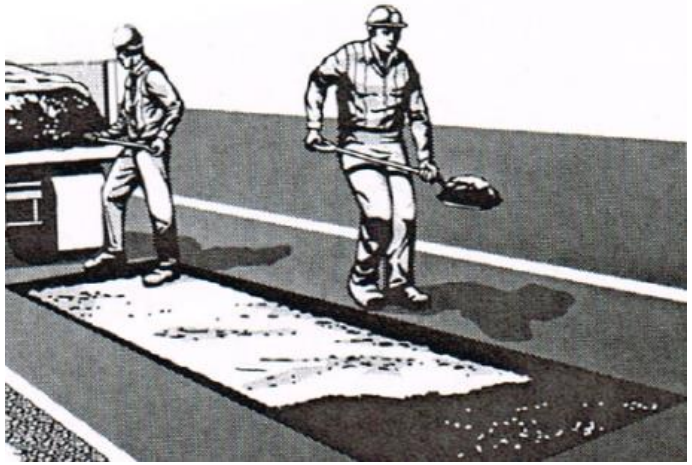
Leveling course in a large depression

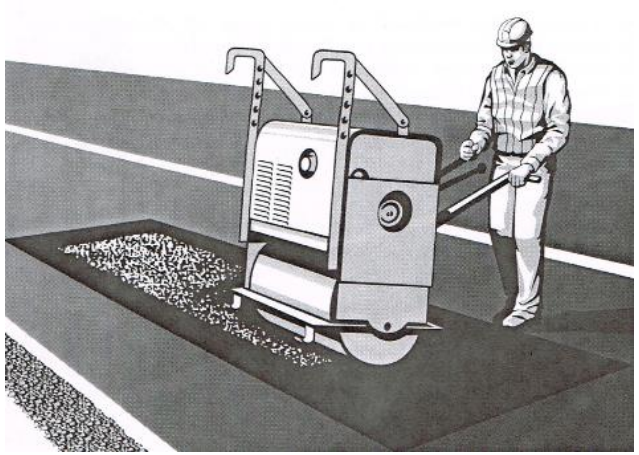
Distortion due to frost heave

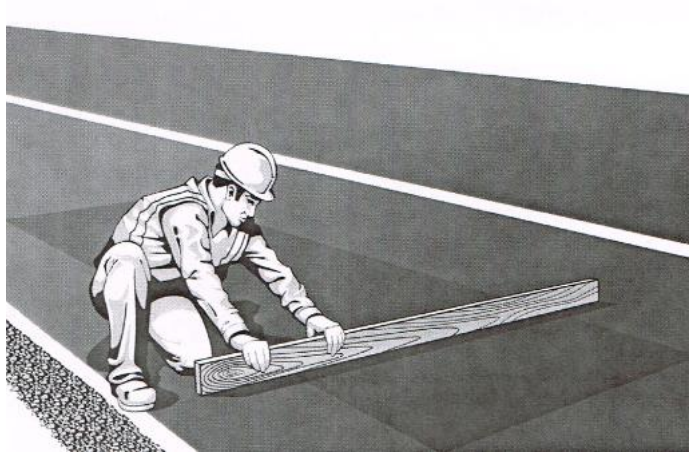
Thin Asphalt Overlays on Pavements with Potholes or Other Localized Distress











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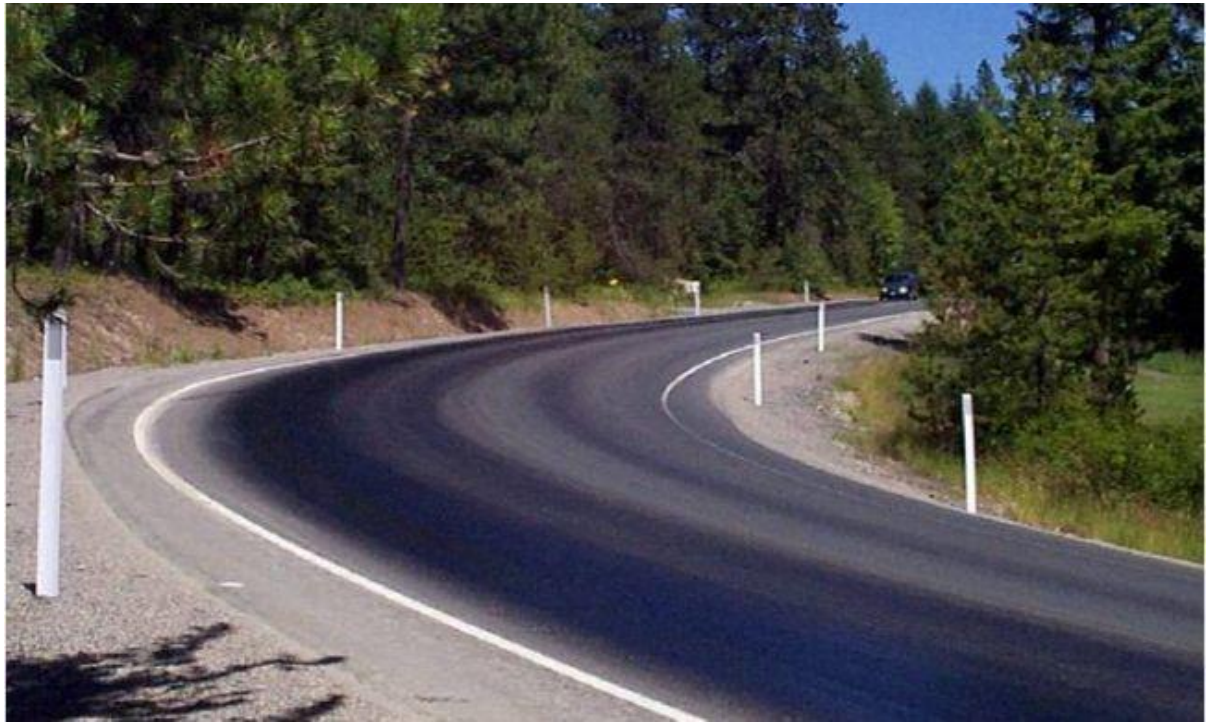
Thin Asphalt Overlays on Pavements with Weathering or Raveling

Thin Asphalt Overlays on Pavements with Skid Hazards

Polishing



Bleeding and flushing

Project Selection for Thin Asphalt Overlays

EFFECTIVE
MARGINAL
NOT APPROPRIATE

* *Several distress types must be treated or corrected in some manner before thin asphalt overlay*

Low % / Severity ⟷ High % / Severity

Fatigue Cracking			
Block Cracking			
Edge Cracking			
Longitudinal Cracking			
Slippage Cracking (*patched*)			
Reflection Cracking			
Rutting (*if plastic surface mix and milled*)			
Corrugations and Shoving (*patched*)			
Settlement / Grade Depression			
Upheaval / Swell			
Potholes (*after patching*)			
Raveling / Weathering			
Polishing			
Flushing / Bleeding			

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MIX DESIGN FOR THIN LIFTS

Binder Selection

- Superpave - typically based on climate and traffic
- SMAs and PFCs - modified binders often required

Aggregate Selection

- NMAS should be 1/2”, 3/8”, or No. 4.
- The lift thickness should be 3 to 5 times the NMAS.

