CHAPTER 3 – REVIEW OF TECHNICAL REPORTS

PRIME COAT

There were few research reports found on the use or benefits of prime coat. The majority of the research papers found were published during the 1970s and 1980s when there were increased concerns about possible negative environmental impacts with the use of cutback asphalt primes. Only two research reports were found that were specifically related to prime coats; a total of 37 references were cited in these two reports. However, only four of those references were research studies, two relating to prime coats and two relating to tack coats.

Ishai and Livneh [(25)] performed a study to evaluate the functional and structural necessity of prime coat in a pavement structure and to evaluate the use of asphalt emulsion as a replacement for cutback asphalts. The objectives of this study were to determine if prime coat provides a significant contribution to the functional and structural performance of a pavement and to compare the performance of asphalt emulsion with cutback asphalt primes. Mantilla and Button [(11)] performed a study to develop prime coat methods and materials to replace cutback asphalt primes. The main focus of this study was the development of test procedures for evaluation of primed bases and a field and lab evaluation of different prime coat materials. The importance of the bond between base and surface courses was evaluated as well. The findings from these two studies are summarized below.

Curing

Ishai and Livneh [(25)] evaluated the liquid evaporation rates of MC-30 and MC-70 cutback, and MS-10 asphalt emulsion as a measure of cure time. Prime was applied at 0.5, 1.0, 2.0 and 3.0 kg/m^2 (0.92, 1.84, 3.68 and 5.52 lb/yd^2) to 15 cm (5.9 in) diameter tin covers and allowed to evaporate or cure at 25^{o}C (77^{o}F). The amount of liquid lost was determined by weighing daily over a seven-day period. The results at 1.0 kg/m^2 (1.84 lb/yd^2), the amount typically used, are reproduced in Figure 7 [(25)].

As can be seen in Figure 7, the MS-10 asphalt emulsion had a higher liquid evaporation rate than either cutback asphalt. The authors reported that the asphalt emulsion lost about 70 percent of its liquid (mainly water) after one day of curing and up to 90 percent after two days of curing. After one day of curing, the MC-70 and MC-30 cutbacks lost 27 and 15 percent, respectively, of its liquid, mainly kerosene. After seven days of exposure, the MC-70 lost 58 percent and the MC-30 lost 40 percent of its liquid. The authors concluded that under standard curing condition of three days, the MS-10 asphalt emulsion loses almost all of its liquid whereas most of the liquid (kerosene) remains in the cutback prime. The laying of HMA within a period shorter than three days after priming with cutback may cause about 55 to 85 percent of the kerosene of the prime to be trapped in the base. This trapping may lead to detrimental effects from the direct contact between the kerosene and its vapors and the asphalt concrete layer above it.

