

PAVEMENT TECHNOLOGY UPDATE



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Recent Findings on the Use of Tack Coat Between Pavement Layers

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The University of California Pavement Research Center

Using innovative research and sound engineering principles to improve pavement structures, materials, and technologies.

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The University of California Pavement Research Center (UCPRC) conducts research on pavements of all types, including concrete and asphalt. It has operated facilities at UC Berkeley since 1948 and at UC Davis since 2002, and also conducts research on California highways. Primary funding for the UCPRC is provided by Caltrans. Most of the UCPRC's work is done through the Partnered Pavement Research Center contract, whose mission is to apply innovative research and sound engineering principles to improve pavement structures, materials, and technologies through partnership between academia, Caltrans, and industry.

By Larry Santucci, PE

Pavement Specialist, University of California Pavement Research Center, and California LTAP Field Engineer, Technology Transfer Program, Institute of Transportation Studies, UC Berkeley

Introduction

A tack coat is a light application of asphalt or asphalt emulsion used to bond one pavement layer to another. The tack coat acts as an adhesive or glue so that the combined pavement layers perform as a composite section rather than as individual sections. A comparison can be made to the construction of laminated structural lumber where individual wood segments are glued together to produce a thicker, stronger beam or truss. The lack of a tack coat between pavement layers can lead to premature failure such as debonding or delamination (similar to that shown in Figure 1), mat slippage, or early fatigue cracking. Tack coat is also applied to any adjacent surface such as curbs, gutters, structures, or the edges of existing pavements to ensure good adhesion between these surfaces and the freshly placed asphalt mix and to help keep water from collecting at the interface.

FIGURE 1 Debonding between pavement layers



SOURCE: WASHINGTON STATE DEPARTMENT OF TRANSPORTATION

The most commonly used tack coats are anionic and cationic slow setting (SS, CSS) asphalt emulsions. Anionic and cationic rapid setting (RS, CRS) emulsions are sometimes used where faster cure times are desired. Hot asphalt cement is often the tack coat of choice where multiple pavement layers are being placed and closure time is critical, as was the case in the rehabilitation of a heavily traveled interstate (I-710) in Long Beach, California¹. Cutback asphalt is also used by some agencies for tack coat. Application rates of tack coat depend on the condition of the existing pavement, surface type (asphalt or concrete pavement), and dilution rate in the case of asphalt emulsions.

Agencies are often asked, "Is it necessary to apply a tack coat when subsequent pavement layers are placed on the same day and in light of the inconvenience associated with pick up of tack material on the tires of construction vehicles?" To help answer this question, we examined the research findings from a full scale accelerated pavement testing program on bonded and unbonded pavement layers and explored the practices for using tack coat by several highway agencies.

Research Findings

The University of California Pavement Research Center (UCPRC) at Berkeley and Davis conducts extensive research on

asphalt and concrete pavements under a Partnered Pavement Research Program with the California Department of Transportation (Caltrans). A unique feature of this research is the ability to carry out accelerated pavement testing using the Heavy Vehicle Simulator (HVS) shown in Figure 2. The HVS applies loads on either single or dual tires that are driven backward and forward over a roughly 5-foot wide by 20-foot long pavement test section. Wheel loads of 7,000 to 45,000 pounds can be applied at speeds up to 8 miles per hour. Performance data is collected with a series of instruments, both on the surface and embedded in the pavement. Changes in pavement

temperature and moisture can be created with a temperature control chamber and a surface/subgrade water injection system. The HVS allows evaluation of the rutting or permanent deformation and fatigue cracking potential (two of the most critical performance characteristics) of asphalt pavements. Typical rutting and fatigue cracking results after HVS testing are shown in Figure 3.

In a series of HVS experiments in the late 1990s, the performance of bonded (tack coat applied) and unbonded (no tack coat) pavement layers was compared². The test sections evaluated are described in Table 1.

