Best Practices For Tack Coat And Achieving Bond Strength

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Outline

- Purpose of Tack Coats
- Definitions
- Consequences of Poor Bonding
- Materials and Handling
- Tack Coat Application Best Practices
- Testing and Verification

Tack Coat

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Why do we use Tack Coat?

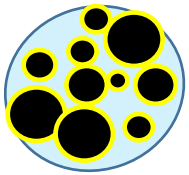
- To promote the bond between old and new pavement layers
  - Vital for structural performance
- To prevent slippage between pavement layers
- To provide an additional moisture barrier, especially when applied along the transverse and longitudinal vertical surfaces

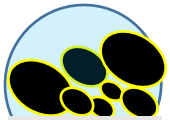
Far too frequent practices

Tack Coat Definitions

- ***Undiluted Emulsion*** - an emulsion which consists primarily of a paving grade asphalt binder, water, and an emulsifying agent.
- ***Diluted Emulsion*** - an emulsion with additional water added to it. The most common dilution rate is 1:1 (one-part undiluted emulsion and one-part additional water).
- ***Residual Asphalt*** - the remaining asphalt after an emulsion has set, typically 57-70 percent of the undiluted emulsion.
- ***Tack Coat Break*** - the moment when water separates enough from the asphalt to show a color change from brown to black.
- ***Tack Coat Set*** - when all the water has evaporated, leaving only the residual asphalt. Some refer to this as completely broken.

Emulsion Breaking & Setting



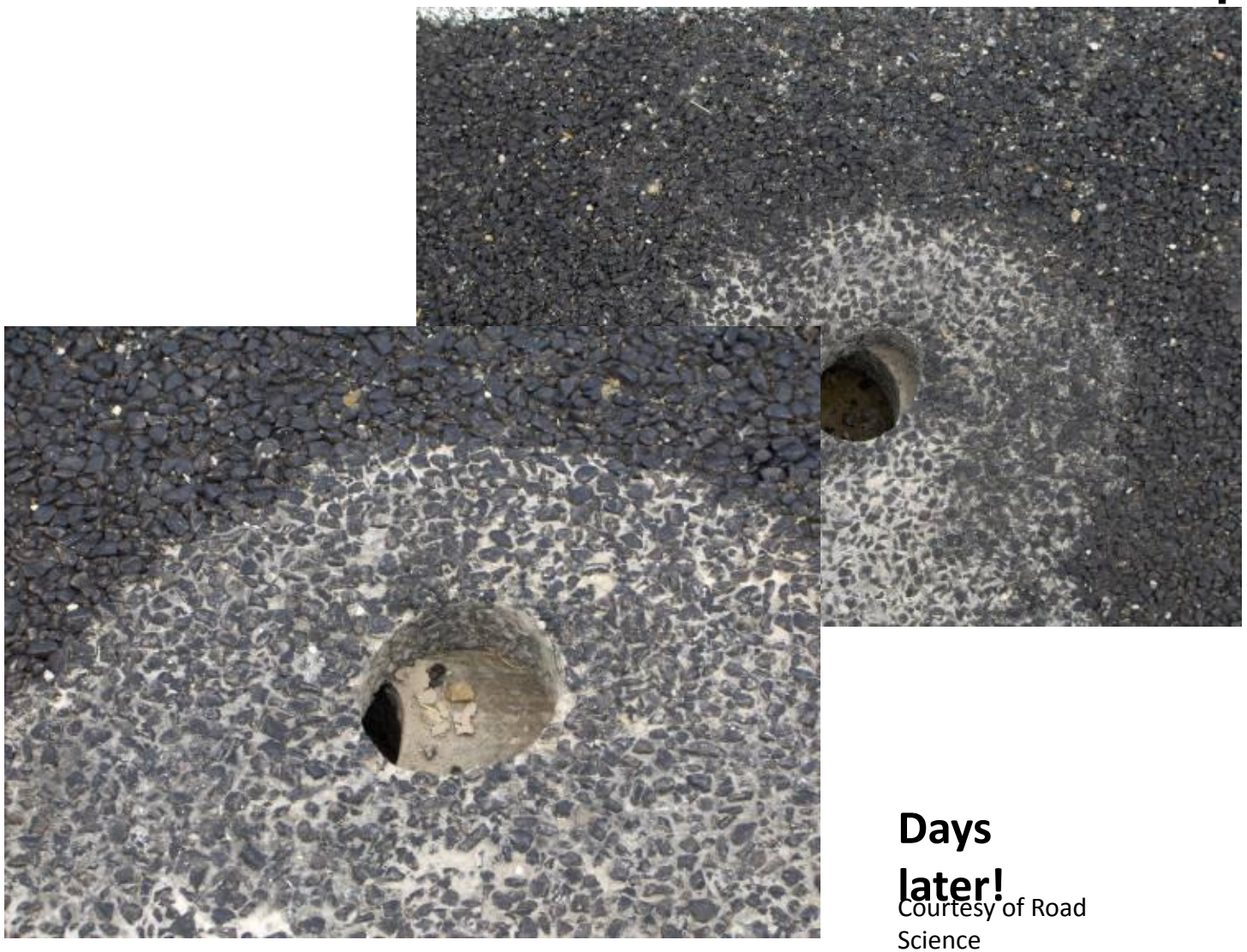


Emulsions are asphalt droplets suspended in water

- Breaking
  - Contact with surface changes pH; reducing charge
- Setting
  - Evaporation leads to coalescence
  - Original asphalt characteristics return

Consequences of Poor Bonding

- Poor pavement performance
  - Slippage cracks
  - Shoving
  - Early fatigue cracking
    - Bottom up
    - Top down
- Costly pavement repairs
  - Repair of isolated area relatively inexpensive
  - Removal and replacement of a portion or the entire pavement structure is very expensive
  - Shorter than expected pavement life can be devastating for agency budgets



Days later!