Aggregate Quality for Small NMAS Dense-Graded Asphalt Mixtures

NMAS	12.5mm		9.5mm		6.3mm	4.75mm		
Agency	**Alabama**	**N. Carolina**	**Nevada**	**Utah**	**New York**	**Maryland**	**Georgia**	**Ohio**
Aggregate Quality								
LA Abrasion, % loss	48 max	35 max	37 max	35/40 max[1]				40 max
Sodium Sulfate Soundness, % loss	10 max	15 max	12 max	16/16 max[1]				12 max
% 2 or More Fractured Faces		85 min	80 min	90/90 min[1]				
% 1 or More Fractured Faces		100 min		95/90 min[1]				10/100 min[1]
Sand Equivalent, %		45 min		60/45 min[1]	45 min		28/40 min[2]	
FAA, %	43/45 min[1]	40 min			43 min	40 min		

[1] Low or Medium Volume / High Volume

[2] Carbonate / Other Aggregates

Aggregate Types

- For skid resistance, the coarse portion should consist of angular, polish-resistant aggregate.
- Granites, sandstones, quartzites, rhyolites, etc.

Crushed Granite

Crushed Quartzite

Mine Chat

RAP Use

- Use RAP in reasonable quantities to reduce cost
- RAP will help
  - Stabilize cost
  - Prevent rutting
  - Prevent scuffing
- Use up to maximum allowable while maintaining gradation and volumetrics

RAP Use

- RAP may need to be fractionated
- Finer fractions will have a higher binder content
- Rap Binder Ratio of lower % Fine RAP = higher % of unprocessed RAP

AASHTO Gradations for Small NMAS Dense-Graded Asphalt Mixtures

NMAS	37.5mm		25.0mm		19.0 mm		12.5mm		9.5mm		4.75mm	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Sieve Size (mm)	% Passing											
50.0	100	-	-	-	-	-	-	-	-	-	-	-
37.5	90	100	100	-	-	-	-	-	-	-	-	-
25.0	-	90	90	100	100	-	-	-	-	-	-	-
19.0	-	-	-	90	90	100	100	-	-	-	-	-
12.5	-	-	-	-	-	90	90	100	100	-	100	
9.5	-	-	-	-	-	-	-	90	90	100	95	100
4.75	-	-	-	-	-	-	-	-	-	90	90	100
2.36	15	41	19	45	23	49	28	58	32	67	-	-
1.18	-	-	-	-	-	-	-	-	-	-	30	55
0.075	0	6	1	7	2	8	2	10	2	10	6	13
VMA	11.0		12.0		13.0		14.0		15.0		16.0	

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Example State Gradations for Small NMAS Dense-Graded Asphalt Mixtures

NMAS	12.5mm		9.5mm		6.3mm	4.75mm		
Agency	Alabama	N. Carolina	Nevada	Utah	New York	Maryland	Georgia	Ohio
Gradation								
Sieve Size	% Passing							
19.0 mm	100	100						
12.5 mm	90 - 100	85 - 100	100	100			100	100
9.5 mm	< 90	60 - 80	85 - 100	90 - 100	100	100	90 - 100	95 - 100
4.75 mm		28 - 38	50 - 75	< 90	90 - 100	80 - 100	75 - 95	85 - 95
2.36 mm	28 - 58	19 - 32		32 - 67	37 - 70	36 - 76	60 - 65	53 - 63
0.300 mm		8 - 13					20 - 50	9 - 19
0.075 mm	2 - 10	4 - 7	3 - 8	2 - 10	2 - 10	2 - 12	4 - 12	3 - 8

NAPA IS 135 - Newcomb 2009

Molding Thin Lift Asphalt Mixtures in the Lab

How many gyrations should be used on asphalt mixtures intended for thin lifts?

- AASHTO R 35 specifies the following for all Superpave mixtures:

Design ESALs (M)	Compaction Parameters		
	$N_{initial}$	N_{design}	N_{max}
< 0.3	6	50	75
0.3 to < 3	7	75	115
3 to < 30	8	100	160
≥ 30	9	125	205

Different Criteria for Asphalt Mixtures Intended for Thin Lifts

For Dense-Graded mixtures (AASHTO M 323):

9.5mm mixes

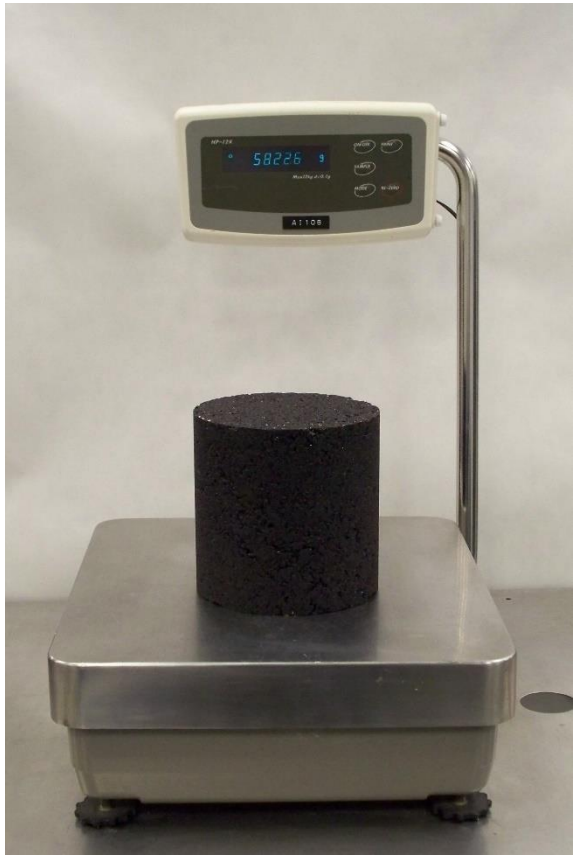
For design ESALs ≥ 3M, **VFA** shall be **73% to 76% ***
(other mix sizes 65% to 75%)

4.75mm mixes

For design ESALs < 3M, **dust-to-binder ratio** shall be **1.0 to 2.0**
(other mix sizes 0.6 to 1.2)
For design ESALs ≥ 3M, **dust-to-binder ratio** shall be **1.5 to 2.0**
(other mix sizes 0.6 to 1.2)

The **relative density** shall be **94.0 to 96.0** *(other mix sizes 96.0)*

For design ESALs ≥ 0.3M, **VFA** shall be **66% to 77%**
(other mix sizes 65% to 75%)



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Natural Sand Usage

Many states limit the use of natural sand to 15% maximum, even if FAA parameters are met.