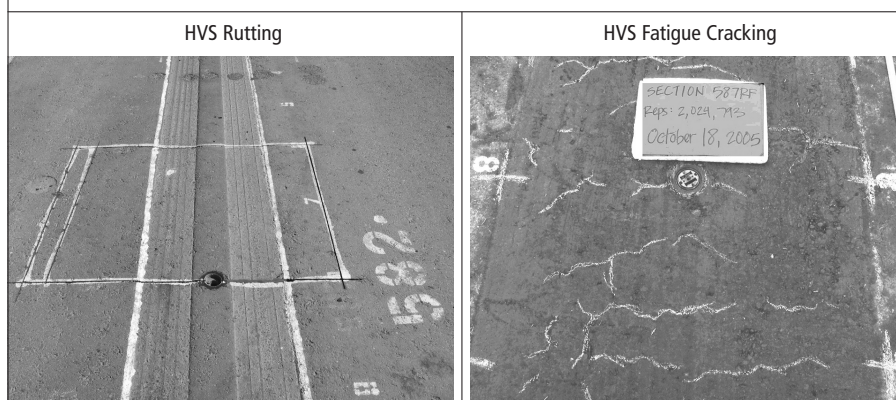
As can be seen from Table 1, the two cases analyzed were for pavement sections that were identical except for the bonding conditions between the two lifts. Fatigue results, in terms of 18,000 pound equivalent single axle loads (ESALs) or 9,000 pound wheel loads, were estimated from the HVS testing. The results for Section 500 predicted that 292×10^6 ESALs could be applied to the Case 1 pavement section and only 6.74×10^6 ESALs to the Case 2 section to produce the same level of fatigue cracking. Three additional pavement sections were tested under HVS loading to confirm these initial findings.

FIGURE 2 Heavy Vehicle Simulator (HVS)



SOURCE: UNIVERSITY OF CALIFORNIA PAVEMENT RESEARCH CENTER

FIGURE 3 Typical HVS test results



SOURCE: UNIVERSITY OF CALIFORNIA PAVEMENT RESEARCH CENTER

Results show a 10- to 45-fold increase in estimated loadings (ESALs) for the bonded pavement sections over the unbonded sections.

The large difference in estimated performance between the frictionless and full-friction conditions is due primarily to a shift in the critical strain (initial cracking) location from the bottom of the lower lift for the full friction interface to the bottom of the upper lift for the frictionless interface. In the upper lift, the air-void content is much greater, and the load repetitions needed to propagate cracks to the top surface are less because of the reduced thickness through which the cracks must propagate. The larger air-void content and reduced overlay thickness significantly reduces the predicted fatigue life. A schematic illustrating this effect is shown in Figure 4.

Contrary View

Not everyone agrees that a tack coat must be used between pavement layers, especially between fresh hot mix asphalt (HMA) layers placed on the same day with no opportunity for dust contamination or much cooling of the underlying layer prior to placing the upper layer. Hachiya and Sato³ reported on the shear strength at the interface of HMA sections using four different construction procedures: monolithic, hot joint, cold joint, and tack coat construction. Shear tests were conducted at 0°C, 20°C, and 40°C (32°F, 68°F, and 104°F) on cylindrical and rectangular test sections of HMA at loading rates of 1 and 100 mm/min (~0.04 and 4.0 inches/min). The dimensions and load application of the specimens are shown in Figure 5. For the monolithic section, a 100 mm (~4.0 inch) thick layer was constructed in one lift. For the hot joint section, the upper layer was constructed when the temperature of the lower layer dropped to 60°C (140°F), while the cold joint construction was done at ambient temperature. In

TABLE 1 Predicted fatigue results from HVS testing on bonded and unbonded pavement layers			
		Case 1 Bonded/Full Friction	Case 2 Unbonded/Frictionless
Pavement Section Description		4.4% air voids (lower lift) 7.8% air voids (upper lift) 4.8% asphalt content	4.4% air voids (lower lift) 7.8% air voids (upper lift) 4.8% asphalt content
Test Section			
500 RF	Estimated ESALs x 10 ⁶	292	6.74
501 RF		66	6.42
502 CT		456	9.68
503 RF		216	17.1