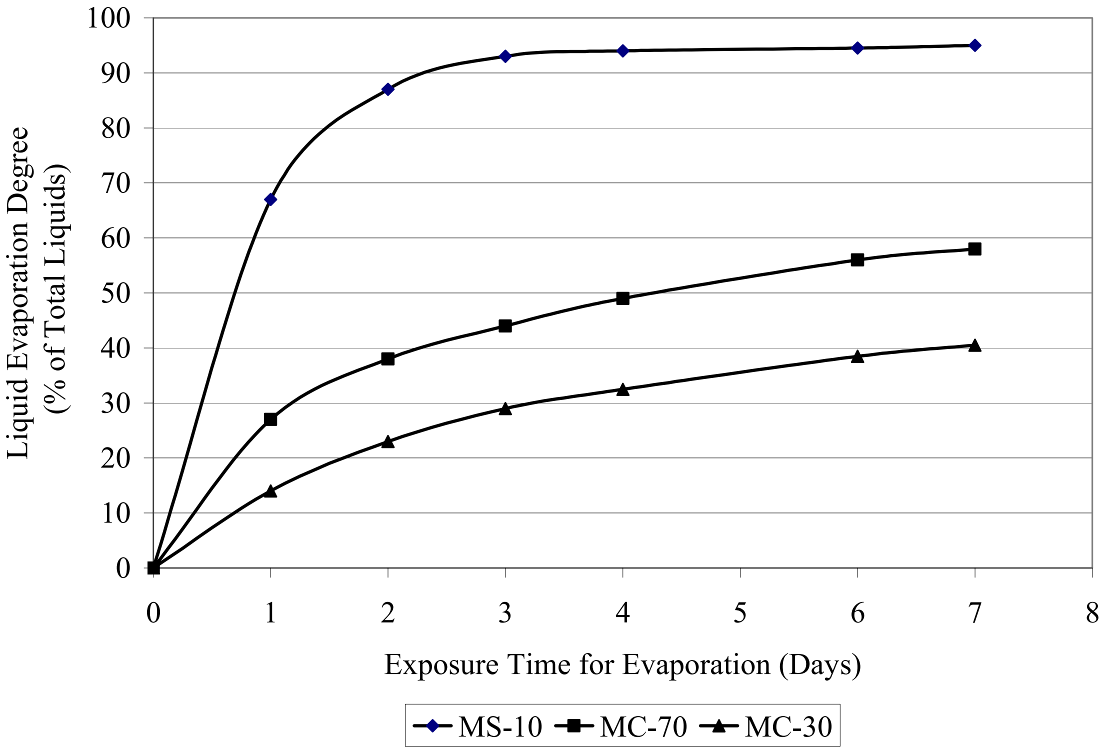

Figure 7. Graph. Liquid evaporation with exposure period at 1.0 kg/m^2 application rate.

Penetration

Mantilla and Button [11] evaluated the penetration depth of various prime materials. The authors compared the penetration of two MC-30 cutbacks, two asphalt emulsion primes (AE-P), penetrating emulsion prime (PEP) and emulsified petroleum resin (EPR-1) in base material compacted at different moisture contents. The maximum penetration obtained 24 hours after application for some of the materials tested are reproduced in Figure 8 [11]. A minimum penetration depth of 5 mm (0.2 in) was considered necessary for adequate performance. As shown in Figure 8, all materials met the minimum 5 mm (0.2 in) penetration depth except the EPR-1. None of the materials evaluated penetrated as deep as the two MC-30 cutbacks. The authors reported that conventional emulsified asphalts did not adequately penetrate most compacted bases. Dilution with water helped penetration but did not provide acceptable penetration [11].

Ishai and Livneh evaluated penetration in their study as well. Their results are reproduced in graphical form in Figure 9 [25]. The authors reported that higher values of penetration were obtained with cutbacks than asphalt emulsions but that the penetration depths with the asphalt emulsion were satisfactory and were of a similar order of magnitude [25].