Courtesy of Road Science

Consequences of Poor Bonding

- Layer independence
  - Reduced fatigue life
  - Increased rutting
  - Slippage
  - Shoving
- Compaction difficulty

Direction of traffic?

Bonding Demonstration

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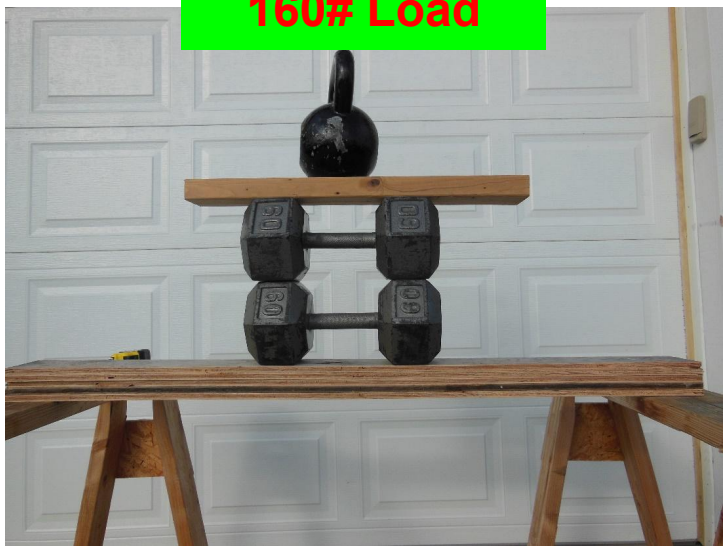
½” Deflection,
60# Load

Unbonded

¼” Deflection,
160# Load



Fully Bonded

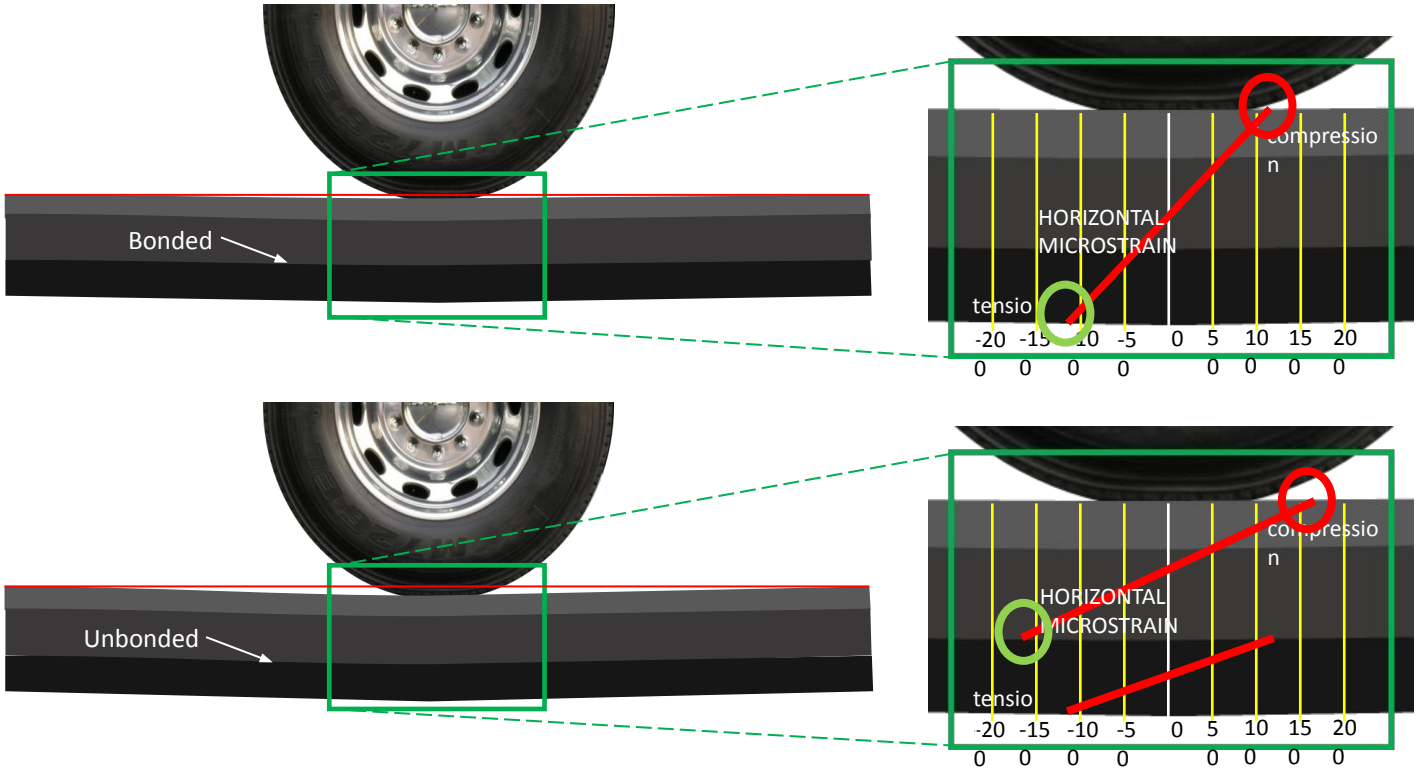
Bonding Demonstration Highlights

- 5 unbonded layers deflected 4x more than 5 bonded with the same loading.

- 2 bonded layers had less deflection than 5 unbonded with the same loading.