SOURCE: HARVEY ET AL²

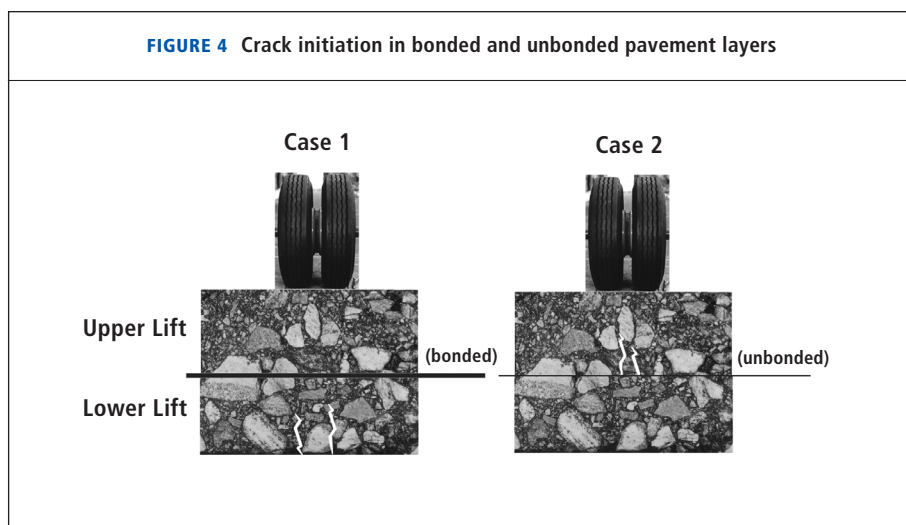
the tack coat section, tack was applied over the lower layer and allowed to cure for 24 hours before the upper layer was constructed.

The measured shear strengths for a loading rate of 1 mm/min (~0.04 inches/min) are shown in Figure 6. As expected, the monolithic construction gave the highest strength values. The hot joint and tack coat construction produced comparable shear strengths over the temperature range selected. The cold joint construction

showed a significant drop in strength at the higher temperature.

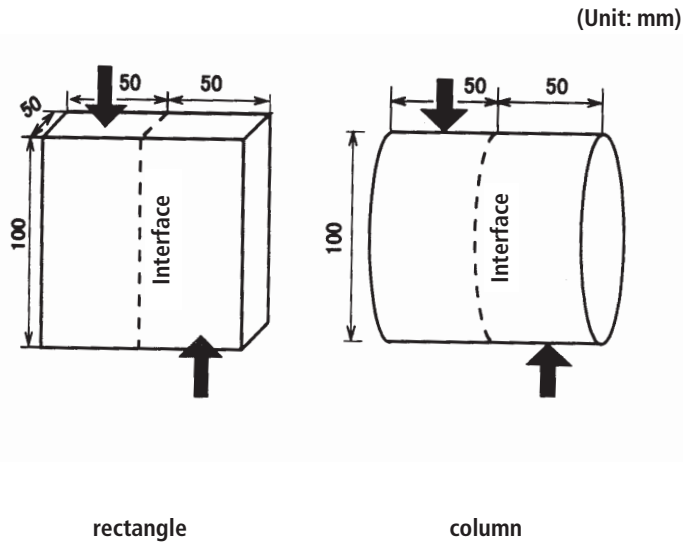
Some agencies and contractors report that they see little difference in mix behavior or appearance during construction between tacked and non-tacked HMA layers placed on top of each other on the same day. However, as noted earlier, the benefit of a tack coat is more likely realized in the long term fatigue performance of the total pavement structure. Another interesting observation is that experienced roller

FIGURE 4 Crack initiation in bonded and unbonded pavement layers



SOURCE: UNIVERSITY OF CALIFORNIA PAVEMENT RESEARCH CENTER

FIGURE 5 Shear testing of HMA samples

SOURCE: HACHIYA AND SATO³

operators, interviewed on the job by UCPRC researchers, have indicated they “feel” a difference in mix behavior when an HMA layer is compacted over a properly tacked versus a non-tacked lower layer. They report that the mix does not move as much under the roller and it is easier to reach the target mix density, especially on inclines or on- and off-ramp construction.

The question then remains: “Does the risk of not applying a tack coat between HMA layers outweigh the potential advantage of improved long term pavement performance?”

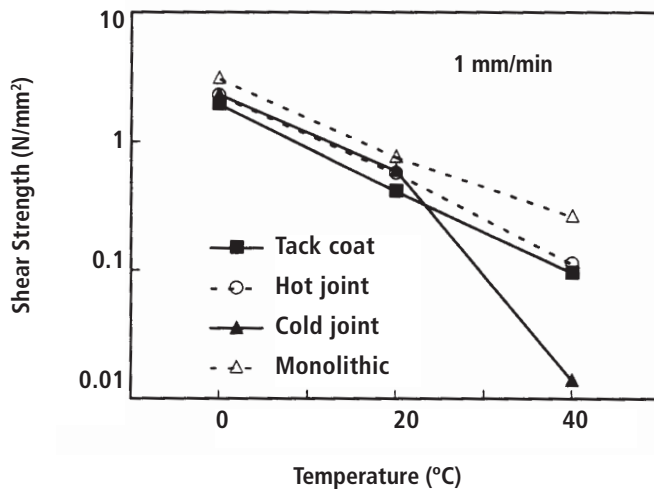
Caltrans’ position and a worldwide survey on the use of tack coat suggest that most agencies opt for tack coating between pavement layers as good insurance against earlier than expected pavement distress.

