

Tack Coats, Bond Strengths and Pavement Performance

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Overview of Today's Webinar

- What are tack coats and what is their purpose
- What are some of the most common tack coat materials and products currently in use
- What is tracking and why is it a problem
- What causes tracking and what are some of the solutions



Tack Coats

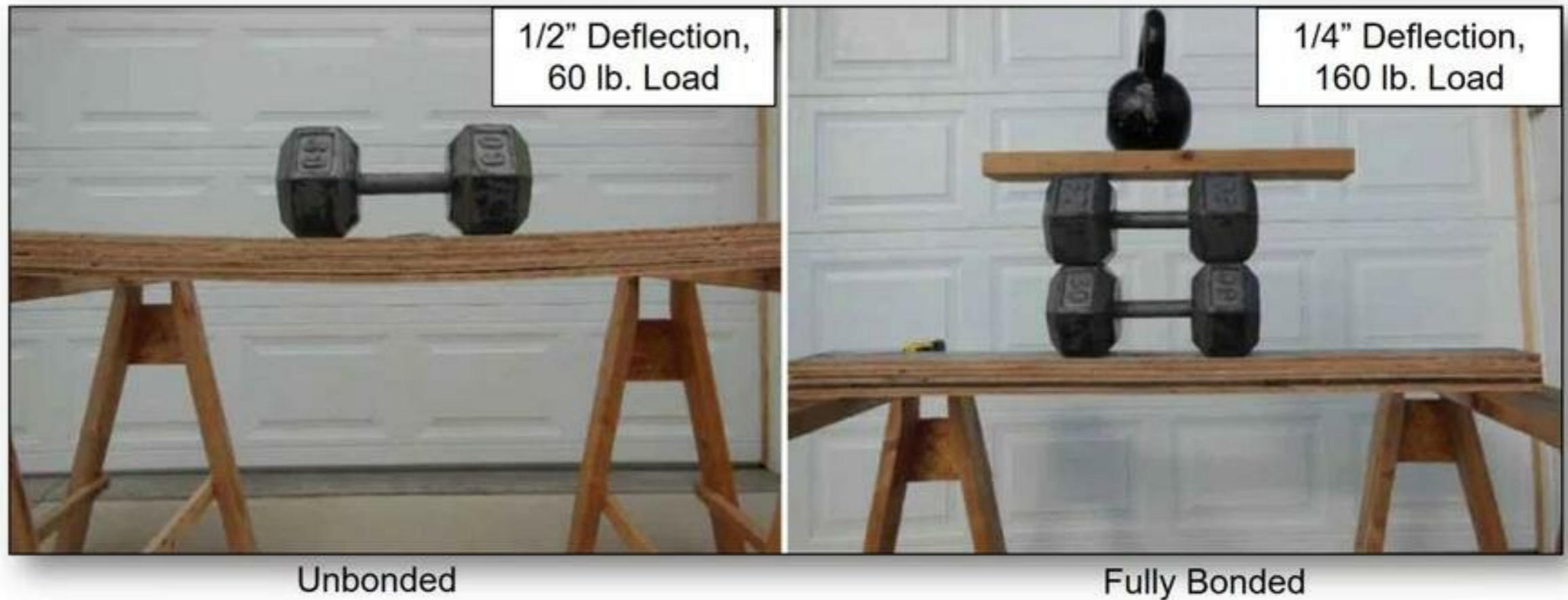
- Applied liquid asphalt material used to bond pavement layers together
- Allows two pavement layers to behave as a single layer
 - Provides greater ability to withstand traffic and environmental stresses
- Long-term performance of an asphalt pavement is directly related to proper bonding between layers
 - Pavement design assumes total bonding



Importance of Tack Coats

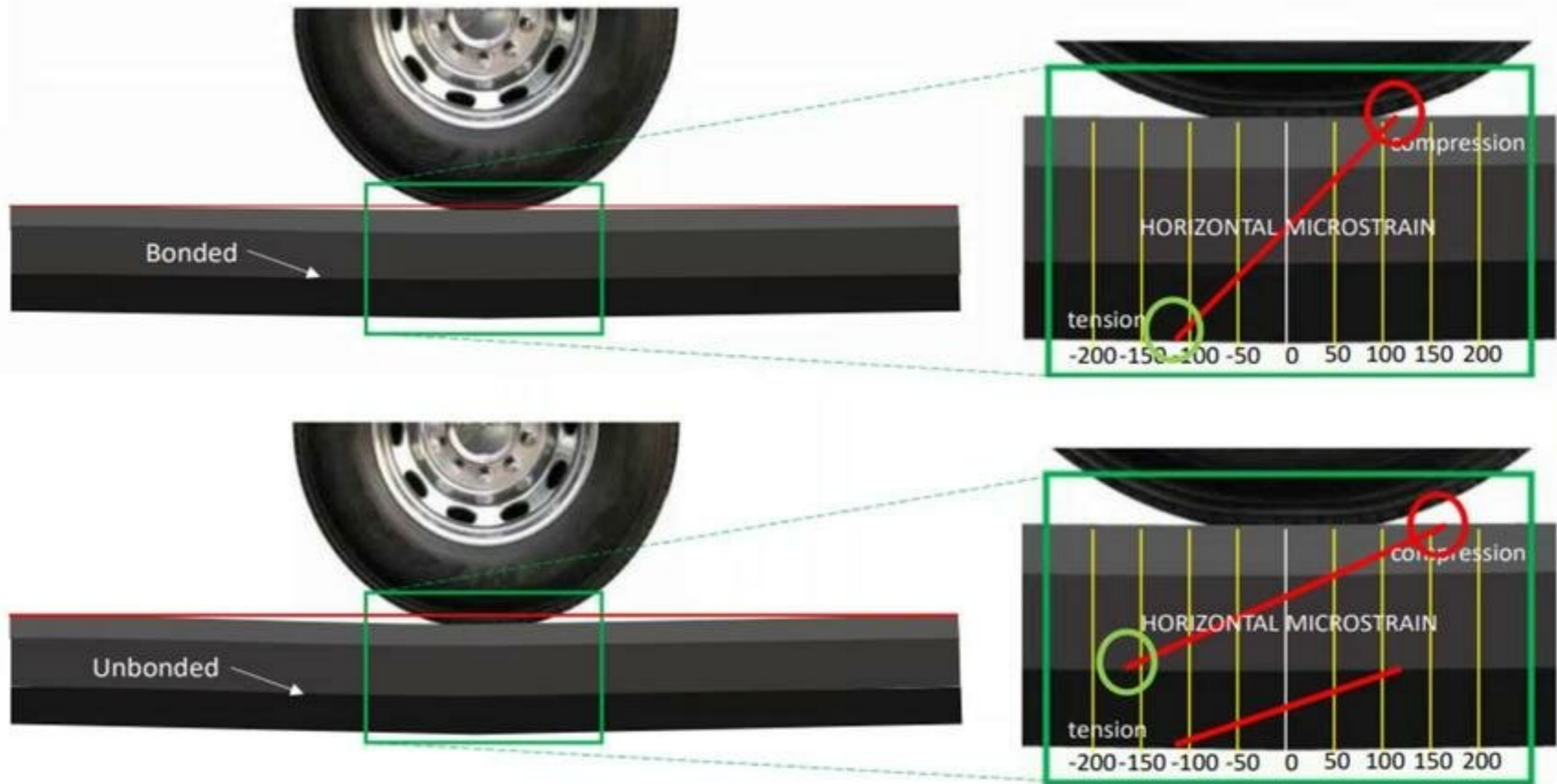
- Past research shows debonding between layers can reduce the pavement's fatigue life by more than 50 percent
- When pavement layers lose adhesion and separate:
 - Pavement stiffness decreases;
 - Higher deflections occur - which can lead to delamination, top down cracking, and ultimately fatigue cracking;
 - Extensive repairs such as full-depth patches or complete reconstruction are frequently required

Impact of Unbonded Layers



(Harder, 2018)