- ***5 bonded layers with over 2½x the load deflected half as much as 5 unbonded.***

Consequences of Debonding



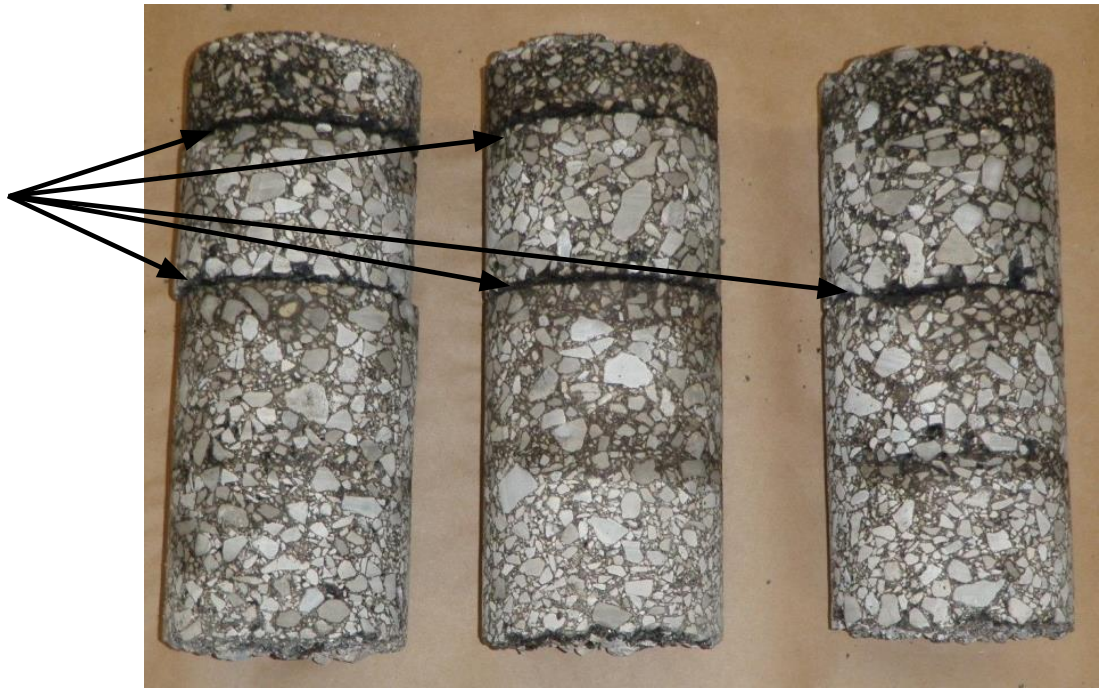
Courtesy of NCAT

Importance of Tack Coat

- Full and adequate bond is essential to ensure that stresses caused by pavement loading are uniformly transferred to the lower supporting layers
- A 30% loss in bonding can result in the loss of up to 70% of the expected pavement service life
- Poor layer bonding can result in three distress types:
  - Layer delamination
  - Slippage cracks
  - Fatigue cracking

8 – 10 years (est.) Interstate Pavement

Cores Showing Debonding



Courtesy of
MODOT

What Does It Cost?

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Cost of Tack Coat

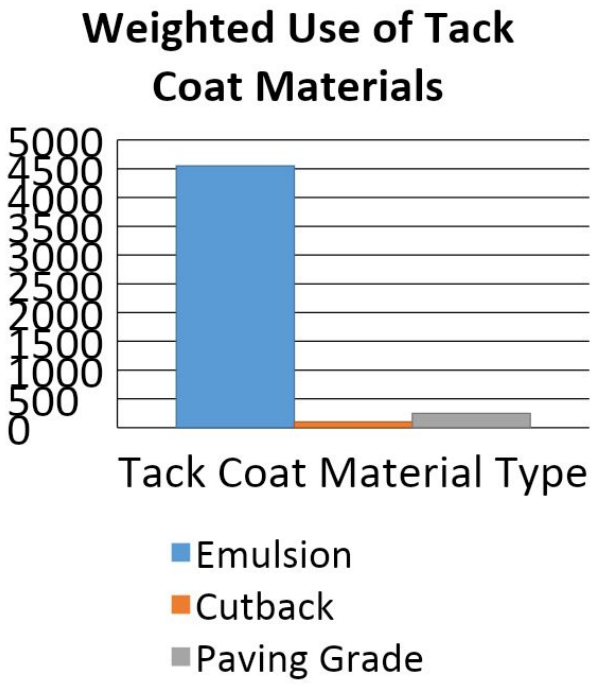
- New or Reconstruction
  - About **0.1-0.2%** of Project Total
  - About **1.0-1.5%** of Pavement Total Cost

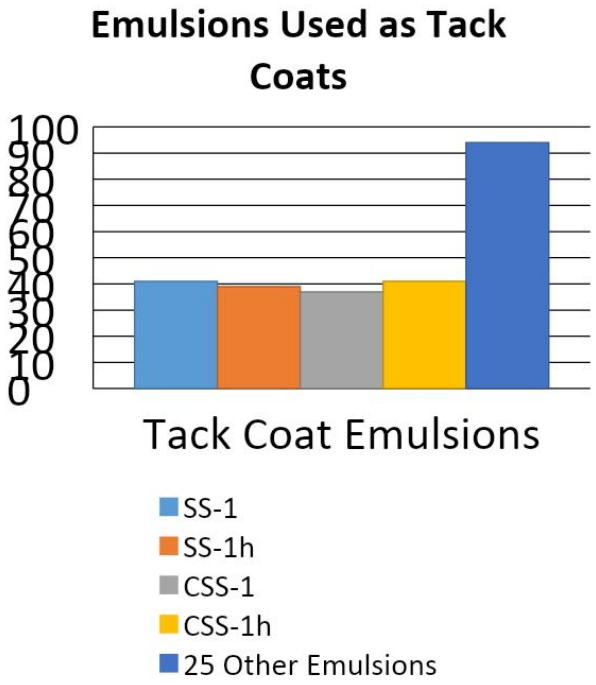
- Mill and Overlay
  - About **1.0-2.0%** of Project Total
  - About **1.0-2.5%** of Pavement Total Cost

Common Tack Coat Materials

- Emulsified Asphalt
  - Most common option
    - SS-1, SS-1H
    - CSS-1, CSS-1H
    - RS-1, RS-1H, RS-2
    - CRS-1, CRS-2
    - PMAE
- PG Graded Binders
  - Neat Binders
    - PG 58-28
    - PG 64-22
    - PG 67-22
  - Polymer Modified
- Reduced or Non-tracking Emulsions

Common Tack Coat Materials (NCHRP Report 712)





Handling of Emulsions

- Do NOT mix anionic and cationic emulsions.
- Vertical tanks preferred—skin formation.
- Protect from freezing.
- Avoid overheating—typically <180°F.
- Minimal low-shear pumping.