Caltrans’ Position

Caltrans produced “Tack Coat Guidelines” for its design and construction personnel⁴. In the Guidelines, Caltrans requires the application of a tack coat between all pavement lifts and to all vertical surfaces of existing pavements, curbs, gutters, and construction joints where a new overlay will be placed, with the following exceptions:

- Tack coat should not be applied to an area that cannot be covered by the same day’s paving.
- Tack coat should not be applied to a pavement reinforcing fabric that is already saturated with paving asphalt.
- Tack coat should not be applied to a Stress Absorbing Membrane Interlayer (SAMI) unless a flush coat (fog seal plus sand) was placed on the SAMI.
- Tack coat is not required before placing a chip seal.

FIGURE 6
Shear strength of HMA sections using various construction procedures

SOURCE: HACHIYA AND SATO³

- Tack is not generally required before a slurry seal or micro-surfacing application unless the existing pavement surface is extremely dry and raveled or is Portland Cement Concrete.
- Tack coat should not be applied to a bleeding surface.
- Tack coat should not be applied to untreated bases. A prime coat should be used instead.

In a recent revision to the Guidelines, which is currently in draft form, Caltrans has taken the position that a tack coat can be eliminated between HMA layers placed on the same day, upon contractor request and engineer authorization, if the surface to be paved does not have a film of dust or clay that could prevent bonding and the temperature of the underlying surface is at least 65.5°C (150°F).

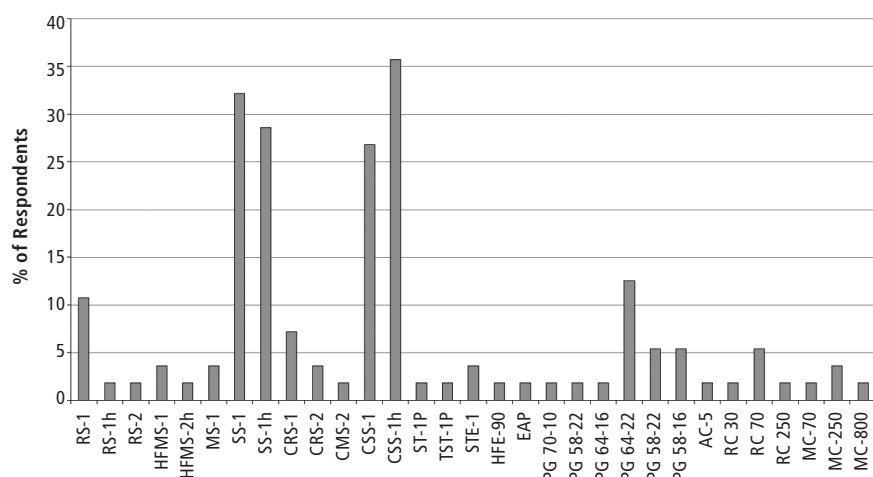
Agency Survey

The results of a comprehensive survey on the use of tack coat worldwide were presented at the Government and Industry Forum of the Association of Asphalt Paving Technologists (AAPT) in Philadelphia, Pennsylvania on April 27, 2008⁵. The survey is part of the National Cooperative Highway Research Project (NCHRP) 9-40 entitled "Optimization of Tack Coat for Hot Mix Asphalt (HMA) Placement." The following agencies responded to the survey: 46 State Departments of Transportation (DOTs), the Federal Highway Administration (FHWA), and highway agencies in Canada, Denmark, Finland, South Africa, and the Netherlands. The survey covered the use of tack coat placed: between new HMA layers; on existing HMA; on milled HMA surfaces; on surface treatments, seal coats, or chip seals; on asphalt treated bases; on Portland Cement Concrete (PCC); and on milled or diamond ground PCC.