PLANT OPERATIONS FOR THIN LIFTS

Moisture Considerations

Thin lift mixes are composed of a high percentage of fine aggregate

Coarse Stockpile
% Moisture ≈ 0.5 to 2%

Fine Stockpile
% Moisture ≈ 3 to 7%

Moisture Considerations

- *Aggregates must be properly dried*
- *May mean slowing down production*
- *Aggregates containing moisture after the plant drying process contribute to stripping and tenderness issues with mixes*

Moisture Considerations

- Construct paved, sloped stockpile areas
  - Reduces aggregate waste
  - 1% decrease in moisture ≈ 10% decrease in burner fuel usage.

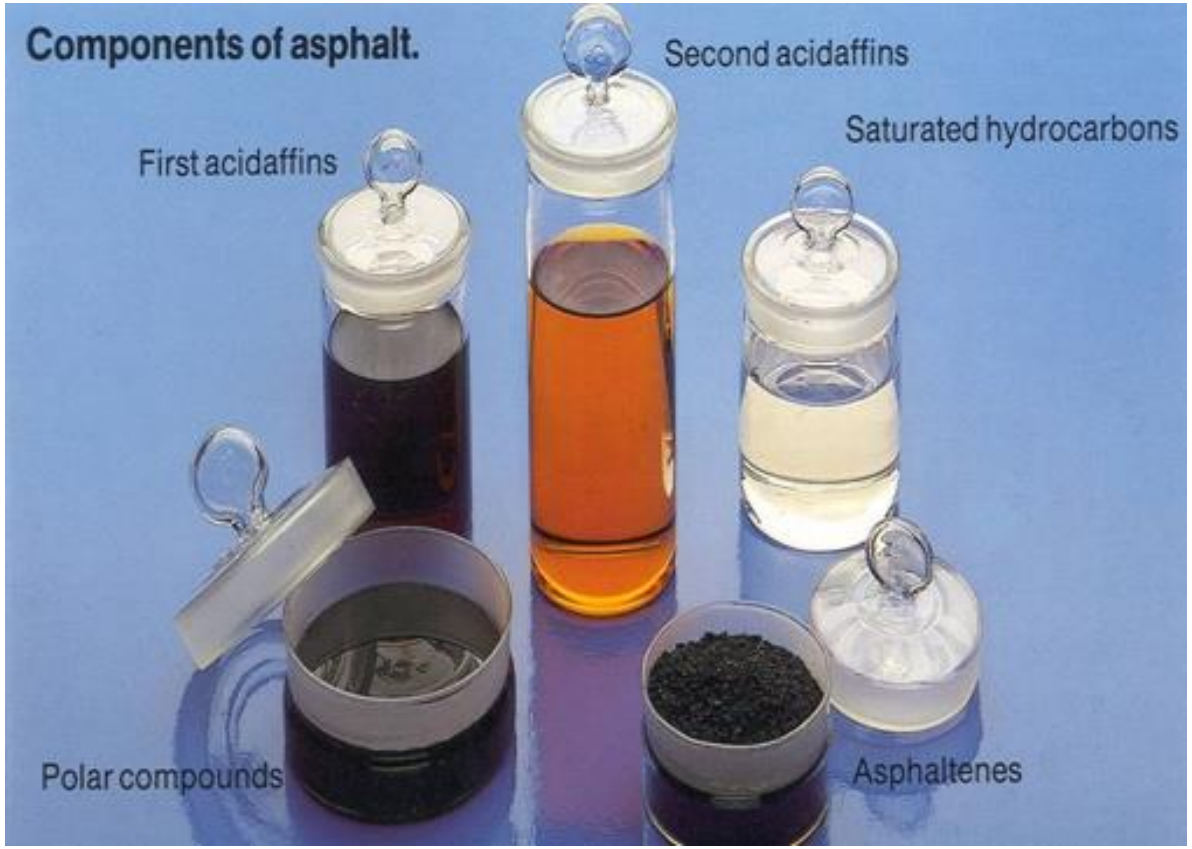
Moisture Considerations

- Cover stockpiles to reduce moisture from rainfall
- Covers can be permanent or temporary
- Cover fine aggregates especially

Temperature Considerations

At the plant:

- Don’t run the plant hotter to account for heat loss
- Volatilizes light fractions
- Prematurely ages mix



Mitigation of Temperature Concerns Using WMA

Photo courtesy of Steve Muench, U. of Washington

At the plant:

- WMA can mitigate rapid heat loss

Managing Variability

At the plant:

- Thin overlays mixes include a high percentage of fines.
- Split aggregate component used at a rate of about 50% into two cold feed bins to reduce the potential variability

SURFACE PREPARATION FOR THIN LIFTS

Repair of Distresses Covering Entire Surface

If there is surface cracking or rutting due to plastic movement of the mix, the entire surface should be milled. Benefits include:

- Removal of distressed pavement (core to help determine proper depth)
- Improved smoothness
- Reshape cross slopes (uniform overlay thickness)
- Maintain or create curb exposure
- Maintain clearances at overhead structures
- Maintain or create drainage
- Create a textured surface to help prevent sliding of new HMA overlays

Mill Deep Enough to Remove Entire Distressed Layer

Milling into the structurally sound surface will help avoid scabbing and delamination.