Consult with the Supplier for any unique handling needs for their product(s)!

Handling of Hot AC

- Proper personal protective equipment.
- Proper protection of hot elements.
- Ensure a water-free distributor.

Handling of Emulsions

- Dilution
  - Verify if it is allowed.
  - If allowed, where?
    - Supplier only?
    - Contractor?
  - Control amount of water added.
    - 1:1 typical (Original Emulsion: Added Water)
  - Use acceptable/approved water.
  - Terminal added or field diluted.
  - Always add water to emulsion.

Tack Coat
Field Operations

Manuals of Practice

- Asphalt Institute
  - MS-4 *The Asphalt Manual, 7th Edition* (2007)
  - MS-16 *Asphalt Pavement Preservation and Maintenance, 4th Edition* (2009)
  - MS-19 *Basic Asphalt Emulsion Manual, 4th Edition* (2008)
  - MS-22 *Construction of Quality Asphalt Pavements, 3rd Edition*
- Comments
  - AI has a long history of promoting the proper use of tack coats.

Manuals of Practice

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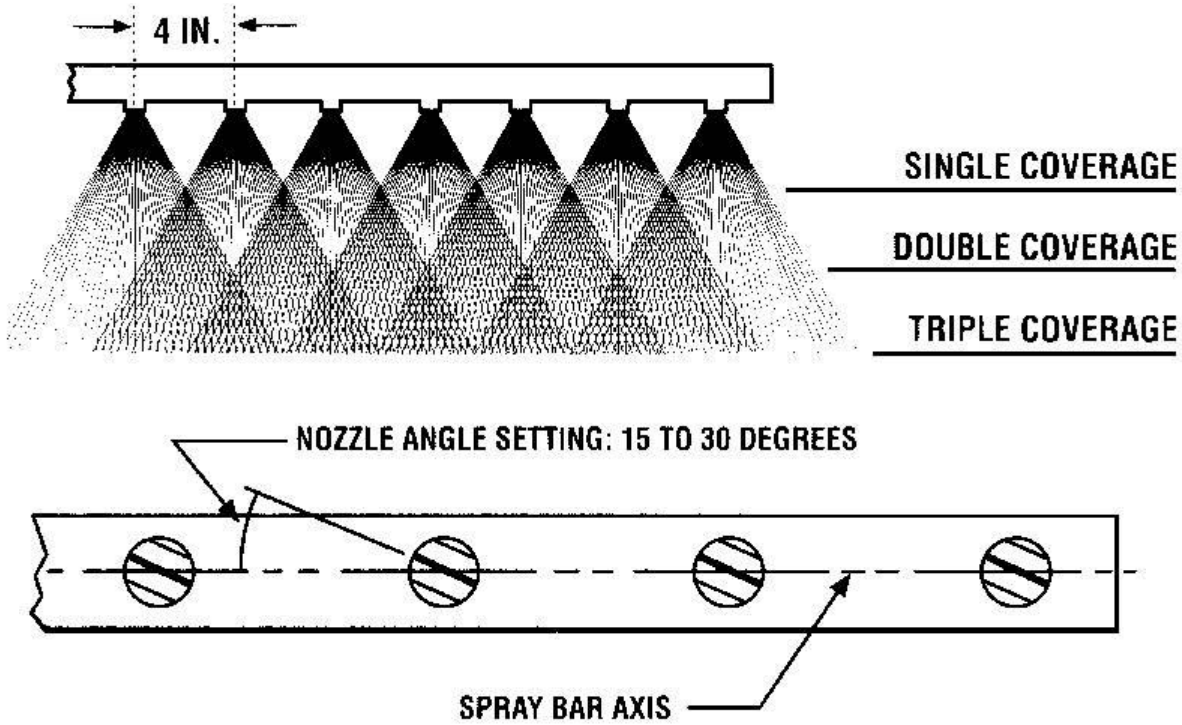
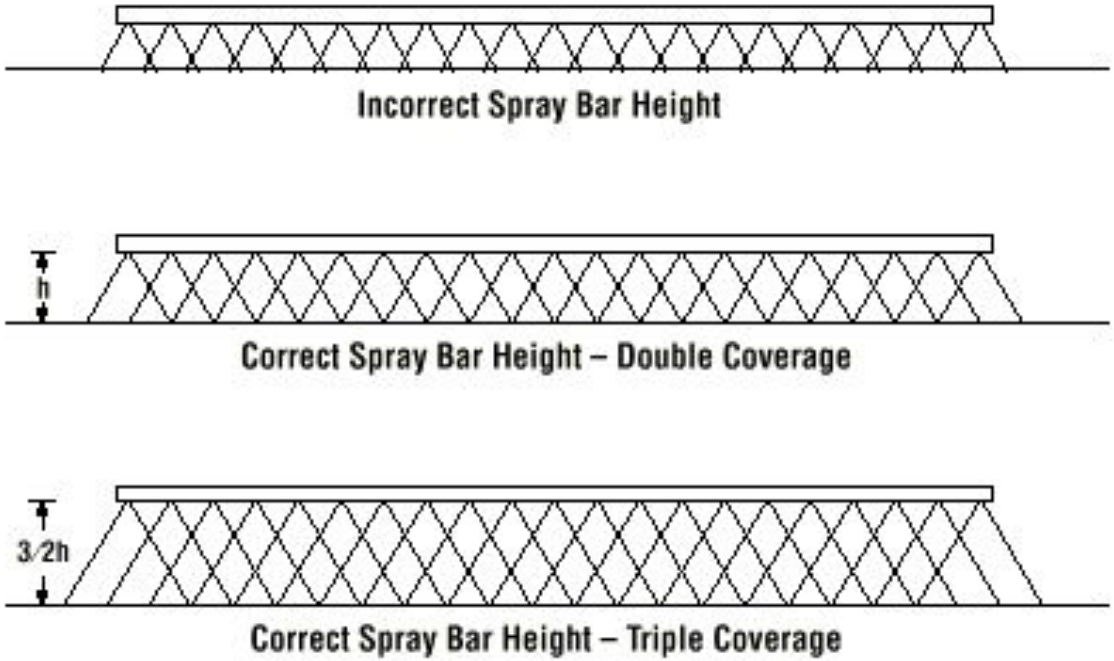
- QIP-128,*Tack Coat Best Practices*, NAPA (2013)
- *Hot-Mix Asphalt Paving*, US Army Corp of Engineers (2000)
- *Airfield Asphalt Pavement Construction Best Practice Manual*, NCAT (2008)
- *Tack Coat Guidelines,* Caltrans (2009)
- *Tack Coats: How and what to apply!* Colorado Asphalt Pavement Association (CAPA) (2011)
- *Guide for Using Prime and Tack Coats, C*FLHD (2005)
- *Best Practices for Applying Undiluted Emulsified Asphalt Tack Coats,* CAPA (2013)