Impact of Unbonded Layers



Impact of Unbonded Layers

Poorly bonded layers can lead to performance problems

- Delamination
- Slippage cracking
- Top-down cracking
- Fatigue cracking



Delamination



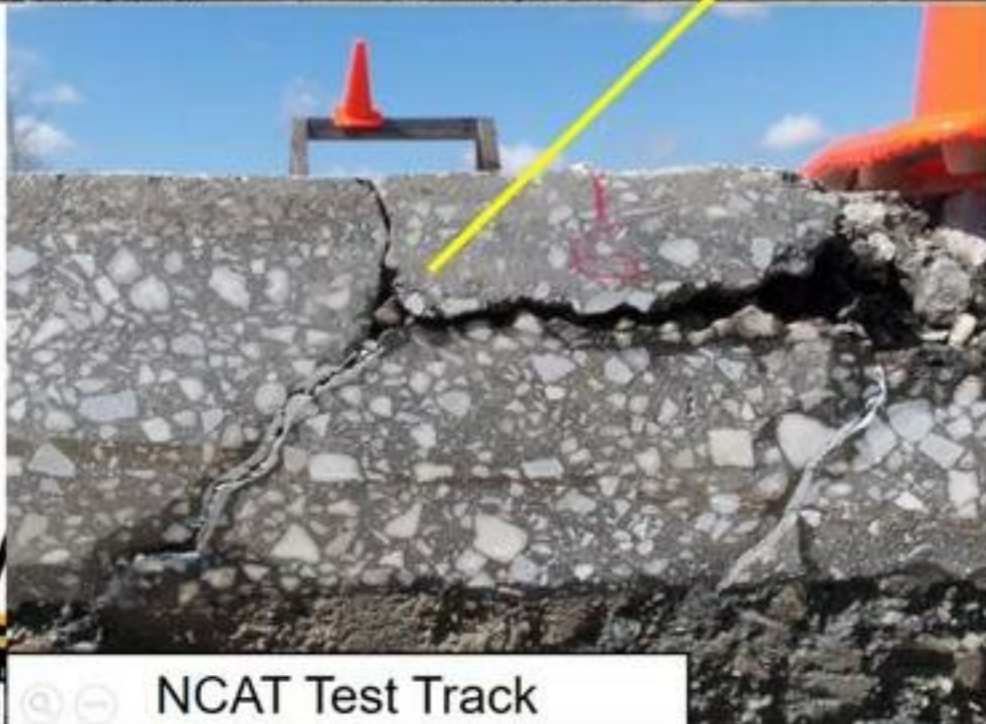
Florida DOT

Delamination



NCAT Test Track

Fatigue Cracking



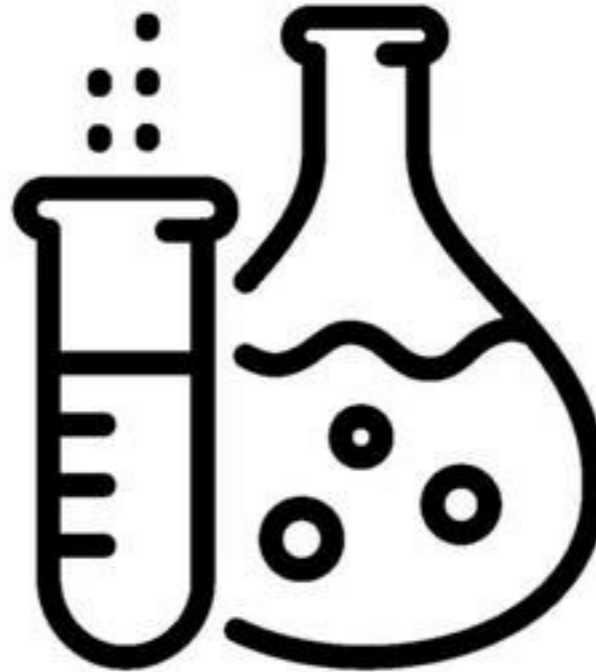
NCAT Test Track



Slippage Cracking



Tack Coat Materials



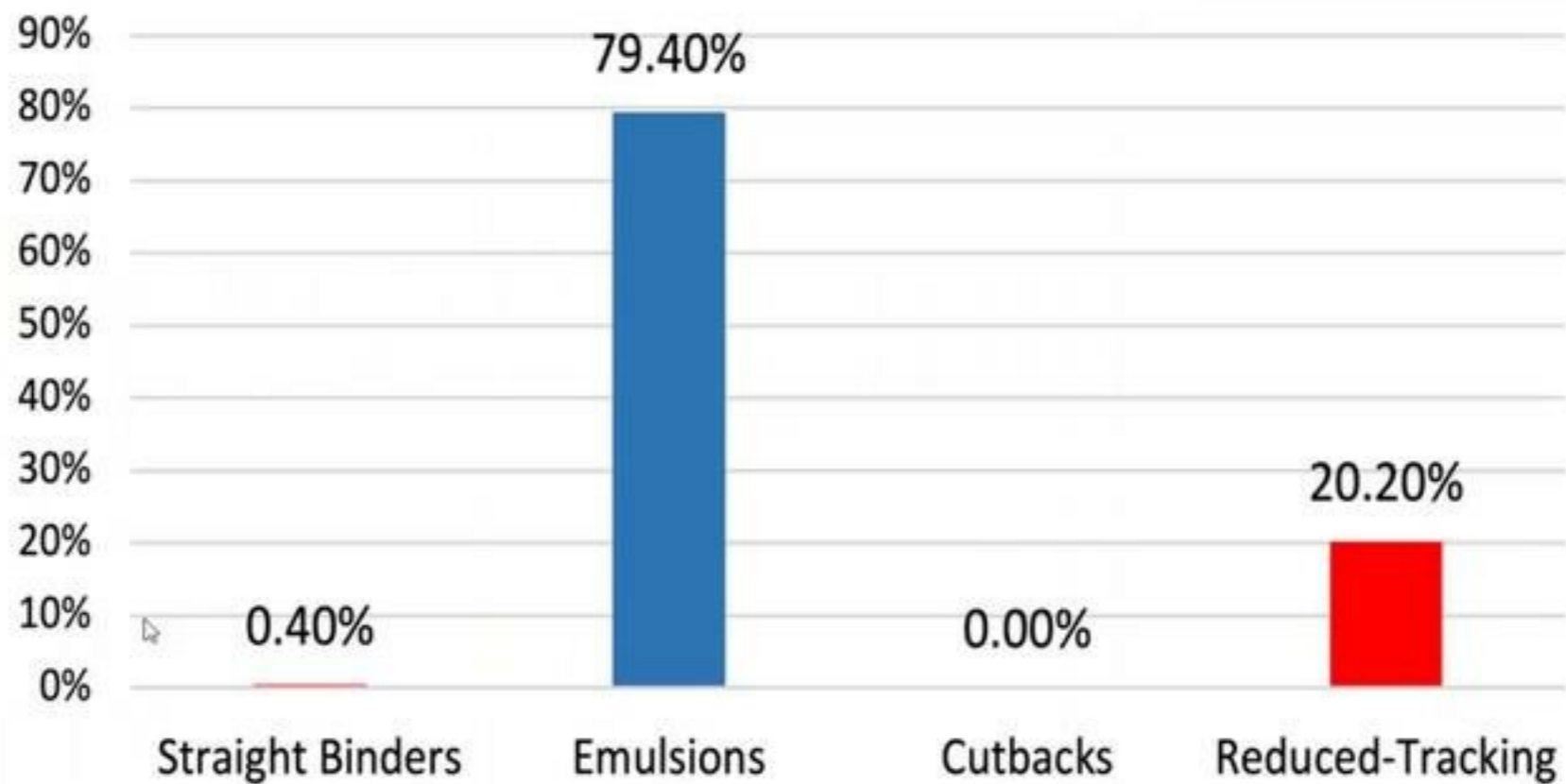
Common Tack Coat Materials

- Asphalt Emulsions
 - Conventional emulsions (SS-1, SS-1h, RS-1, CSS-1h, etc.)
 - Reduced-tracking emulsions (NTSS-1hm, e-Tac, etc.)
- Hot-Applied Asphalt Binders
 - Straight asphalt binders (PG 64-22, PG 58-22, etc.)
 - Hot applied reduced-tracking materials (Ultrafuse, DOTC-LT, etc.)
- Cutback Asphalts (Rarely used)
 - Not in today's discussion



FHWA

Percentage of Tack Coat Materials Used in U.S.

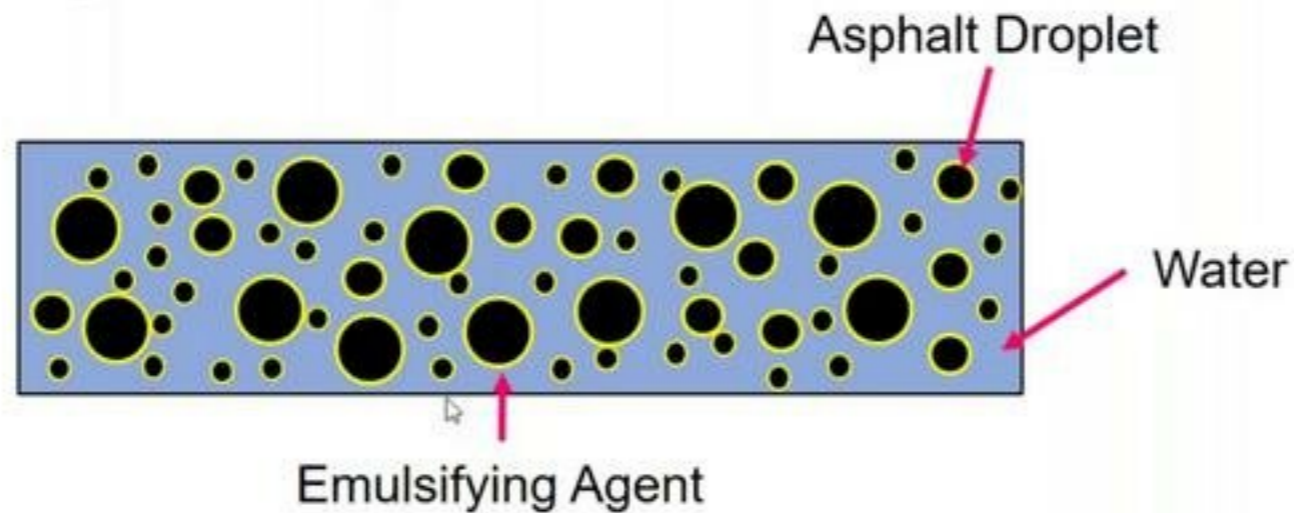


NCHRP Synthesis 516

Asphalt Emulsions

What are emulsions?