Use Leveling Course on Uneven Surfaces

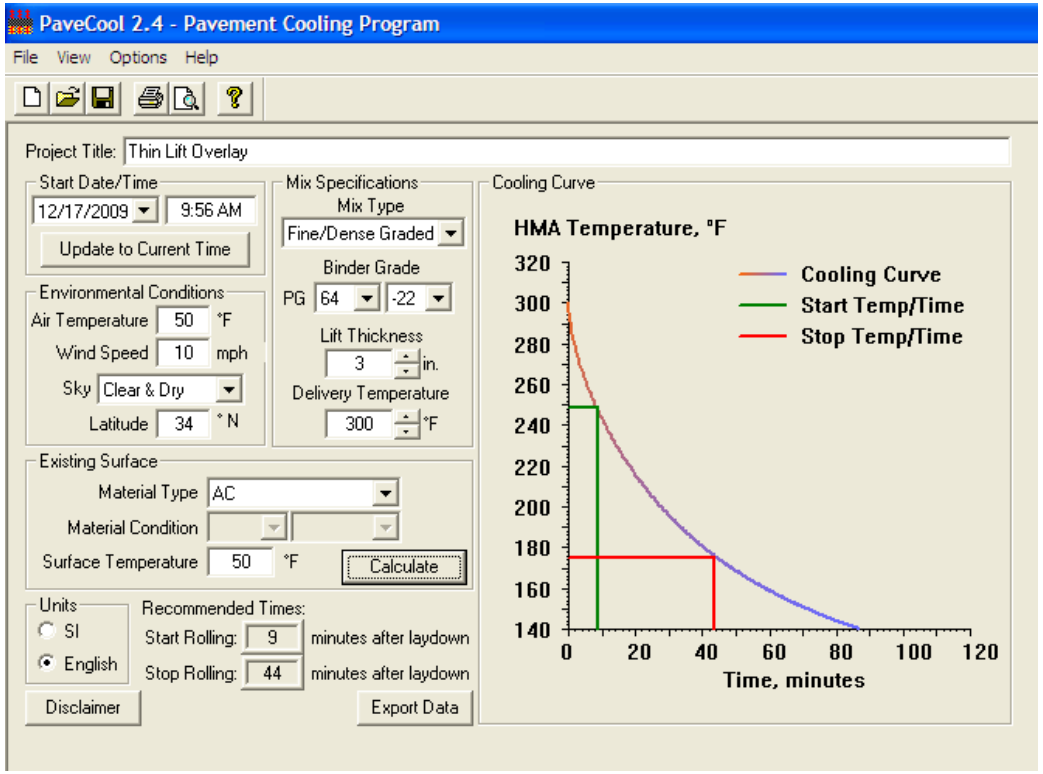
Use 4.75mm or sand mix for leveling course. Note how fine mix fills in lower areas and skims across high areas for a smooth paving surface. (Clearly shows where screed adjustments are needed)

Don’t try placing a leveling course using a mix with coarse aggregate!

CONSTRUCTION OF THIN LIFTS

Climate Considerations for Thin Lift Overlays

Download MultiCool for free at the NAPA store!



1 Inch Lift

50°F Air, Surface Temp

Mix Delivery temp - 300°F

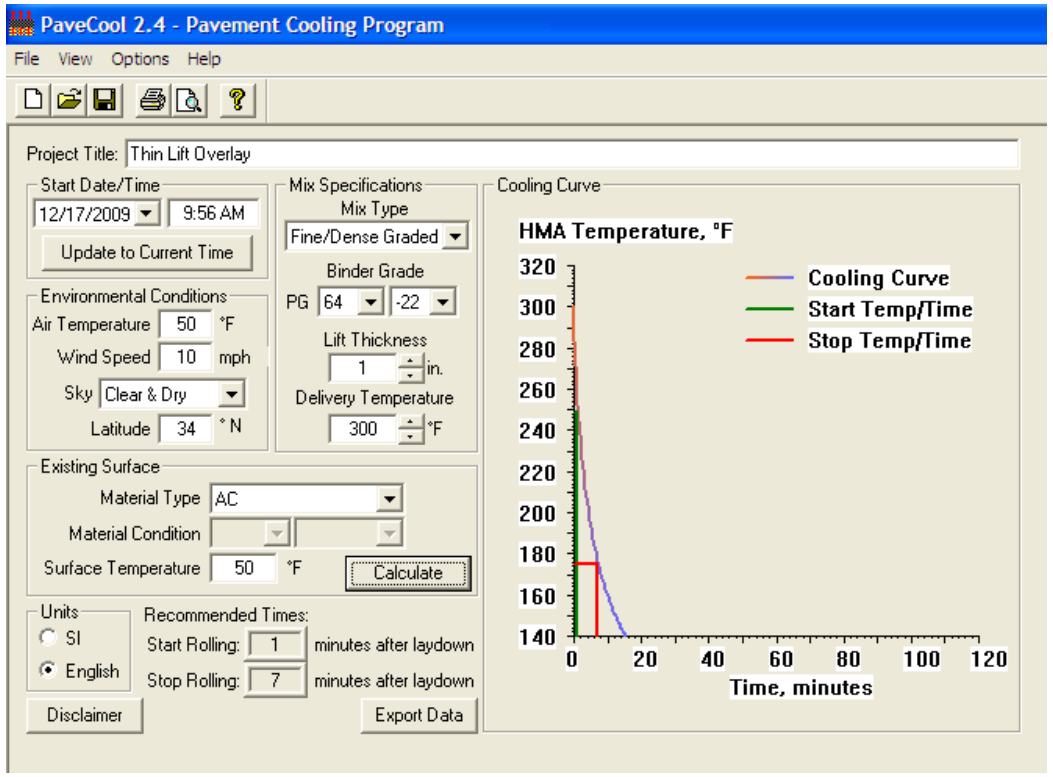
7 minutes to complete compaction operations