Distributor Truck Setup

Placement of Tack Coat



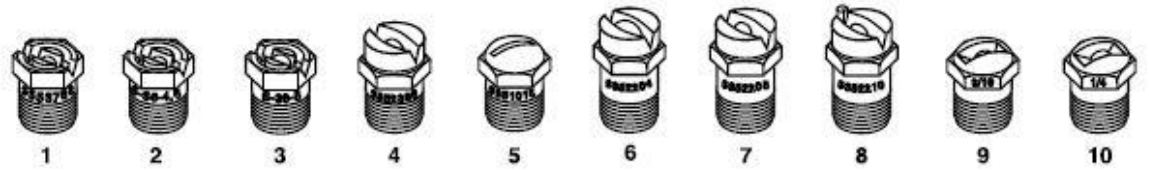
Spray Bar Height and Coverage



Nozzle Selection

- Consult with distributor truck manufacturer to match the material to the nozzle.
- ONE SIZE DOES NOT FIT ALL

Etnyre Spraybar Nozzles

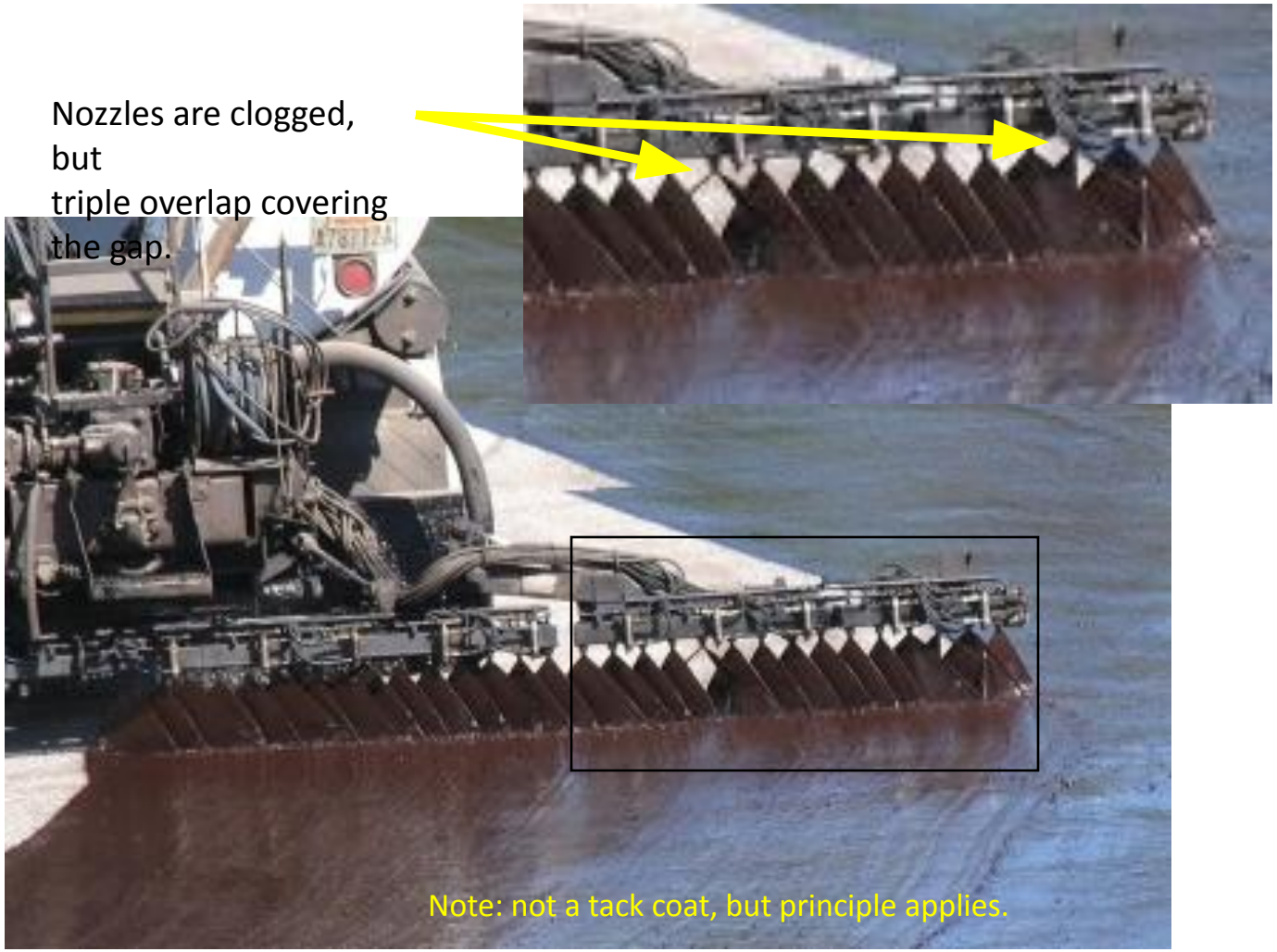


1	2	3	4	5	6	7	8	9	10
3353788	3351008	3351009	3352368	3351015	3352204	3352205	3352210	3351014	3351010