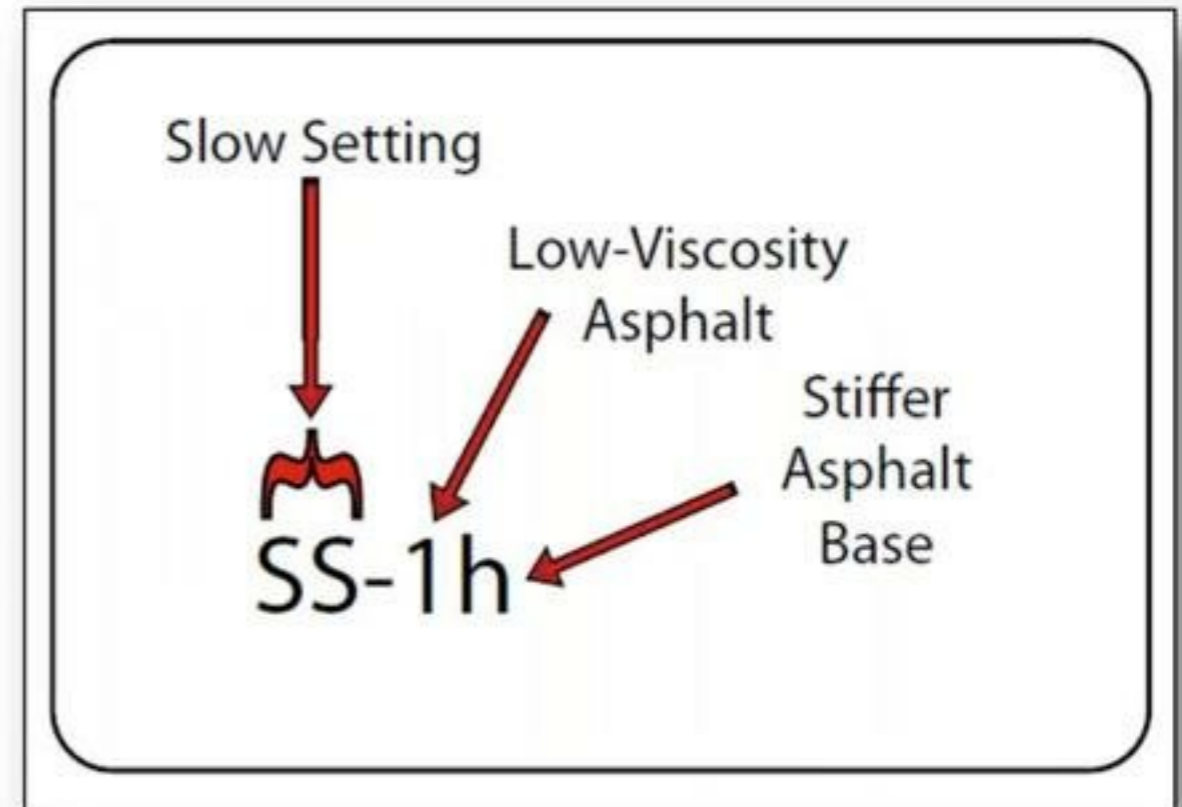
- Liquid asphalt binder emulsified in water
- Three components: asphalt (~55% to 70%), water, and emulsifying agent (surfactant)
- Produced through a colloid mill



Types of Emulsions

- Four categories relating to set times:
 - QS – Quick Set
 - RS – Rapid Set
 - MS – Medium Set
 - SS – Slow Set

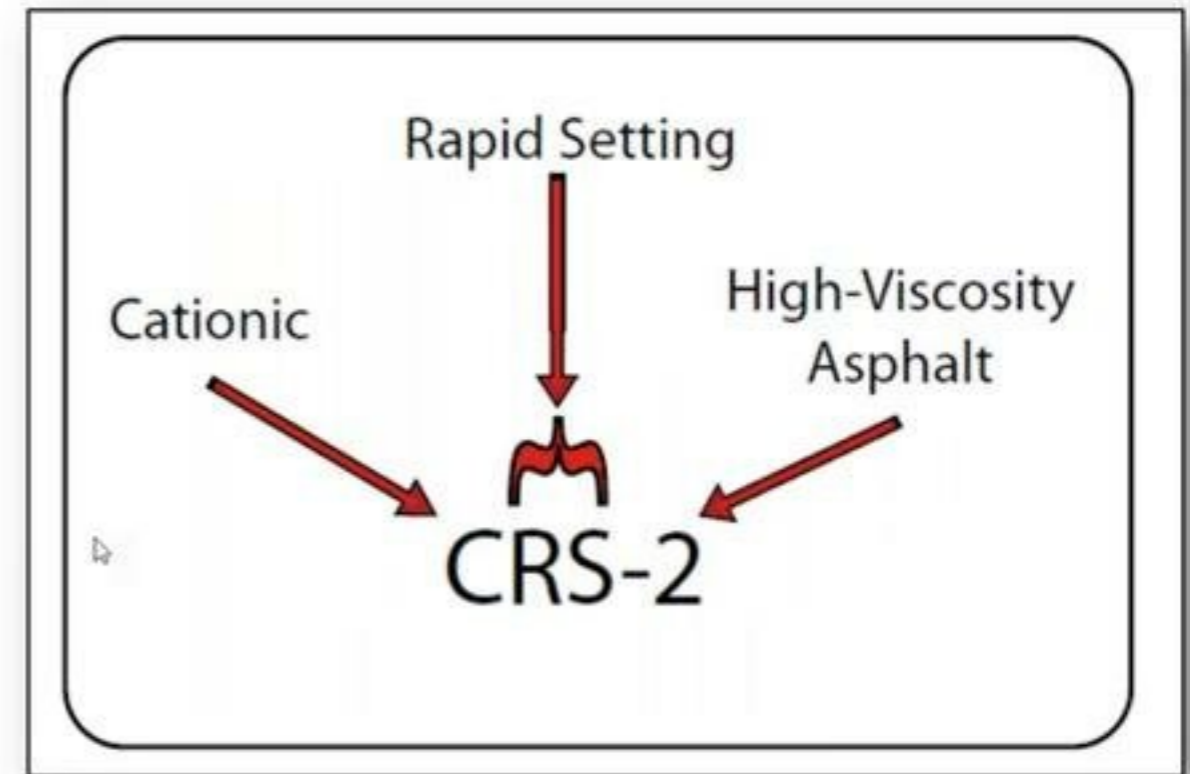
Emulsion type is not always a significant factor in curing time for tack coats.



NAPA QIP-128

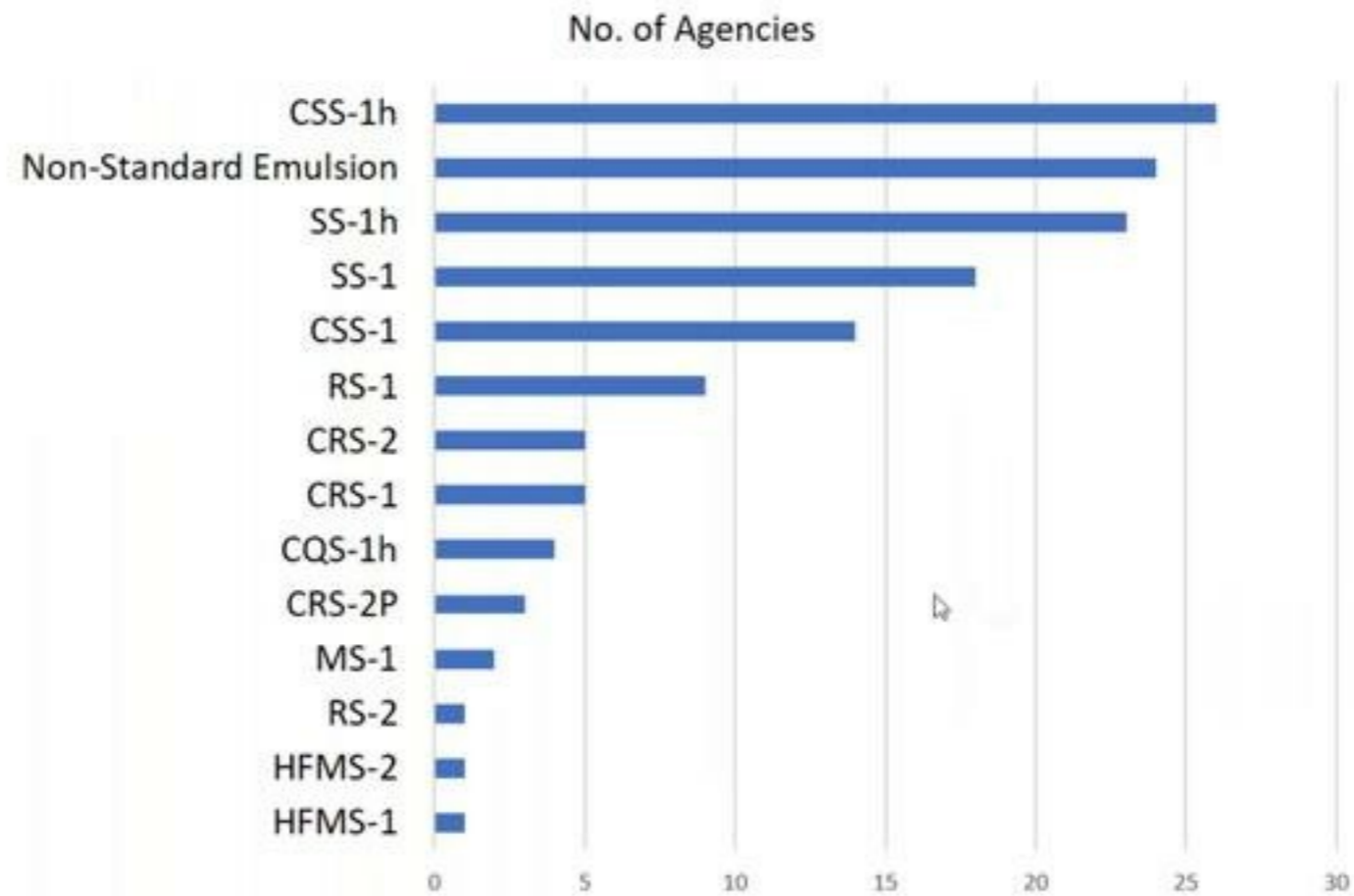
Types of Emulsions

- Three Categories related to particle charge:
 - Anionic (-)
 - Cationic (+)
 - Nonionic (neutral)



NAPA QIP-128

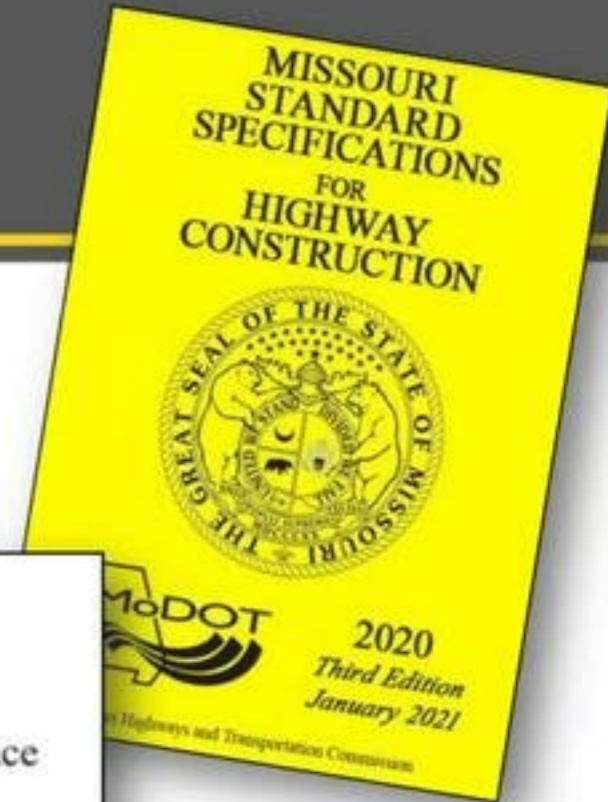
Commonly Used Emulsions



Number of U.S. and Canadian Agencies that use emulsions as tack coats

NCHRP Synthesis 516

Tack Coat Specifications



SECTION 407 TACK COAT

407.1 Description. This work shall consist of preparing and treating an existing bituminous or concrete surface with bituminous material, in accordance with these specifications.