3 Inch Lift

50°F Air, Surface Temp

Mix Delivery temp - 300°F

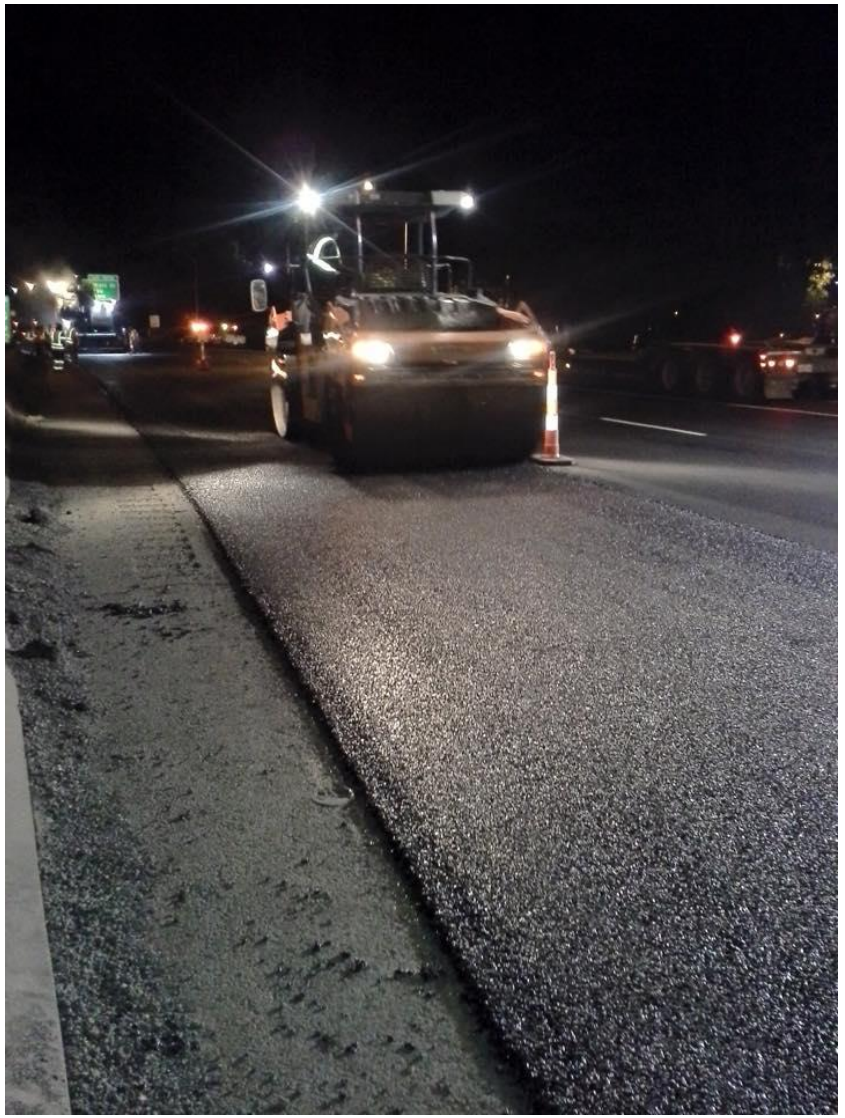
44 minutes to complete compaction operations



Climate Considerations for Thin Lift Overlays

Night paving can also be a challenge:

- **Tack break times extended**
  - **cooler temperatures and often higher humidity**
- **Cooler temperatures make obtaining proper compaction more difficult**
- **General visibility issues**



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Proper Tack Coat is Critical for Thin Lift Overlays

On the project:

- Interface between the old and new pavement is in close proximity to the shear forces created by vehicles during turning and braking movements.
- The tack coat between the old surface and the new overlay is especially important

Proper Tack Coat is Critical for Thin Lift Overlays

On thin lifts, pay extra attention to:

- Existing roadway cleanliness (milled surfaces especially)
- Tack coat application rate
- Tack coat uniformity

Tack pickup due to unclean roadway surface

Looking good!

Low tack coat application rate AND non-uniform tack coat application

Recommended Tack Application Rates

Surface Type	Residual Rate (gsy)	Appx. Bar Rate Undiluted* (gsy)	Appx. Bar Rate Diluted 1:1* (gsy)
New Asphalt	0.020 – 0.045	0.030 – 0.065	0.060 – 0.130
Existing Asphalt	0.040 – 0.070	0.060 – 0.105	0.120 – 0.210
Milled Surface	0.040 – 0.080	0.060 – 0.120	0.120 – 0.240
Portland Cement Concrete	0.030 – 0.050	0.045 – 0.075	0.090 – 0.150

Manage Paver Speed

On the project:

- When paving thin lifts, each ton goes a long way
- The paver can get down the road very quickly
- Don't allow the paver to leave the rollers behind
- Thin lifts cool very rapidly and need to be compacted more quickly than thicker lifts

Hello-o-o-o-o back there!

ASPHALT INSTITUTE

NAPA NATIONAL ASPHALT PAVEMENT ASSOCIATION

National Center for Asphalt Technology NCAT at AUBURN UNIVERSITY

Material Transfer Vehicles Often Specified for Placing SMAs and OGFCs

On the project:

- Thin lifts of SMA and OGFC (PFC) are often placed using a Material Transfer Vehicle.
- Some agencies require the use of an MTV when placing “premium” mixtures such as SMA and PFC

Spray Pavers Often Specified for Placing Ultra Thin Bonded Wearing Courses

On the project:

- Thin lifts of Ultra Thin Bonded Wearing Course are typically placed using a Spray Paver.
- Other types of thin asphalt lifts can be placed using a spray paver also.
- Specialized tack material must be used because paver sprays tack about 6” in front of mixture during paving.

Spray paver being used on NCAT’s Lee Road Pavement Preservation experiment.

Rolling Thin Asphalt Overlays

On the project:

- Rolling strategies depend on the type of thin lift
- For Superpave and SMA, you *may* be able to use a vibratory roller (but probably not) - check for roughness, broken aggregate
- Otherwise, use static rollers. (may be able to use pneumatic on Superpave)

Rolling Thin Asphalt Overlays

On the project:

- For PFCs and OGFCs, static rollers are typically used
  - only one or two passes to seat the mix onto the existing surface
  - mix is intended to be permeable, so don't overcompact
- Be very careful with pneumatic rollers on OGFC and SMA mixes because they can pick up badly

TESTING AND QUALITY ASSURANCE

Determining Density on Thin Asphalt Overlays

Determining roadway density on thin lifts:

- Cannot get accurate, repeatable results from thin roadway cores
- If thickness is at least 1”, thin lift nuclear gauges or electromagnetic gauges could be used
- Roller types, patterns are often set and documented as sole source of QA

Determining Smoothness on Thin Asphalt Overlays

- Increases in smoothness are minimal with thin lifts
- Smoothness can be improved with milling or leveling course

CASE STUDIES

Thin Lift Case Studies - Ohio DOT's "Smoothseal"

Section 424: Fine Graded Polymer Asphalt Concrete

Type A

Recipe Mix

P_b = 8.5%

1/2"	100
3/8"	100
No. 4	95 - 100
No. 8	90 - 100
No. 16	80 - 100
No. 30	60 - 90
No. 50	30 - 65
No. 100	10 - 30
No. 200	3 - 10

Type B

Volumetric Design

P_a = 4.0%, VMA 15.0% min., P_b 6.4% min.