Ref.	Part No.	Description	Application Gallons Per Square Yard	Application (Metric) Liters Per Square Meter	US Flow Gallons Per Minute Per Foot
1	3353788	V Slot Tack Nozzle	.05 - .20	.23 - .91	3.0 to 4.5
2	3351008	S36-4 V Slot	.10 - .35	.45 - 1.58	4.0 to 7.5
3	3351009	S36-5 V Slot	.18 - .45	.81 - 2.04	7.0 to 10.0
4	3352368	Multi-Material V Slot	.15 - .40	.68 - 1.81	6.0 to 9.0
5	3351015	3/32" Coin Slot	.15 - .40	.68 - 1.81	6.0 to 9.0
6	3352204*	Multi-Material V Slot	.35 - .95	1.58 - 4.30	12.0 to 21.0
7	3352205*	Multi-Material V Slot	.20 - .55	.91 - 2.49	7.5 to 12.0
8	3352210	End Nozzle (3352205)	.20 - .55	.91 - 2.49	7.5 to 12.0
9	3351014	3/16" Coin Slot	.35 - .95	1.58 - 4.30	12.0 to 21.0
10	3351010	1/4" Coin Slot	.40 - 1.10	1.81 - 4.98	15.0 to 24.0

* Recommended nozzles for seal and chip with emulsified asphalts.

Nozzles are clogged,
but
triple overlap covering
the gap.



Note: not a tack coat, but principle applies.

Best Practices

- Surfaces need to be clean and dry.
- Uniform and complete application.
- All surfaces are tacked.
- Tack should not be tracked off the road.

Surface Preparation

- Milling
  - Improves profile
  - Typically improves bonding characteristics
  - Increases cleaning effort
  - Adds cost
- Surface Sweeping
- Visually Verify Moisture Free

Highly inconsistent tack application.

Apply past full-width of mat to minimize movement of unsupported edge


MACK
520719
A812341
Nicely
tacked

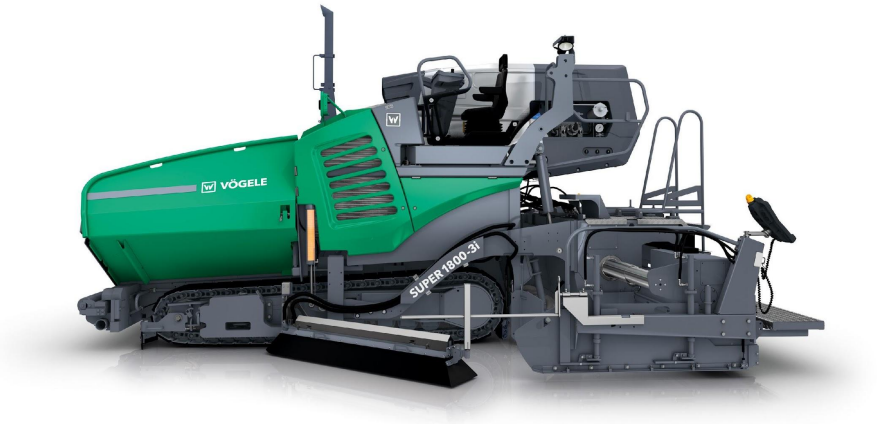
Tracking and Pickup

Pictures courtesy of Road Science™

Spray Pavers/Bonded Overlays

- Spray Paver-Single Pass Paving and Sealing
  - Hot mix asphalt overlay
  - Polymer modified emulsion tack
  - Placed with spray paver
    - Paver & Distributor
  - High Application Rates
    - 0.08-0.20 gsy residual

Spray Pavers



Purported Spray Paver Benefits

- No tracking of the tack
- Better bonding of overlays
  - Increased Overlay life
  - Reduce Rutting
  - Reduce Cracking
- Improved joint compaction
- Easier compaction

Best Practices

- Match application to conditions.
  - Materials
  - Residual rate
- Verify application rate.
- Resist tacking too far ahead of paver.
- Typical Weather Requirements
  - +60°F (+15°C)
  - No fog or rain

Application Rates?

- **What is the Optimal Application Rate?**
  - Surface Type
  - Surface Condition
- **Recommended Ranges**
  - Application rate must be clearly stated in terms of residual, undiluted, or diluted condition

Surface Type	Residual Rate (gsy)	Appx. Bar Rate Undiluted* (gsy)	Appx. 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

*Assume emulsion is 33% water and 67% asphalt.

Calculating field application rates

- There are three primary methods of determining field application rates.
  - Determination by volume.
  - Determination by weight or mass.
  - Determination by direct measurement, ASTM D2995

Calculating rates by Volume

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- The rate of material applied is calculated by determining the volume of material distributed. Either by:
  - By observation and recordation of an onboard volume meter or gauge ***<u>on a distributor truck</u>***.
  - Or, using a tank stick method where the depth of material is measured in the tank and the volume is calculated or by the us ed stick.

Calculating Asphalt Volume - Distributor Method

- Measure asphalt volume in distributor
- Record asphalt temperature
- Spray tack coat over a known area
- Measure remaining asphalt volume in distributor
- Correct volume for temperature variation from 60°F

Correcting for temperature

- Asphalt and water expands and contracts when temperatures deviate from 60° F.
- As temperatures rise above 60°F expansion occurs and the resulting density (#/gal.) decreases.
- As temperatures cool below 60°F contraction occurs and the density increases.
- A Temperature–Volume correction table for asphalt emulsion is available in MS-19, page 91.

Table 13. Temperature - volume corrections for asphalt emulsions [6].