407.2 Material. All material shall be in accordance with [Division 1000](#), Material Details, and specifically as follows:

Item	Section
Emulsified Asphalt or Performance Graded Asphalt Binder	1015

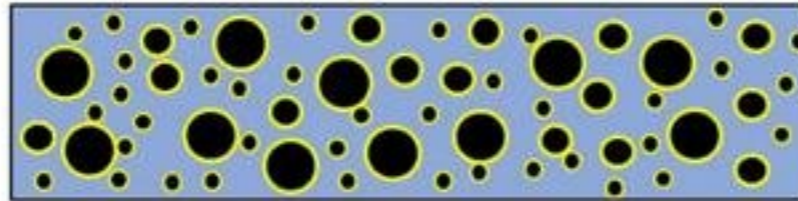
Emulsions used in Missouri

NCHRP Synthesis 516 survey results (2018) from Missouri:

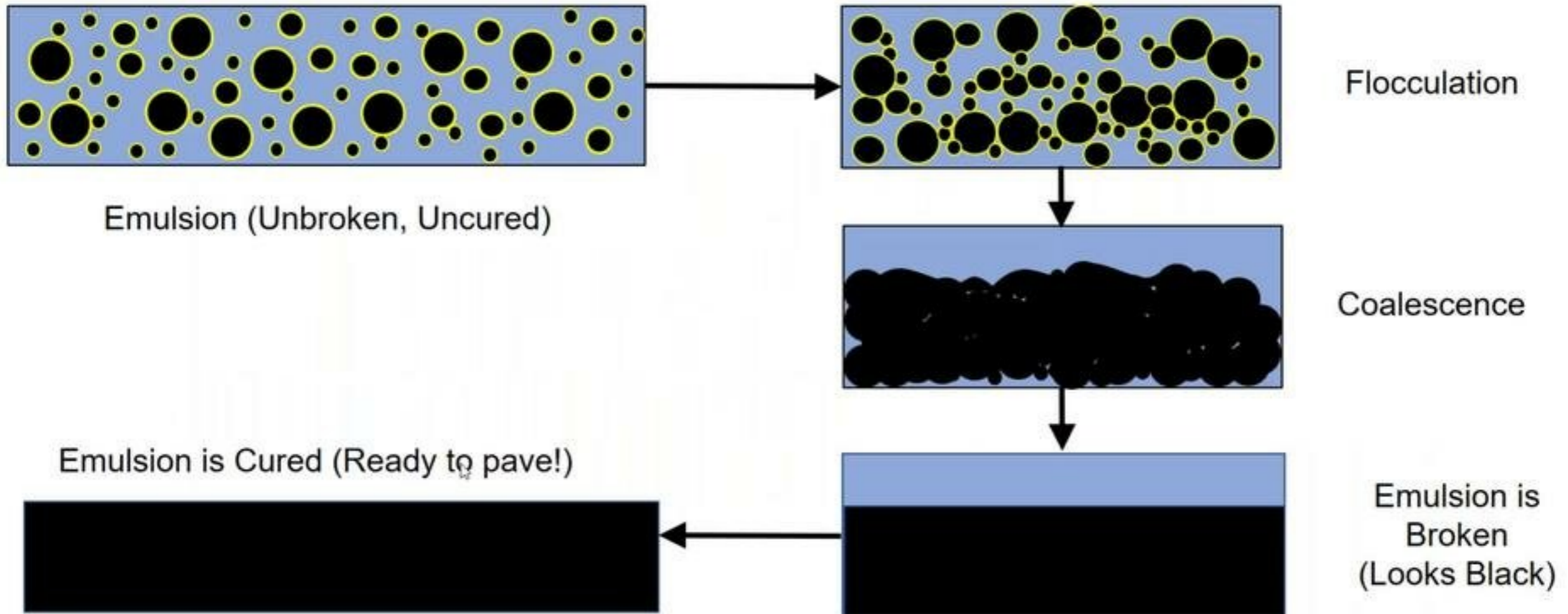
- 60% SS-1h
- 15% SS-1
- 10% SS-1hp
- 10% NTSS
- 3% CRS-1p
- 2% CRS-2p

Emulsions - Breaking and Curing Process

- Breaking and Curing
 - After emulsion is applied, it begins to “break”
 - Asphalt particles separate from the water
 - Color turns from brown to black
 - Breaking: Separation and subsequent evaporation of water from the residual asphalt film
 - Curing: The water fully evaporates and the mechanical properties of the residual asphalt are restored.



Emulsion - Breaking and Curing Process



Emulsion (Unbroken, Uncured)

Flocculation

Coalescence

Emulsion is Cured (Ready to pave!)

Emulsion is Broken
(Looks Black)



Broken and Unbroken Tack Coverage Over an Un-Milled Pavement Surface (Washington State Department of Transportation, 2003)

Breaking and Curing

- The time it takes to break and cure are affected by:
 - Air temperature
 - Pavement surface temperature
 - Humidity
 - Wind speed
 - Application rate of the emulsion
 - Dilution rate of the emulsion
 - Type of emulsifying agent used

An unbroken or uncured asphalt emulsion will track!

Conditions that Require Longer Cure Times

- Cooler air temperatures
- Cooler pavement surfaces
- High humidity
- Overcast day or paving at night
- Heavier application rates
- Diluted emulsions



AsphaltPro Magazine

Diluted vs. Undiluted Emulsions

- Refers to adding additional water to an emulsion to allow for a greater volume of tack coat
- Purpose is to achieve more uniform tack coat coverage on the pavement
- When diluting an emulsion, a higher application rate is required in order to obtain the desired residual asphalt content.

Diluted vs. Undiluted Emulsions

- Primary drawbacks of dilution:
 - Reduced residual asphalt on the pavement – which can impact performance
 - Emulsion takes longer to cure – potential for more tracking
 - University of Wisconsin Study: Dilution of the asphalt emulsion was found to significantly delay curing, doubling the total curing time for some emulsions.
 - Dilution can impact pay items

AASHTO M 140 – Standard Specification for Emulsified Asphalt

Type	Slow Setting			
	SS-1h		SS-1	
Grade	Min	Max	Min	Max
<i>Tests on emulsified asphalt:</i>				
Viscosity, Saybolt Furol at 25°C (77°F), s ^{b,c}	20	100	20	100
<i>Or</i>				
Viscosity, Rotational Paddle at 25°C (77°F), mPa·s ^{b,c}	40	200	40	200
Storage stability test, 24 h, % ^{b,c}		1.0		1.0
Sieve test, % ^{b,c}		0.10		0.10
Cement mixing test, %		2.0		2.0
<i>Distillation:</i>				
Residue, % ^d	57		57	
<i>Tests on residue from distillation:</i>				
Penetration, 25°C (77°F), 100 g, 5 s, 0.1 mm	40	90	90	250
Ductility, 25°C (77°F), 5 cm/min, cm	40		40	
Ash content, %		1.0		1.0

^a Refer to R 5 for typical applications.
^b This test requirement and associated specification limits are waived for emulsified asphalt products following dilution.
^c This test requirement on representative samples may be waived if successful application of the material has been achieved in the field.
^d For emulsified asphalts that are diluted, the percent residue requirements must be adjusted accordingly.