1/2"	100
3/8"	95 - 100
No. 4	85 - 95
No. 8	53 - 63
No. 16	37 - 47
No. 30	25 - 35
No. 50	9 - 19
No. 100	-
No. 200	3 - 8

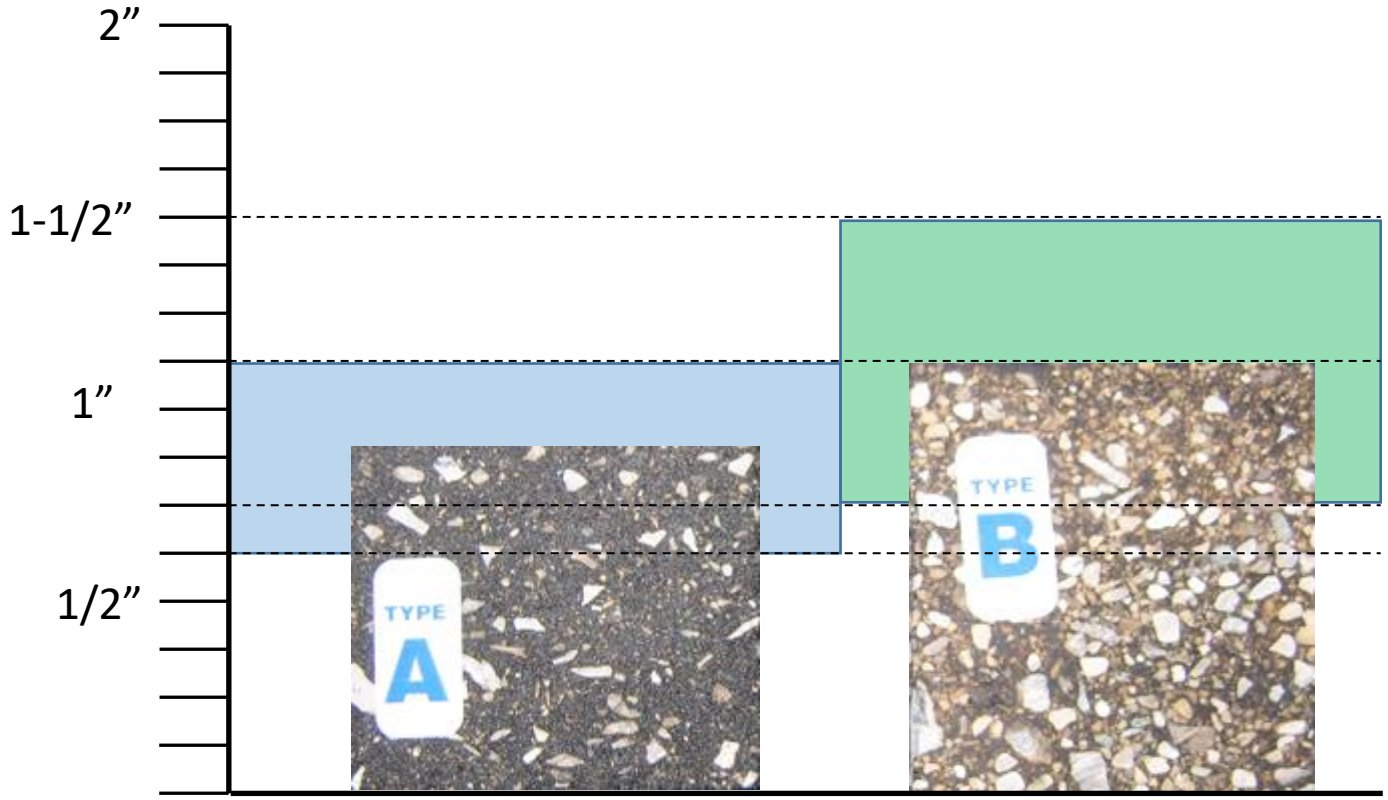
10% RAP allowed in Type B

Binder type must be either PG 76-22M (SBS) or PG 64-22 with 5% SBR

Sand must have at least 50% Silicon Dioxide for skid resistance

Thin Lift Case Studies - Ohio DOT's "Smoothseal"

Overlay Thickness Guidelines



Type A

5/8” to 1-1/8”

Type B

3/4” to 1-1/2”

Thin Lift Case Studies - Ohio DOT's "Smoothseal"

I-71

- City of Cleveand
- Age = 3 years
- Treatment:
  - 1/2" Planing
  - 1" Smoothseal, Type B
- ADT = 99,360 vehicles
- 3% trucks
- Future Resurfacing - 2020
- Anticipated age at next resurfacing - 11 years

One of many examples of Smoothseal given by Ohio DOT's James Marszal, P.E., at the APA's Asphalt Paving Conference in 2012 in Charlotte, NC

Thin Lift Case Studies - Texas DOT

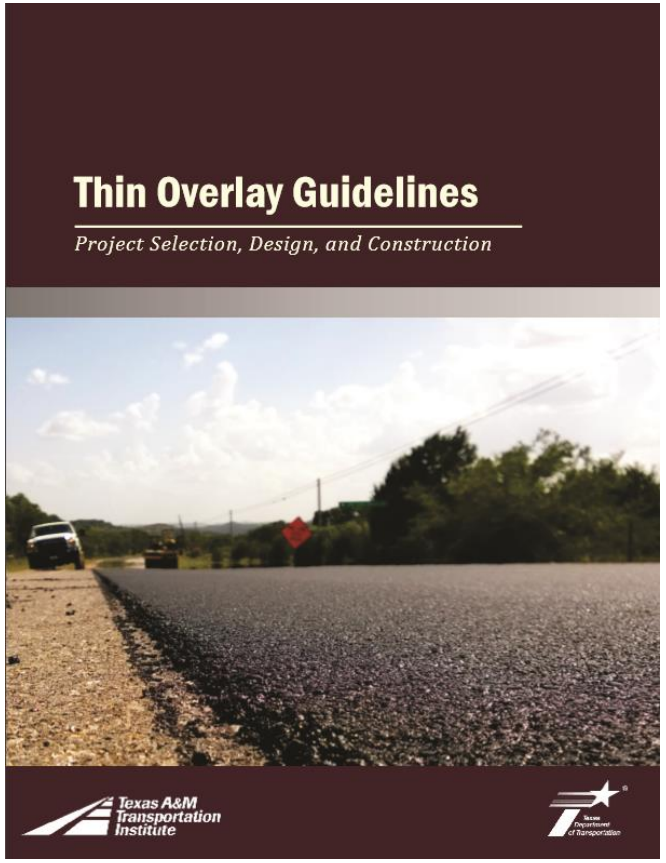


TABLE 1 – Types of Thin HMA Overlays.