°C	°F	M	°C	°F	M	°C	°F	M
10.0	50	1.0025	35.0	95	0.9912	60.0	140	0.9800
10.6	51	1.0022	35.6	96	0.9910	60.6	141	0.9797
11.1	52	1.0020	36.1	97	0.9907	61.1	142	0.9795
11.7	53	1.0017	36.7	98	0.9905	61.7	143	0.9792
12.2	54	1.0015	37.2	99	0.9902	62.2	144	0.9790
12.8	55	1.0012	37.8	100	0.9900	62.8	145	0.9787
13.3	56							0.9785
13.9	57							0.9782
14.4	58	1.0005	39.4	103	0.9892	64.4	148	0.9780
15.0	59							0.9777
15.6	60							0.9775
16.1	61	0.9997	41.1	106	0.9885	66.1	151	0.9772
16.7	62	0.9995	41.7	107	0.9882	66.7	152	0.9770
17.2	63	0.9992	42.2	108	0.9880	67.2	153	0.9767
17.8	64	0.9990	42.8	109	0.9877	67.8	154	0.9765
18.3	65	0.9987	43.3	110	0.9875	68.3	155	0.9762
18.9	66	0.9985	43.9	111	0.9872	68.9	156	0.9760
19.4	67	0.9982	44.4	112	0.9870	69.4	157	0.9757
20.0	68	0.9980	45.0	113	0.9867	70.0	158	0.9755
20.6	69	0.9977	45.6	114	0.9865	70.6	159	0.9752
21.1	70	0.9975	46.1	115	0.9862	71.1	160	0.9750

$$Volume_{@\,°F} \times M_{value} = 60°\text{F}\ Vol.$$

$$Volume_{@\,°C} \times M_{value} = 15.6°\text{C}\ Vol.$$

Calculating Tack Coat Application Rate

$$\frac{9 \times Gallons\ App}{Width \times Leng}$$

(feet) (feet)

Note: 9 to convert from square feet to square yards.

Use as required.

Comments on Calculating by Volume

- Pros:
  - Quick
  - Simple
  - Accuracy improves with larger areas
- Cons:
  - Volume requires
    - Dip Stick, or
    - Volumeter
  - Dilution rate vital
  - Temperature correction required
  - Inaccurate on small areas

Calculating rates by Weight (Mass)

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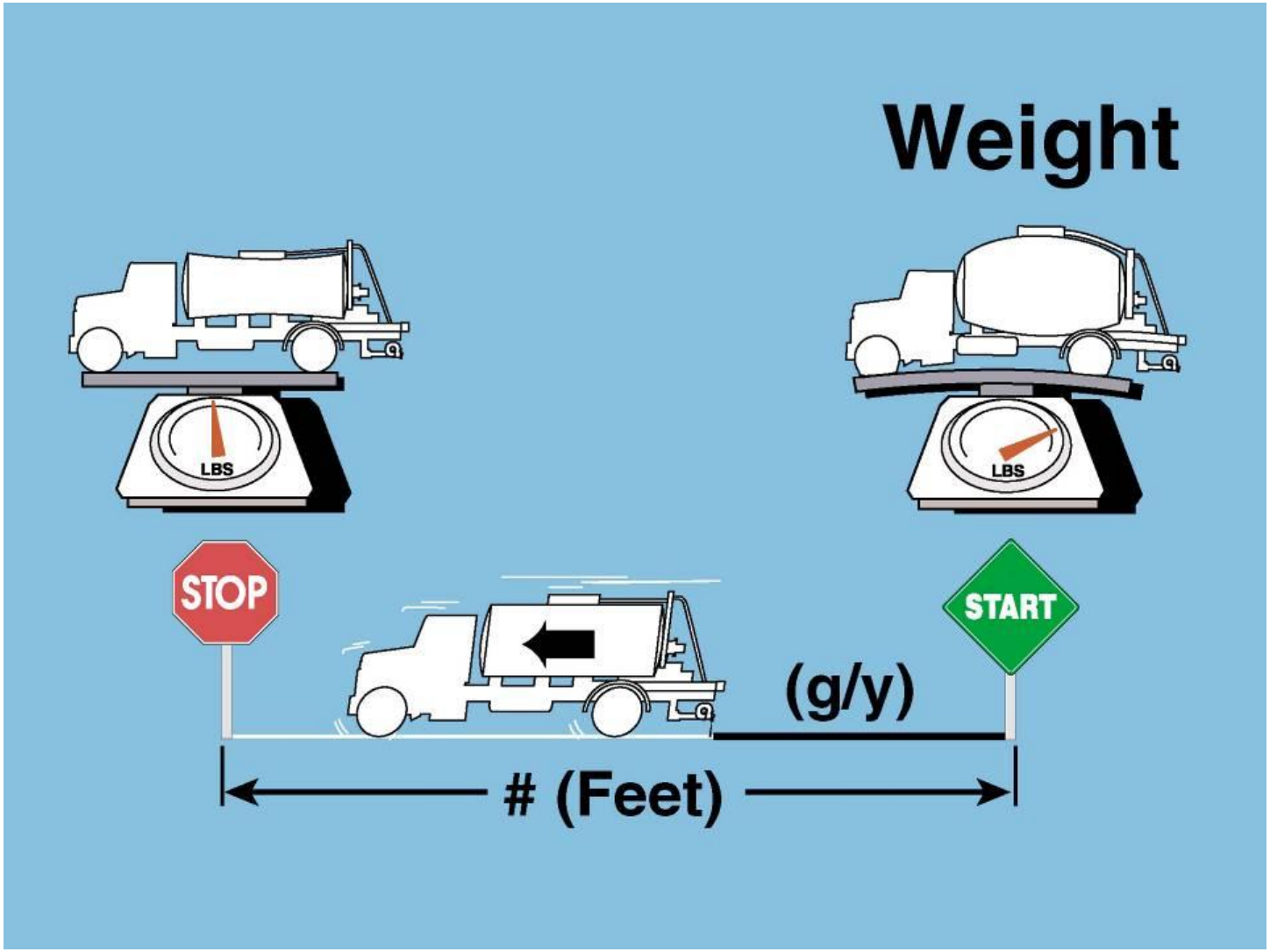
- Calculating an application rate by weight is the most accurate method.
- Bill of lading from the supplier should contain a 60°F weight per gallon.
- Weight measurements are not affected by temperature.
- However constant weighing after each shot can be complicated.
- Recommend using this method for full load applications, calibration, etc.