Reduced-Tracking Emulsified Tack Coats

- Designed to minimize the tracking problems associated with traditional tack coat materials
- Typical characteristics:
 - Stiffer base binders
 - Chemical modifications
 - Less-tacky finish
 - Good bond strengths
 - Break and cure faster
 - Residue is generally harder

Emulsions with softer residues are more likely to track – even if properly cured

Reduced-Tracking Emulsions

- Advantages
 - Reduced tracking – provided that the underlying pavement surface is clean
 - Potentially shorter break and cure times
 - Increased bond strengths
- Disadvantages
 - Handling and storage can be tricky
 - Materials still has to break and cure
 - Cost may be greater than conventional emulsions



Asphalt Binders for Tack

- Paving grade asphalt binder (PG 64-22, 58-28, etc.)
- Applied at higher temperatures (~350°F)
- Application rate is typically lower than emulsions (~60%)
- Currently eight states allow use
 - Georgia DOT big user

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Common Asphalt Binders Used for Tack Coat

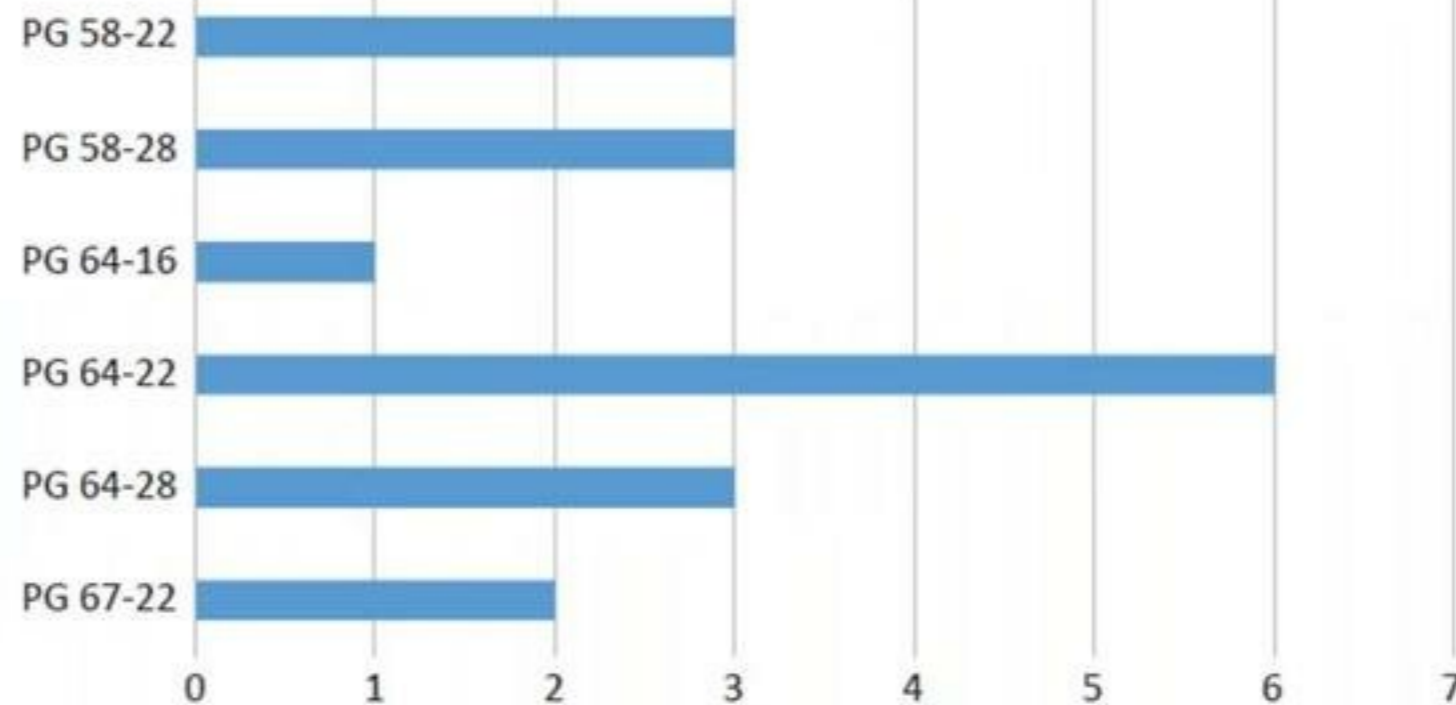


Figure 40. Number of U.S. and Canadian agencies that use PG binders as tack coat material.

Asphalt Binders for Tack

- **Advantages:**
 - Cools very quickly
 - Virtually eliminates tracking
 - Provided the underlying surface is clean
 - Less delays to the paving operation
 - Reduced amount of material can be placed
 - Only placing residue – not water
 - Potentially lower cost
- **Disadvantages:**
 - Higher application temperatures
 - Safety concerns
 - Associated energy costs
 - Time needed to reheat the material



Hot-Applied Reduced-Tracking Materials

- Typically use a very stiff base asphalt binder or polymer modified binder
 - Some products use additives
- Material cools very quickly and resists tracking under traffic
- Advantages include:
 - Less tracking, less delays for the paving operation, and lower application rates
- Disadvantages include:
 - Higher application temperatures, and costs

Spray Pavers



Vögele SprayJet Paver and Roadtec SP-200 Spray Paver



Spray Pavers

- Acts as an asphalt distributor and as an asphalt paver, all in one piece of equipment.
- Tack material is stored on the spray paver, with a storage capacity of 550 to 2100 gals
- The tack is applied beneath the paver, behind the paver tracks and just in front of the screed



Tack Coat Construction Practices

Evaluation of Existing Pavement Condition:

- Cleanliness of the pavement:
 - Bond strengths showed statistically significant differences between clean and dusty conditions
- Pavement age:
 - Older pavements absorb more tack and therefore require more tack; new pavements don't absorb as much

Tack Coat Construction Practices

Evaluation of Existing Pavement Condition:

- Pavement Surface Texture:
 - Has a significant effect on the required residual tack coat application rate;
 - Greater surface texture needs more tack
- Milled surface:
 - Needs to be clean
 - Rough texture helps the bond – still needs tack

Tack Coat Construction Practices

Evaluation of Existing Pavement Condition:

- PCC surfaces:
 - If its been diamond ground or milled, requires more tack
 - Increased tack rate probably not necessary to account for the joints and cracks
- Moisture on the Pavement Surface
 - FHWA Tech Brief: Clean and dry surface
 - More moisture means more time for emulsion to cure

Tack Coat Construction Practices

Application Rates and Temperatures:

- Application Rate vs. Residual Asphalt Binder
 - Application rate is the total amount of liquid sprayed
 - Includes asphalt, water and emulsifying agent
 - Residual rate is just the remaining asphalt after the water has evaporated
 - Residual rate is more important

Nationally Recommended Tack Coat Application Rates

FHWA Tech Brief on Tack Coats, Table 1			
Surface Type	Residual Rate (gsy)	Approximate Bar Rate Undiluted (gsy)	Approximate Bar Rate Diluted 1:1 (gsy)
New Asphalt	0.02 – 0.05	0.03 – 0.07	0.06 – 0.14
Existing Asphalt	0.04 – 0.07	0.06 – 0.11	0.12 – 0.22
Milled Surface	0.04 – 0.08	0.06 – 0.12	0.12 – 0.24
Portland Cement Concrete	0.03 – 0.05	0.05 – 0.08	0.10 – 0.16

NCHRP Report 712, Table 31			
Surface Type	Residual Application Rate (gsy)	Approximate Bar Rate Undiluted* (gsy)	Approximate Bar Rate Diluted 1:1* (gsy)
New Asphalt Mixture	0.035	<i>0.058</i>	<i>0.12</i>
Old Asphalt Mixture	0.055	<i>0.09</i>	<i>0.18</i>
Milled Asphalt Mixture	0.055	<i>0.09</i>	<i>0.18</i>
Portland Cement Concrete	0.045	<i>0.08</i>	<i>0.15</i>

* NCHRP Report 712, Table 31, includes residual application rates only. Values in italics were supplied using an example emulsion with 60% residual asphalt binder for comparison purposes only.

NAPA QIP 128 Best Practices for Emulsion Tack Coats, Table 4-1			
Existing Condition	Residual Asphalt Binder (gsy)	Applied Undiluted Emulsion (gsy)	Applied Diluted Emulsion (gsy)
Dusty or Dirty	Clean the surface	Clean the surface	Clean the surface
New Asphalt	0.03 – 0.04	0.04 – 0.06	0.09 – 0.12
Old, Aged Asphalt	0.04 – 0.06	0.06 – 0.09	0.12 – 0.18
Milled Asphalt	0.03 – 0.05	0.04 – 0.07	0.09 – 0.15
PCC	0.04 – 0.06	0.06 – 0.09	0.12 – 0.18

Missouri DOT Applications Rates

Tack Coat Application Rates		
Surface Type	Target Application Rate; Undiluted (gal/yd ²)	Target Application Rate; 20% Diluted (gal/yd ²)
New Asphalt Surfaces	0.05	0.06
Existing Asphalt or Concrete Surfaces	0.08	0.10
Coldmilled Asphalt or Concrete Surfaces	0.10	0.13

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Emulsion Tack Coat Temperatures

- Proper temperature for the emulsion is very important and depends on the type of product
- Heating of emulsions should only occur while the material is being circulated
- The temperature at which an emulsion is maintained in the distributor tank depends on the grade of the emulsion
- Check with your supplier!

Emulsion Grade	Spraying Temperature °F	Storage Temperature °F
RS-1, SS-1, SS-1h, CRS-1, CSS-1, CSS-1h	70 - 160	70 - 140
RS-2, CRS-2,	140 - 185	125 - 185
Non-Tracking Tack	160 - 180	120 - 130
PMAE	140 - 180	120 - 130

Tack Coat Construction Practices

Cleaning the Surface:

- When tack coat is applied to a dusty or dirty surface, the tack clings to the dust and dirt, not to the roadway.
- It can then be tracked onto other areas as the dust wears off of the moving tires, or
- The overlay bonds to the tack coat but the tack coat isn't properly bonded to the underlying pavement



NCHRP Synthesis 516

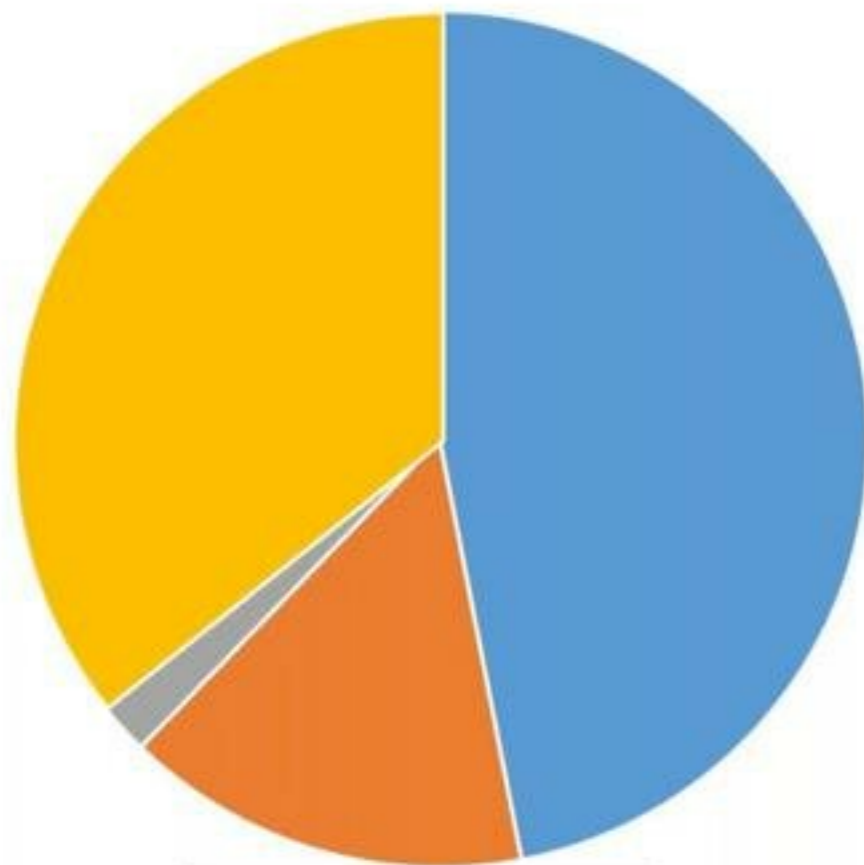
Tack Coat Construction Practices

Cleaning the Surface:

- Cleaning operations can be achieved either through mechanical brooming, flushing the surface with water, blowing off debris using high-pressure air, a vacuum system or a combination of the above
- Allowing milled surfaces to be opened to high-speed traffic for a period of times can also help to properly clean the surface
 - Traffic blows off debris
 - Not always permitted by agencies

Applying tack material to an improperly cleaned surface will cause tracking!

Specified Cleaning Methods



- Power Brooming
- Both brooming and air blowing or vacuum
- Any of multiple specified methods
- Clean but method not specified

NCHRP Synthesis 516



Tymco Regenerative Air Sweeper

Leaving Milled Surfaces Opened to Traffic

• **Pro's:**

- Passing vehicles (high speed) help to clean off the surface
- Greater scheduling opportunities for the contractor

• **Con's:**

- Greater risk to motorists – especially motorcycles
- Issues with drainage
- Noisy – public doesn't like it
- Potential structural issues – depending on the underlying pavement



Milling Striations



Change in
milling speed

Tack Coat Construction Practices

Tack Application - Proper application requires:

- Proper temperature of the tack coat during application
- Proper application equipment, typically a distributor (except for small areas of hand work)
 - Proper distributor speed
 - Proper distributor bar height
 - Proper distributor bar pressure
 - Proper nozzle type
 - Proper nozzle angle
 - Proper nozzle configuration
- Proper application rate, matched to pavement surface type and condition
- Avoiding tacking too far ahead of the pave



NCHRP Synthesis 516

Tracking

- Tack material sticks to the tires of construction vehicles
- Removed from the pavement surface where it is most needed
- Typically deposited on another pavement elsewhere
 - Creates aesthetic and safety concerns



Three Main Causes and Solutions of Tracking



Underlying Pavement Layer not Properly Cleaned

- Tack material sticks to the dust/dirt and not the underlying layer
- Solution: Need to properly clean the surface prior to tacking
 - Brooming/sweeping
 - Brooming/sweeping with high pressure air and/or vacuum system
 - Flush with water*
 - Use high-speed traffic (if feasible)



* May require a longer cure time

Unbroken or Uncured Asphalt Emulsion

- Emulsion hasn't properly bonded to the underlying layer
 - Emulsion needs time to properly break and cure
 - Asphalt separates from the water
 - Water needs time to evaporate
- Solutions:
 - Allow more time for the emulsion to break and cure;
 - Use a reduced-tracking tack material with a shorter break and cure time;
 - Use a hot-applied asphalt binder or trackless product;
 - Use a spray paver



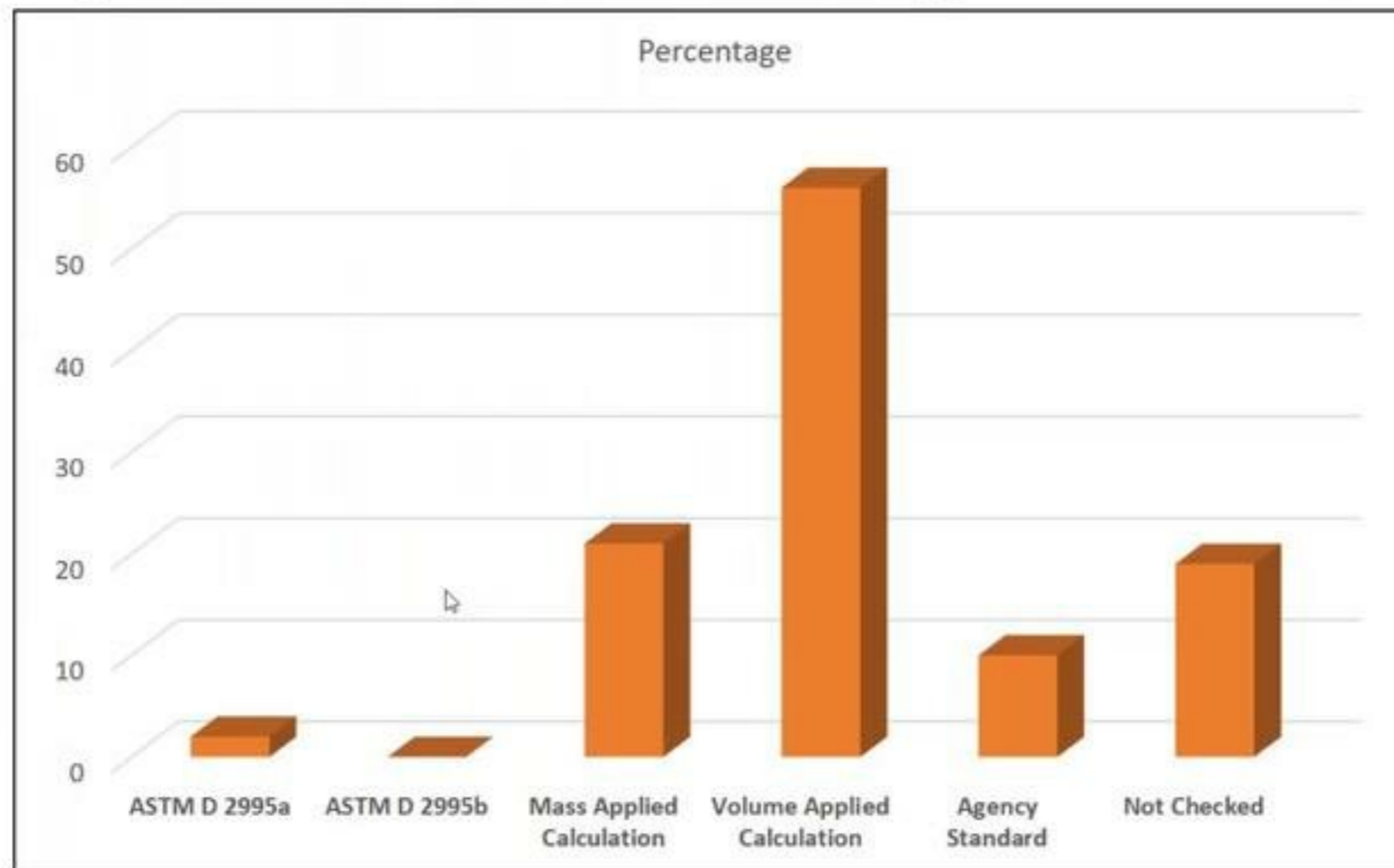
Residual Asphalt from the Emulsion is Too Soft

- Tracking occurs after the emulsion breaks and cures
 - Typically caused by high air and pavement temperatures coupled with softer residue
- Solutions:
 - Use an emulsion with a harder residual binder (SS-1 → SS-1h);
 - Use a reduced-tracking emulsion with a harder residual binder;
 - Use a hot-applied asphalt binder (with a stiffer binder);
 - Use a spray paver



Testing and Acceptance of Tack Coats

During construction, how is the tack application rate checked?



NCHRP Synthesis 516

ASTM D 2995: Standard Practice for Estimating Application Rate and Residual Application Rate of Bituminous Distributors



ASTM 2995: Standard Practice for Estimating Application Rate and Residual Application Rate of Bituminous Distributors