Mix Types	Key Benefits
Dense-Graded	
• Ultra-thin (UT) mix (Item 347) • Crack attenuating mix (CAM) (Special Specification [SS] 3262)	• Resists cracking • Improves ride • Minimizes in-vehicle noise
Gap-Graded	
• Thin overlay mix (TOM) (Item 347) • Stone-matrix asphalt Type F (SMA-F) (Item 3262)	• Improves skid resistance • Improves ride • Resists rutting • Resists cracking
Open-Graded	
• Permeable friction course Type F (PFC-F) (SS 3269)	• Improves skid resistance • Improves ride • Minimizes splash and spray • Reduces ambient traffic noise

Thin Lift Case Studies - Texas DOT

TABLE 3 – Mix Gradations.

Sieve Size	Dense-Graded		Gap-Graded		Open-Graded
	UT Mix	CAM	TOM	SMA-F	PFC-F
1/2 inch	100	100	100	100	100
3/8 inch	98–100	95–100	95–100	70–100	95–100
#4	70–95	70–90	40–60	30–60	20–55
#8	40–65	40–65	17–27	20–40	0–15
#16	20–45	20–45	5–27	10–30	0–12
#30	10–35	10–30	5–27	10–30	0–8
#50	10–20	10–20	5–27	5–20	0–8
#200	2–12	2–10	5–9	2–10	0–4
P_b (*min*):	**6.5**	**6.0**	**6.0**	**6.0**	**6.0**

Thin Lift Case Studies - Texas DOT

FIGURE 2 – TOM on IH 35 Under Construction – Placed in 2009 and Still Performing Excellently.

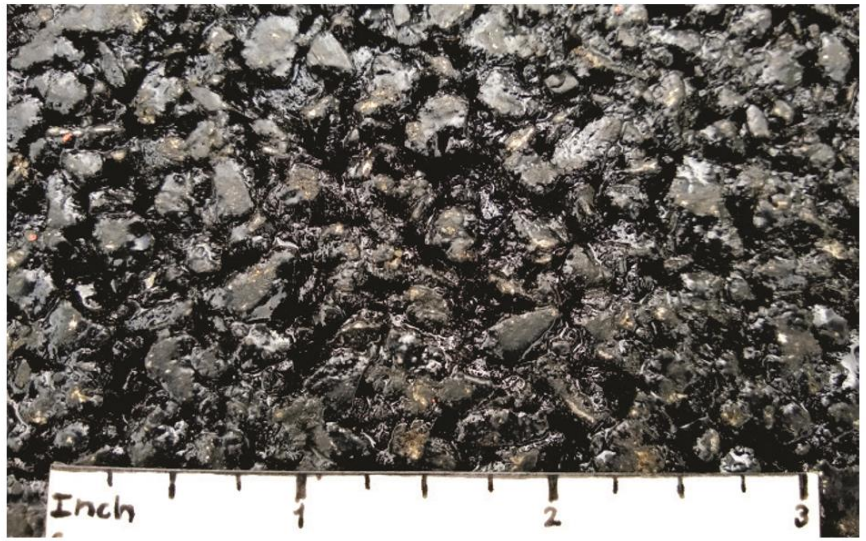


FIGURE 1 – Coarse Surface Texture of TOM.

Thin Lift Case Studies - Arizona DOT

Arizona DOT "Quiet Pavement Program"

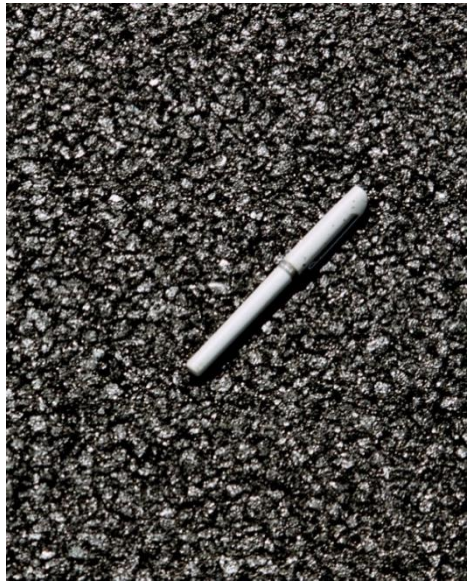
- *A three-year, $34 million project to surface about 115 miles of Phoenix-area* freeways with thin lifts of rubberized asphalt is working toward a smoother ride for motorists and quieter neighborhoods for those who live adjacent to the roads. Noise readings have shown a tire noise decrease by an average of 4 decibels.
- Rubberized asphalt cannot be applied during cold weather or very hot weather. The concrete pavement surface needs to be between 85 and 145 degrees Fahrenheit for the material to adhere properly. So rubberized asphalt can only be applied in the spring and fall in the Phoenix area, from March 15 to May 31 and from September 1 to November 15. Prior to application, contractors must repair pavement cracks, chips and joints and prepare the concrete surface for the rubberized asphalt overlay.

Thin Lift Case Studies - Arizona DOT

Section 414: Asphaltic Concrete Friction Course (Asphalt-Rubber)

P_b "specified by the Engineer"

3/8"	100
No. 4	30 - 45
No. 8	4 - 8
No. 16	-
No. 30	-
No. 50	-
No. 100	-
No. 200	0 - 2.0



* *The asphalt-rubber shall contain a minimum of 20 percent crumb rubber by the weight of the asphalt cement. (Section 1009-2.02)*

** *Requires 1% mineral admixture (Portland cement, blended hydraulic cement, or hydrated lime) by weight of the mineral aggregate*

Thin Lift Case Studies - Arizona DOT

AR-ACFC, IH-10 south of Phoenix, extreme traffic

AR-ACFC on SR 64 east of Bullhead City, AZ.

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

- **Although there is no standard definition of what constitutes a "thin lift," they can be used to address functional issues, safety issues, and to maintain roadways in all traffic conditions as a pavement preservation technique.**
- **Project selection is a key issue for thin asphalt overlays. Thin overlays of structurally sound pavements can last 10 years or more.**
- Thin asphalt overlays can be dense-graded, gap-graded, or open-graded, depending on the need.
- Responsible use of RAP can decrease the price of thin asphalt overlays.