Weight
LBS
LBS
STOP
START
(g/y)
(Feet)

Comments on Calculating by Mass

- Pros:
  - Quick
  - Simple
  - Temperature correction not needed
  - Accuracy improves with larger areas
- Cons:
  - Dilution rate vital
  - Inaccurate on small and irregular areas

Direct Measurement using ASTM D2995

- Field Measurement of Application Rate
  - Longitudinally
  - Transversely
  - Units of Gallons/Yard^2 (Liters/Meter^2)

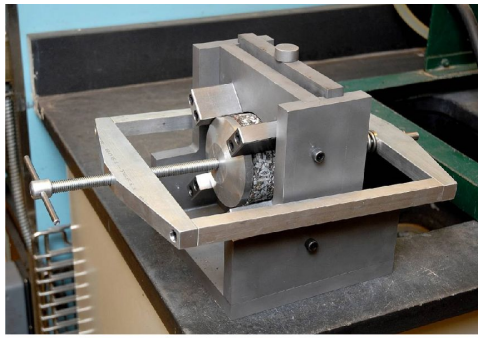
Photos courtesy of
Dr. Louay Mohamad

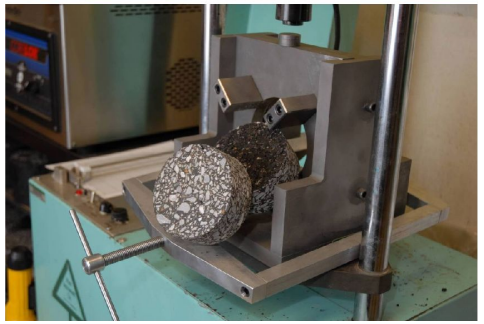
Bond Testing

- Field/Laboratory Bond Testing
  - Shear Testing
  - Torsion Testing
  - Pull-Off Testing (tension)
  - Cyclic

Shear Testing

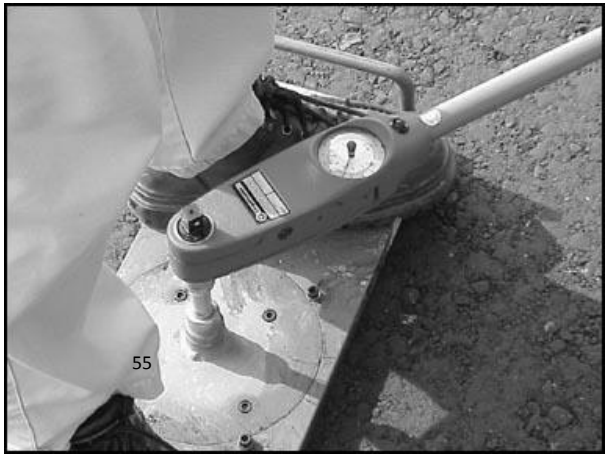
- Cores or Lab Specimens
- 4 or 6-inch
- Common for Product Approval
- Virginia Example
  - Four-inch core or specimens
  - Placed in shear head
  - Tested on Marshall Stability Unit
    - 2 inches per minute of movement
  - Tested at 70°F
  - Record maximum load on each of three tests
  - 100 psi minimum average-none <50 psi (milled)
  - 50 psi min average-none <30 psi (non-milled)





Torsion Example

- Developed in Sweden
- Commonly used in the United Kingdom
- Known as the “Torque Bond Test”
- Manual and automated versions
- Is being used for product approval in US
- Field or laboratory test
- Various configurations



Tension Testing

- Most typically a field test
- May be a modified ACI-503R or
- Direct Tensile Bond Test: ASTM C-1583
- Procedures identified in Texas, Kansas, and Virginia
- AASHTO T 361
  - Asphalt Bond Strength Test
  - Lab tension test

Texas device

Tension Testing

- Virginia Example
  - Lab test @ 70°F
  - Four-inch specimen
  - Apply pre-load of 10 lbs.
  - Load at 1200 lbs. per minute until failure
  - Calculate strength in psi
  - 40 psi minimum average-none <20 psi (milled)
  - 30 psi min average-none <20 psi (non-milled)

Cyclic Loading Testing

- Repeated Load Test
- Shear, Tension, and Torsion Options
- Example: Composite Specimen Interface Cracking (CSIC) Test
  - Developed in Florida
  - Tension Test
  - Monotonic or Cyclic Procedures

Comments on Testing Options

- Shear Testing
  - Lab test
  - Quick
  - Repeatable
  - Most widely promoted
  - Uses common lab equipment
  - Cleanly ranks materials
- Torsional Testing
  - Lab or field test
  - Quick
  - Poorer repeatability (manually ran)
- Tension Testing
  - Lab or field test
  - Quick
  - Repeatable
  - Cleanly ranks materials
  - Used in Texas, Kansas, and Virginia
- Cyclic Testing
  - Lab test
  - More time consuming
  - Repeatable
  - Cleanly ranks materials

Comments on Testing Options

- Testing Method has a Huge Effect on Rankings
  - Shear/Torsion vs. Tension/Cyclic
  - Stiffer vs. Softer Materials

Confused?

Summary

- Layer bonding is vital.
- Surfaces need to be **clean** and dry.
- Milling improves performance but requires additional cleaning
- Uniform and complete application of tack.
  - Rate depends on surface condition
- Distributor
  - Setup
  - Calibration/Verification
  - Maintenance
- All surfaces are tacked.
- Tack should not be tracked off the road.

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In Loving Memory of

Gregory M. Harder

December 12, 2002

December 21, 2022

#LLGH 16

Thank you!

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