Bond Strength Testing

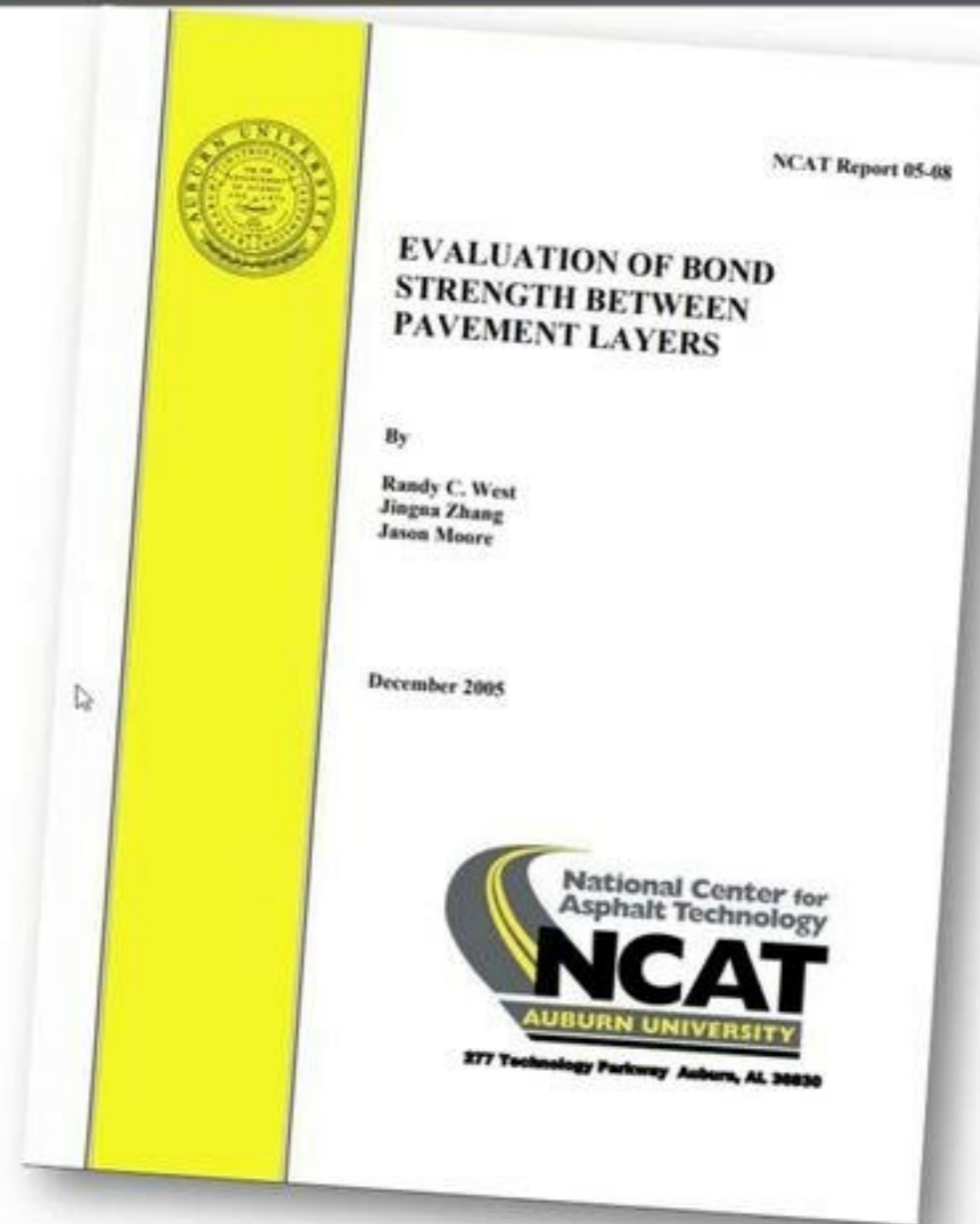
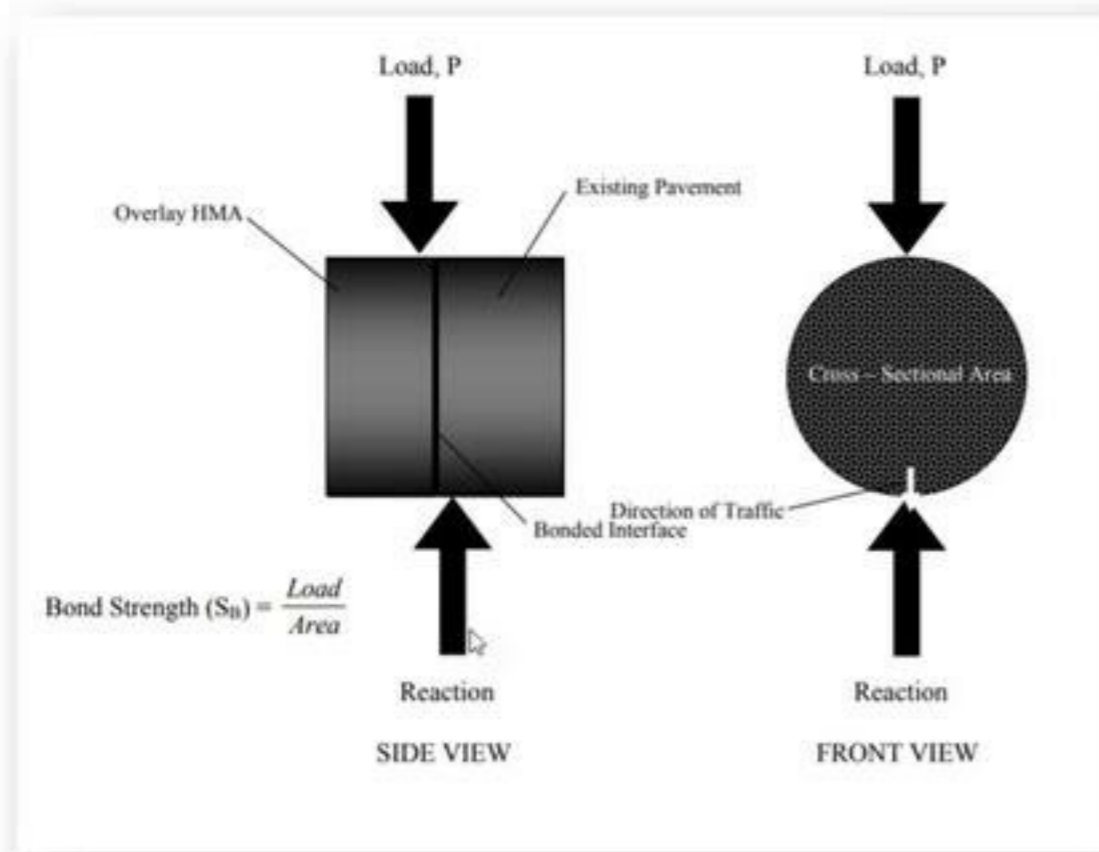


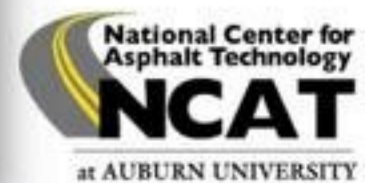
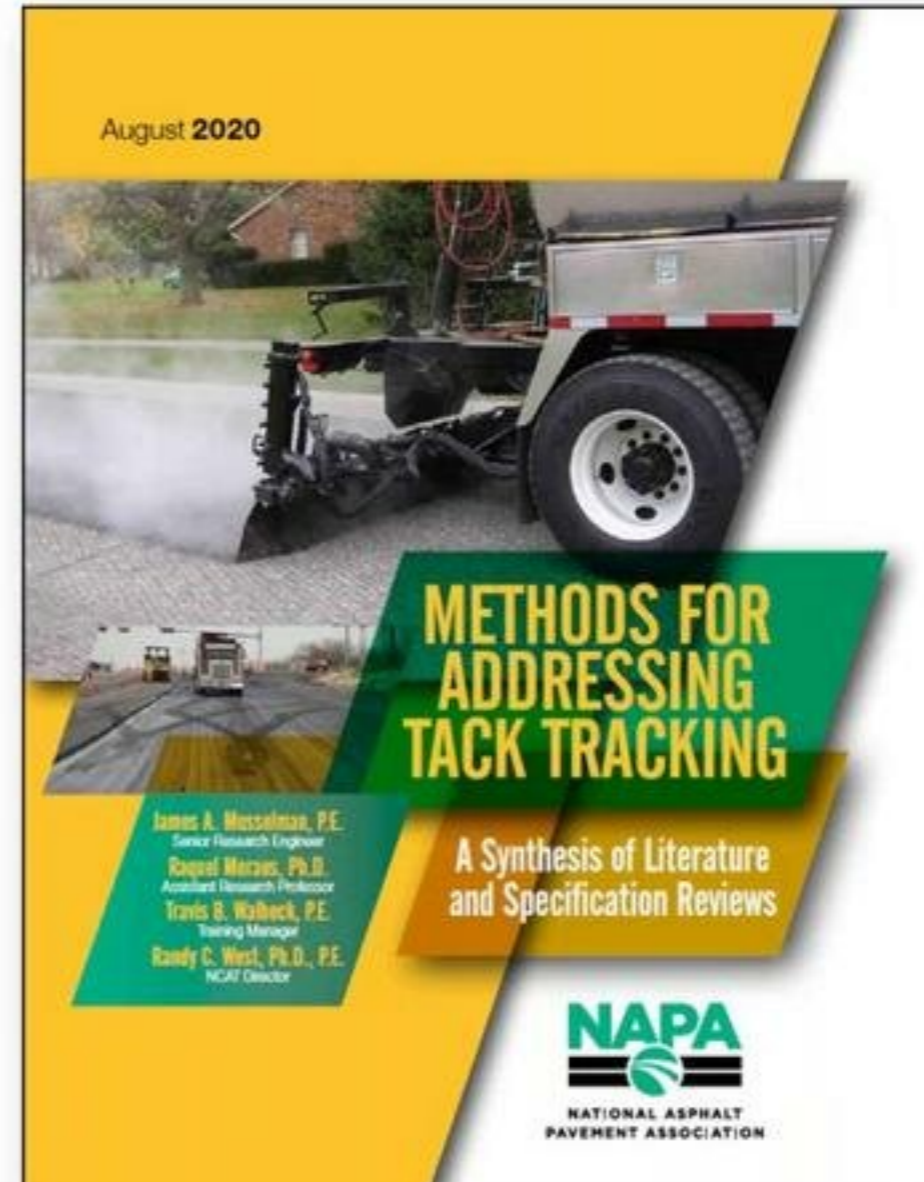
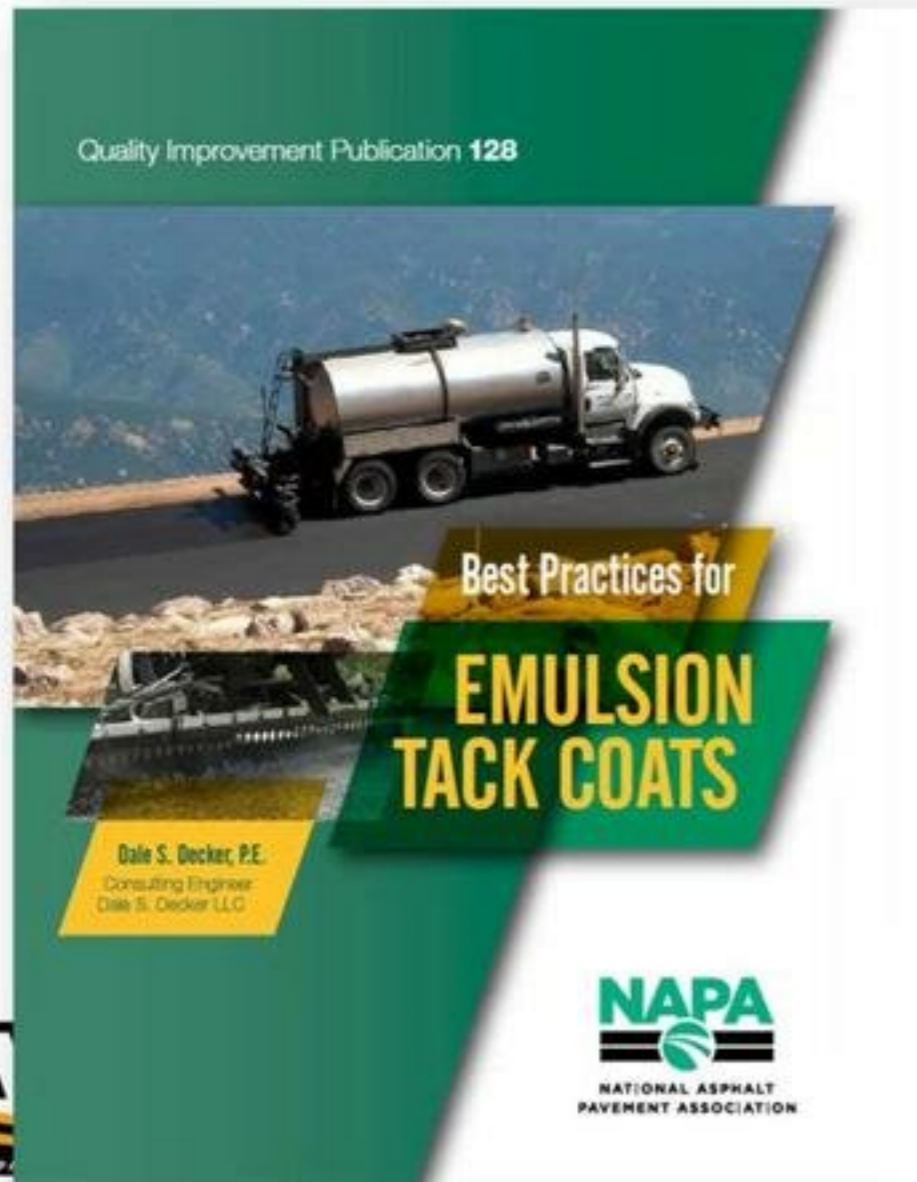
Illustration of NCAT Bond Strength Device