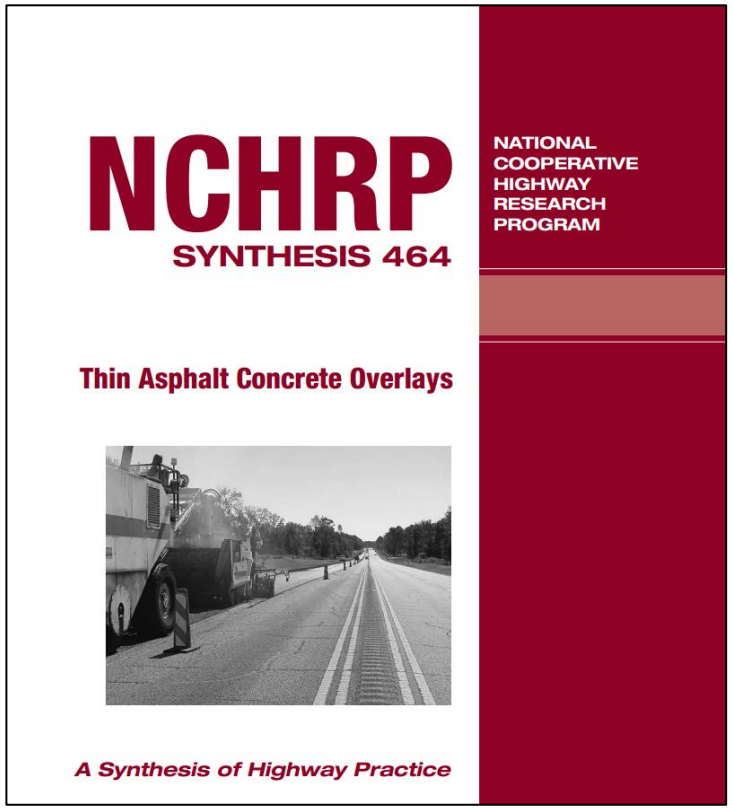
SUMMARY AND CONCLUSIONS (cont.)

- Because the moisture content of fine aggregate stockpiles tend to be higher than coarse aggregate stockpiles, special attention must be paid to drying the aggregates for thin asphalt overlays at the plant.
- **Use cores to evaluate causes of distress and perform local repairs to return existing pavement to adequate structural support before placing a thin overlay.**
- **A uniform tack application at the proper rate is even more important for thin asphalt overlays** because the interface between the old and new pavement is in close proximity to the shear forces created by vehicles.
- **Heat dissipates from thin asphalt layers more quickly than thick asphalt layers, which reduces available compaction time.** This can be mitigated by such things as setting minimum surface, ambient, and/or mix temperatures and through the use of WMA technologies.

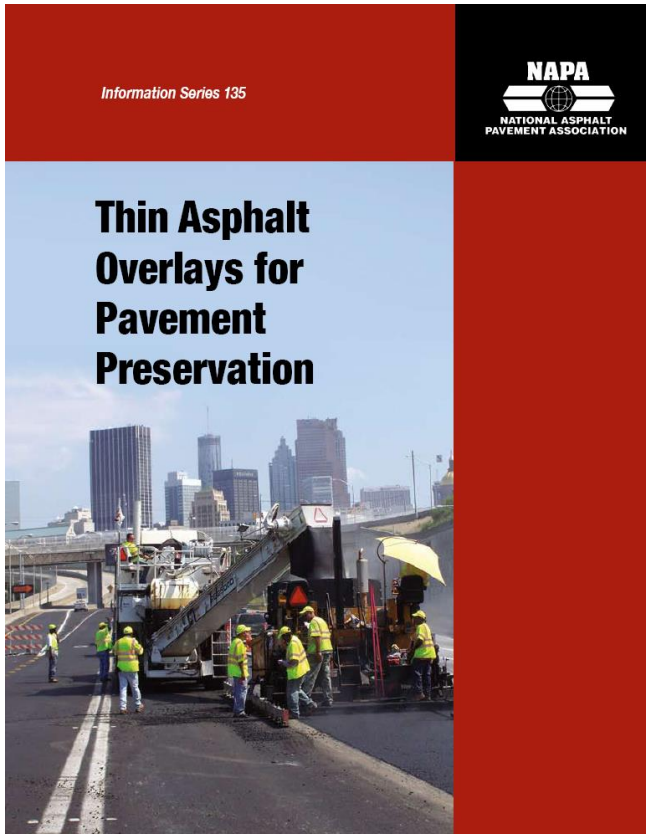
SUMMARY AND CONCLUSIONS (cont.)

- Because a ton of asphalt stretches farther as the lift thickness decreases, it is important for paver operators to maintain a slow, steady pace that can be matched by the roller operators.
- Rolling strategies vary depending on the type of thin lift. Typically, static steel-wheeled rollers are used on thin asphalt overlays to avoid binder sticking and crushing aggregate.
- Determining density through roadway cores is more difficult for thin asphalt lifts, and density gauges are typically recommended only for lifts 1” or greater. A common method of QA for thin asphalt lifts is to daily document the roller types and number of passes.
- A number of states have very successful thin asphalt overlays. Their success stories can be evaluated to facilitate the successful use of thin asphalt overlays in other states.

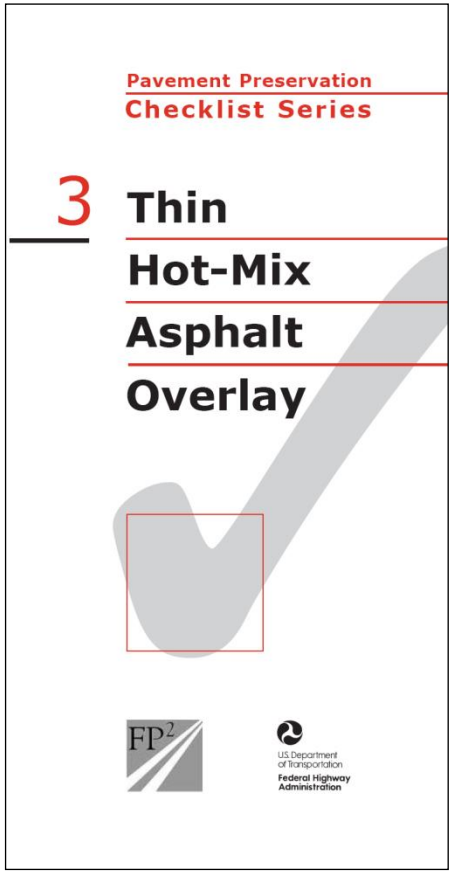
Additional Free, Downloadable Resources



http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_464.pdf



http://store.hotmix.org/index.php?productID=696



http://www.fhwa.dot.gov/Pavement/preservation/ppcl03.pdf

QUESTIONS?

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