Only 4% of the agencies responding to the survey indicated that they do not require tack coat between new HMA layers, while just 2% indicated no tack is required on existing HMA surfaces. As shown in Figures 7 through 9, the most commonly used tack coats on new, existing, and milled HMA surfaces are CSS-1h (32-34%), SS-1 (30-32%), SS-1h (29-32%), and CSS-1 (21-27%) asphalt emulsions. PG 64-22 was the most often used asphalt cement at an average of 11% and RC-70 was the most commonly used cutback (or liquid) asphalt at 5-7%. Similar use patterns were found for tack coat used on surface treatments, seal coats, or chip seals; on asphalt treated bases; and on PCC surfaces.

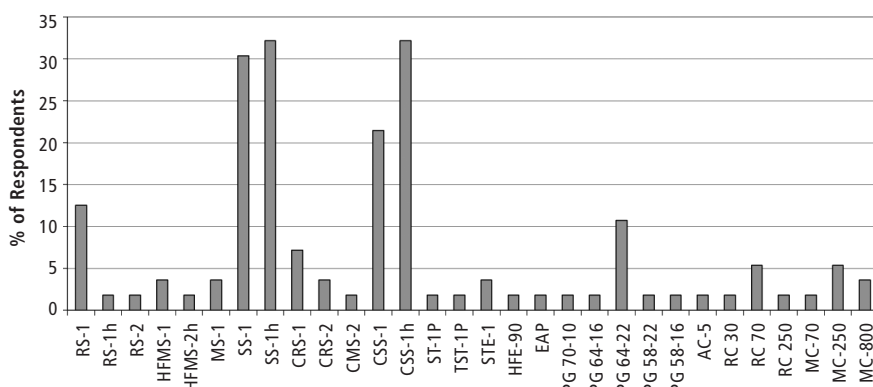
Pick up of tack coat material by construction truck tires can be a significant problem. Thirty-eight percent (38%) of the respondents to the survey indicated that the tack material should be completely set before haul trucks are allowed on it. Only 13% of respondents allow haul trucks to drive on the tack coat before it breaks.

FIGURE 7 Tack coat materials placed between new HMA layers



SOURCE: MOHAMMAD ET AL⁵

FIGURE 8 Tack coat materials placed on existing HMA



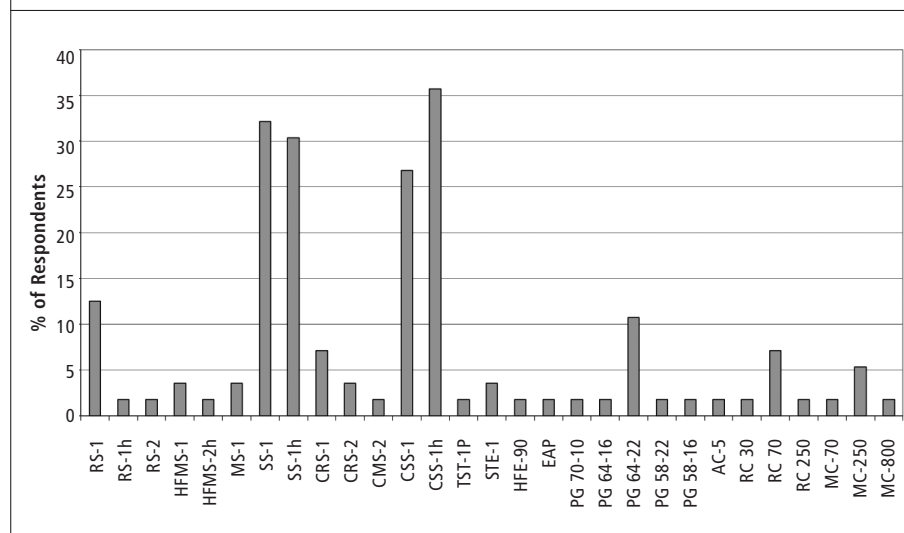
SOURCE: MOHAMMAD ET AL⁵

Some agencies require a 1- to 2-hour cure time before traffic is allowed on the tacked pavement. Research by Hachiya and Sato³ has shown that the strength of the wearing course increases as the time for the tack to break increases. For example, a 24-hour cure time produces higher bond strength between pavement layers than a

1-hour cure time. Techniques used to minimize pick up include: require the tack coat to break before haul trucks are allowed on it; clean the existing pavement surface before applying tack; and minimize the distance haul trucks are allowed to drive on the tack coat.