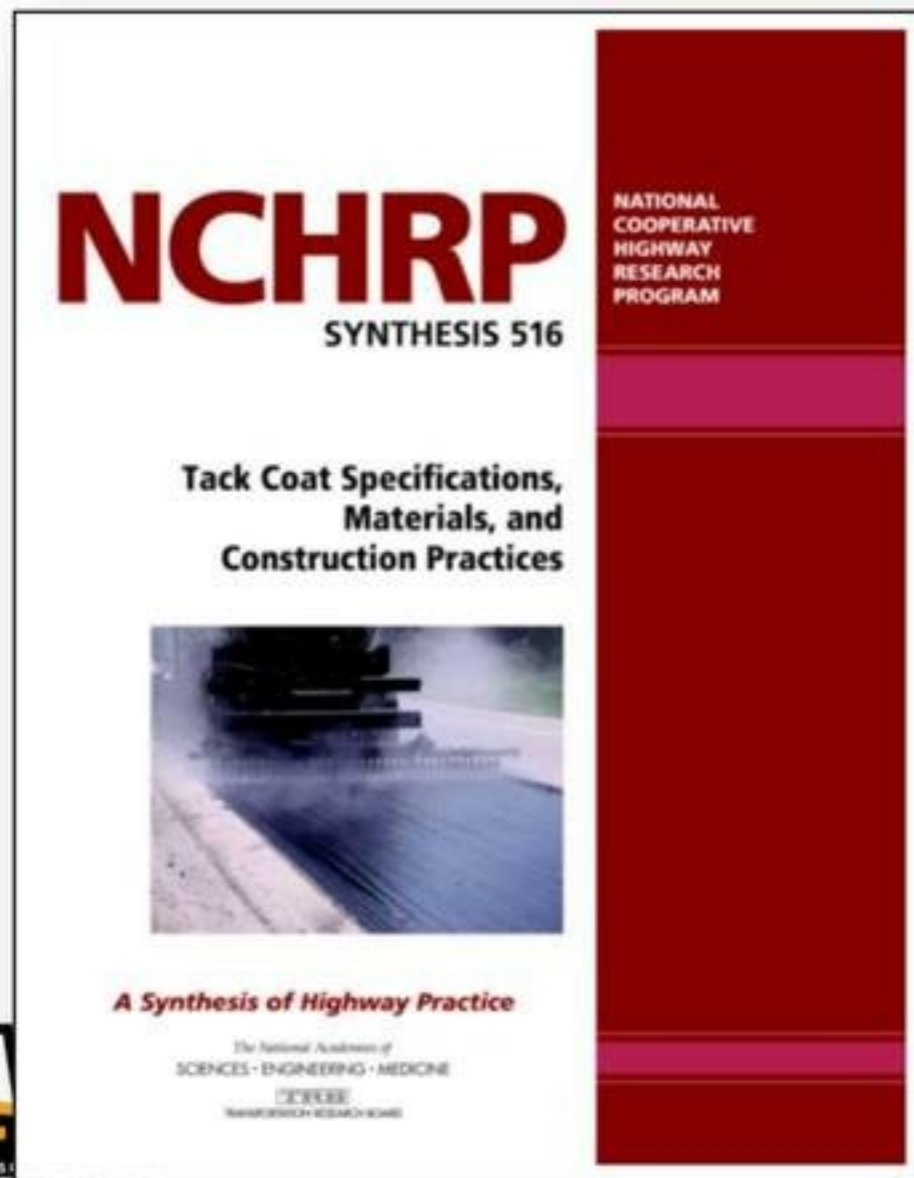
NCAT Bond Strength Test

- Testing is performed on three 6" diameter roadway cores
- Recommended test temperature is 77°F
- No normal pressure applied
- Loading rate 2"/minute: Marshall press can be used
- A minimum bond strength using the bond strength test procedure is 100 psi.
 - Marginal bond strength results appear to be between 50 and 100 psi.
 - Bond strength results below 50 psi are considered poor.

Available Reference Materials




Available Reference Materials



NCHRP
SYNTHESIS 516

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Tack Coat Specifications, Materials, and Construction Practices



A Synthesis of Highway Practice

The National Academy of SCIENCES • ENGINEERING • MEDICINE
CENTRE FOR TRANSPORTATION RESEARCH BOARD



TechBrief

The Asphalt Pavement Technology Program is an integrated, national effort to improve the long-term performance and cost effectiveness of asphalt pavements. Managed by the Federal Highway Administration through partnership with state highway agencies, industry and academia the program's primary goals are to reduce congestion, improve safety, and foster technology innovation. The program was established to develop and implement guidelines, methods, procedures and other tools for use in asphalt pavement materials selection, mixture design, testing, construction and quality control.

U.S. Department of Transportation
Federal Highway Administration

Office of Asset Management, Pavements, and Construction

IHWA-HF-16-017

April 2016

Tack Coat Best Practices

This Technical Brief provides an overview of tack coats and their vital role bonding multiple asphalt layers into one monolithic system. Poor tack coat techniques result in compromised bonding of the asphalt layers. This leads to pavement distresses. Possible slippage cracking and delamination are associated with poor bonding. Additionally, poor bonding can lead to structural distresses, namely fatigue cracking and potholes. Often this lack of sufficient bonding is not recognized as the source of failures.

Introduction

A key, but sometimes overlooked, component of an asphalt pavement is the bond strength between asphalt pavement layers. Tack coat is a sprayed application of an asphalt binder upon an existing asphalt or Portland cement concrete pavement prior to an overlay, or between layers of new asphalt concrete. This thin membrane of asphalt binder provides the glue between the layers, creating a monolithic structure which performs as a unit as opposed to unbound, independent, layers. When properly built, a pavement will provide the desired characteristics for its users, while meeting the needs of an agency for an economical, environmentally friendly and sustainable material.

Poor bonding of a pavement surface layer is a direct result of inadequate tack coat practices resulting in slippage and shoving of the pavement, as seen in Figure 1. This type of failure is most frequently seen in locations where braking or acceleration is common, such as intersections. Other distresses can also be made related to poor tack coat bonding, most notably pavement fatigue cracking.

1

Key Takeaways

- Long-term performance of an asphalt pavement is directly related to proper bonding
- Breaking and Curing
 - After emulsion is applied, begins to “break”
 - When the water completely evaporates, the emulsion has “cured”
 - Breaking and curing are affected by a lot of things:
 - ambient air temperature,
 - relative humidity,
 - wind speed,
 - pavement surface temperature,
 - application rate of the emulsion,
 - dilution rate of the emulsion, and
 - type of emulsifying agent used

Key Takeaways

- If possible, don't dilute the emulsion
 - Reduces residual asphalt on the pavement – which can impact performance
 - More water means emulsion takes longer to cure (break and set)
 - Potential for more tracking and lower bond strengths
 - Dilution can impact pay items and freak out agency staff
- Asphalt binders can be successfully used for tack
 - Georgia DOT uses them regularly

Key Takeaways

- Make sure the pavement is as clean as possible prior to tacking.
- Be aware of Application Rate vs. Residual Asphalt Residue Rate
 - Need to get an accurate idea of what your actual tack application rate is
- Bond strength testing is a relatively simple method of determining how effective the bond is
 - >100 psi is generally easy to obtain



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Thank You!

Questions?