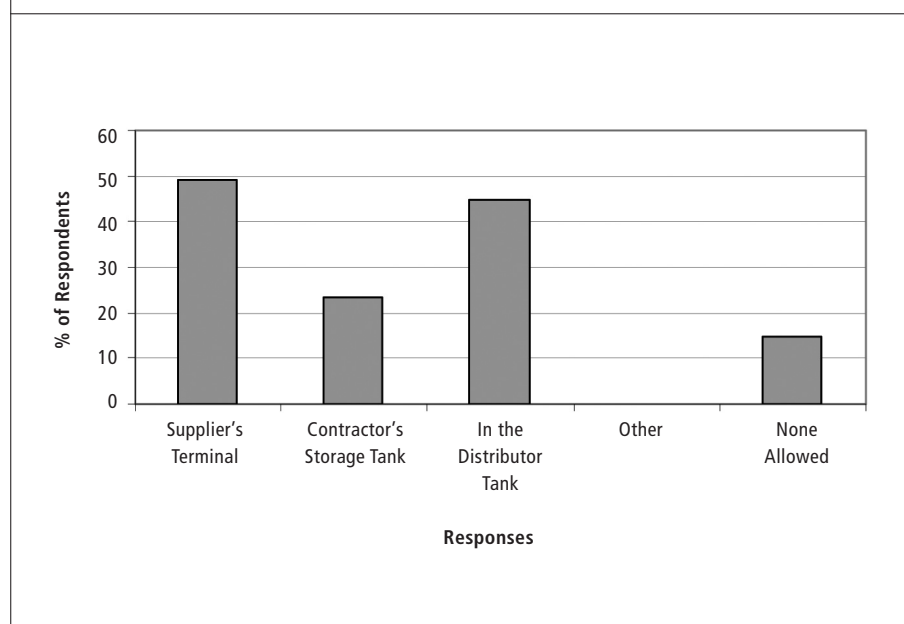
The Washington State DOT emphasizes that proper surface preparation of the existing pavement is critical to effective tack coat performance⁶. A good bond is unlikely to occur if the pavement surface is not thoroughly cleaned. The tack coat is absorbed into the debris on the roadway rather than the existing surface, resulting in pick up on the tires of haul trucks and construction equipment. Prior to applying the tack coat, brooming and vacuuming may be required to completely clean the existing surface, especially if it has been milled.

FIGURE 9 Tack coat materials placed on milled HMA surfaces



SOURCE: MOHAMMAD ET AL⁵

FIGURE 10 Potential sites for dilution of emulsified asphalt



SOURCE: MOHAMMAD ET AL⁵

Asphalt emulsions used for tack coat are often diluted with water up to a 1:1 ratio. Only 15% of those surveyed do not allow dilution of emulsified asphalt for tack. As shown in Figure 10, 49% of respondents reported that the dilution occurs at the supplier's facility, while 45% of those responding allow dilution to occur in the distributor tank. The residual application rates for most emulsions ranged from 0.03-0.05 gal/yd². Asphalt cement application rates were 0.04-0.1 gal/yd² while the range of residual rates for cutback asphalts was 0.03-0.05 gal/yd². Suggested application rates for various pavement types from the Caltrans publication on Tack Coat Guidelines⁴ are included in Table 2.

Asphalt cement rates vary from 0.01-0.07 gal/yd² depending on pavement type and condition. The application rates for undiluted asphalt emulsions, which contain approximately 60% asphalt residue, range from 0.02-0.12 gal/yd², while the rates for diluted emulsions (1:1) range from 0.04-0.24 gal/yd². Selecting the proper tack coat application rate is critical since the use of excessive tack can create a slip plane between the pavement layers or allow migration into the overlay resulting in an over-asphalted mix.

TABLE 2 Tack coat application rates

Asphalt Concrete Overlay (<i>except open graded</i>) Gallons / Square Yard			
Type of Surface to Be Tack Coated	Slow-Setting Asphaltic Emulsion	Rapid-Setting Asphaltic Emulsion	Paving Asphalt
Dense, Tight Surface (<i>e.g., between lifts</i>)	0.04 - 0.08 ^A	0.02 - 0.04 ^B	0.01 - 0.02
Open Textured or Dry, Aged Surface (<i>e.g., milled surface</i>)	0.08 - 0.20 ^A	0.04 - 0.09 ^B	0.02 - 0.06
Open-Graded Asphalt Concrete Overlay			
Type of Surface to Be Tack Coated	Slow-Setting Asphaltic Emulsion	Rapid-Setting Asphaltic Emulsion	Paving Asphalt
Dense, Tight Surface (<i>e.g., between lifts</i>)	0.06 - 0.11 ^A	0.02 - 0.06 ^B	0.01 - 0.03
Open Textured or Dry, Aged Surface (<i>e.g., milled surface</i>)	0.11 - 0.24 ^A	0.06 - 0.12 ^B	0.03 - 0.07

^A Asphaltic emulsion diluted with additional water. The water must be added and mixed with the asphaltic emulsion (which contains up to 43 percent water) so that the resulting mixture will contain one part asphaltic emulsion and not more than one part added water. The water must be added by the emulsion producer or at a facility that has the capability to mix or agitate the combined blend.

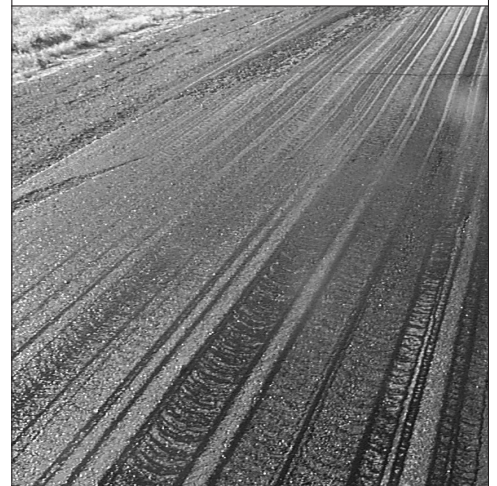
^B Undiluted asphaltic emulsion.

SOURCE: CALIFORNIA DEPARTMENT OF TRANSPORTATION⁴**FIGURE 11** Proper overlap and spray bar height

SOURCE: WASHINGTON STATE DEPARTMENT OF TRANSPORTATION

Construction Practices

Selecting the proper distributor equipment is also critical to the successful application of tack coat. For larger jobs, approved distributor trucks equipped to spray a uniform film of tack should be used. The distributor must be capable of maintaining proper temperature, pressure, and spray bar height to apply the correct tack coat rate. For asphalt emulsion tack, the temperature may range from 21°C (70°F) to 60°C (140°F) with the higher temperature being used for the more viscous materials. Asphalt cement tack coat should be applied at much higher temperatures, on the order of 140.5°C (285°F) to 176.5°C (350°F). The pressure of the tank and speed of the distributor truck need to be adjusted according to the application rate, type of tack, and type of spray bar nozzles. The angle of the nozzles and spray bar height are also important to the application process. The spray bar height may have to be adjusted throughout the day as the amount of tack in the distributor changes. An example of a good spray pattern overlap is shown in Figure 11, while Figure 12 illustrates the results of incorrect angle adjustment, spray bar height, or pressure. Trial runs should be conducted with the selected distributor equipment and all necessary adjustments made prior to the actual job.

FIGURE 12 Uneven distribution of tack coat

SOURCE: WASHINGTON STATE DEPARTMENT OF TRANSPORTATION

Recommendations

To realize a successful tack coat application, the following recommendations are offered:

- Thoroughly clean the roadway surface to be tack coated in order to increase bonding ability and to minimize pick up on the tires of haul trucks and construction equipment.
- Choose the proper application rate for the tack coat being used and existing surface conditions. Recognize that the application rates will be different for asphalt cement, asphalt emulsion, or diluted asphalt emulsion since the residual asphalt amount is different for each of these materials.
- Check to see that all distributor equipment functions are properly adjusted, including tank pressure, nozzle size and angle, spray bar height, and tack coat temperature.
- Allow the tack to break prior to paving so that the best possible bond between the layers can be obtained.

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Technology Transfer Program

- **UC Berkeley**
Institute of Transportation Studies
1301 South 46th Street
Building 155
Richmond, CA 94804
Phone: 510-665-3410
Fax: 510-665-3454
Email: techtransfer@berkeley.edu

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The University of California Pavement Research Center

- **UC Berkeley**
Institute of Transportation Studies
1353 South 46th Street
Building 452, Room 109
Richmond, CA 94804
Phone: 510-665-3411
Fax: 510-665-3562

- **UC Davis**
Department of Civil and Environmental Engineering
One Shields Avenue
Davis, CA 95616
Phone: 530-574-2216
Fax: 530-752-7872