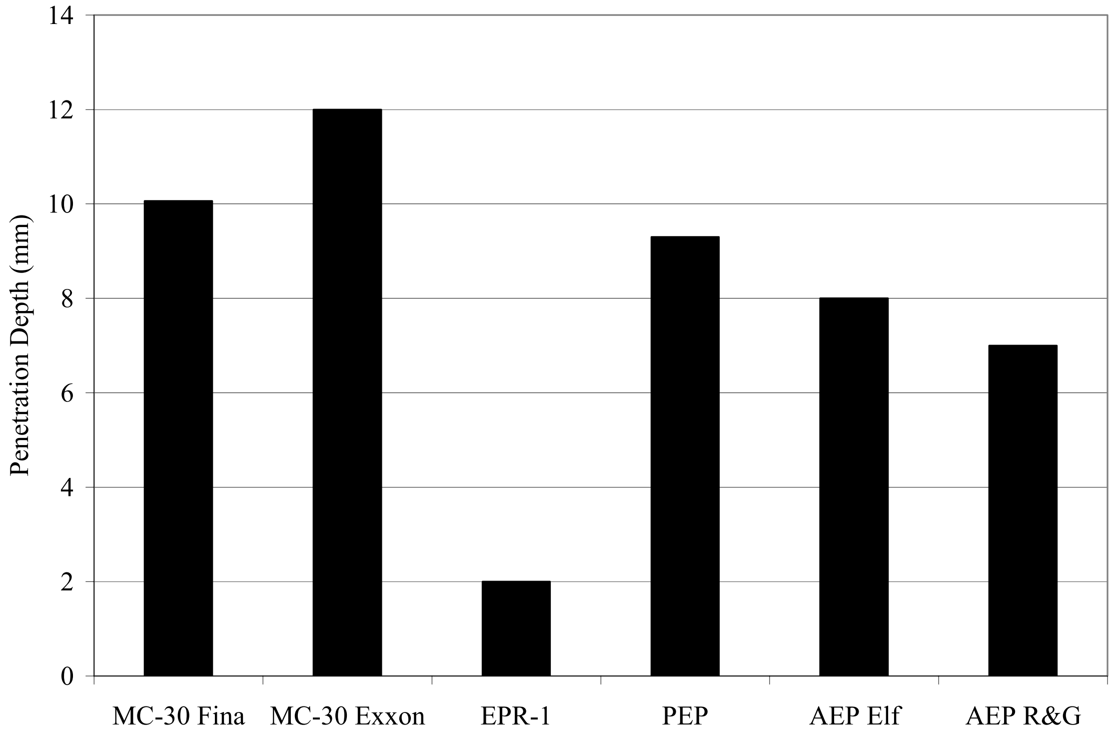

Figure 8. Graph. Penetration depth achieved by various primes after 24-hour cure.

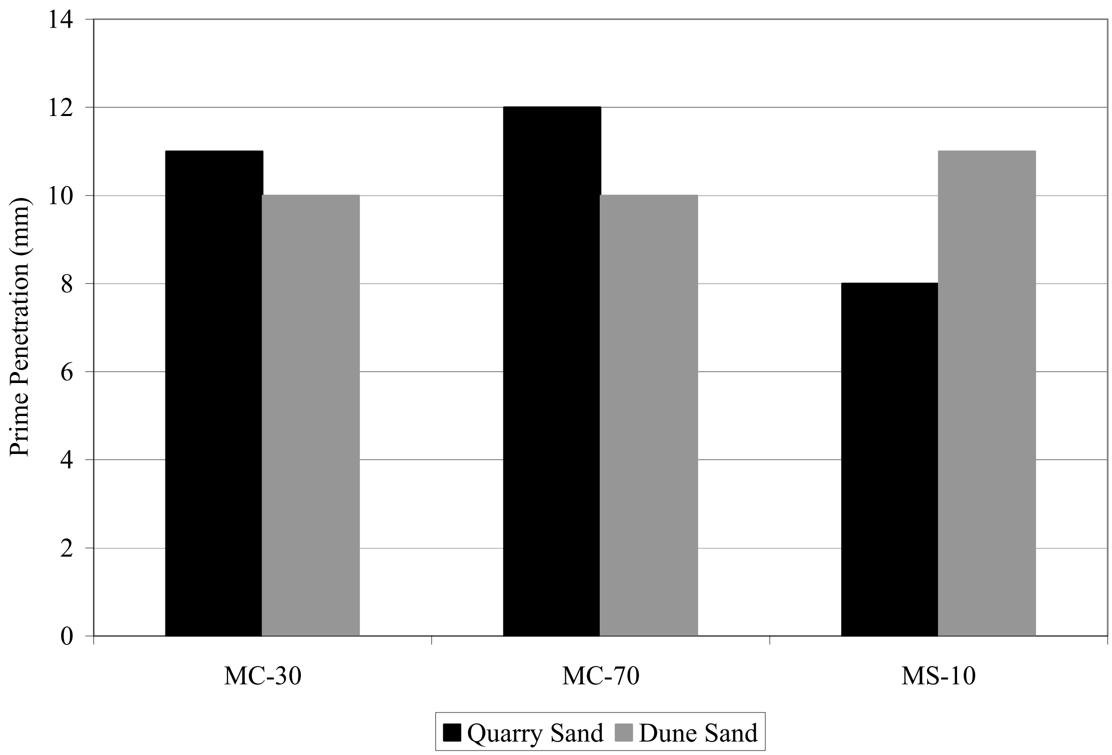

Figure 9. Graph. Average prime penetration into compacted sand samples.

To further evaluate penetration and curing, Ishai and Livneh [(25)] evaluated the penetration resistance of samples of primed, compacted dune sand for unconfined compressive strength using a pocket penetrometer. Their results are shown in Figure 10. The authors reported that the MC-70 cutback did not gain any significant strength during the first 10 days of curing and only minor strength gain during the next 10 days. Significant early strengthening and accelerated strength gain with time were reported in the asphalt emulsion samples. The results were reported to be in good agreement with their curing data [(25)].

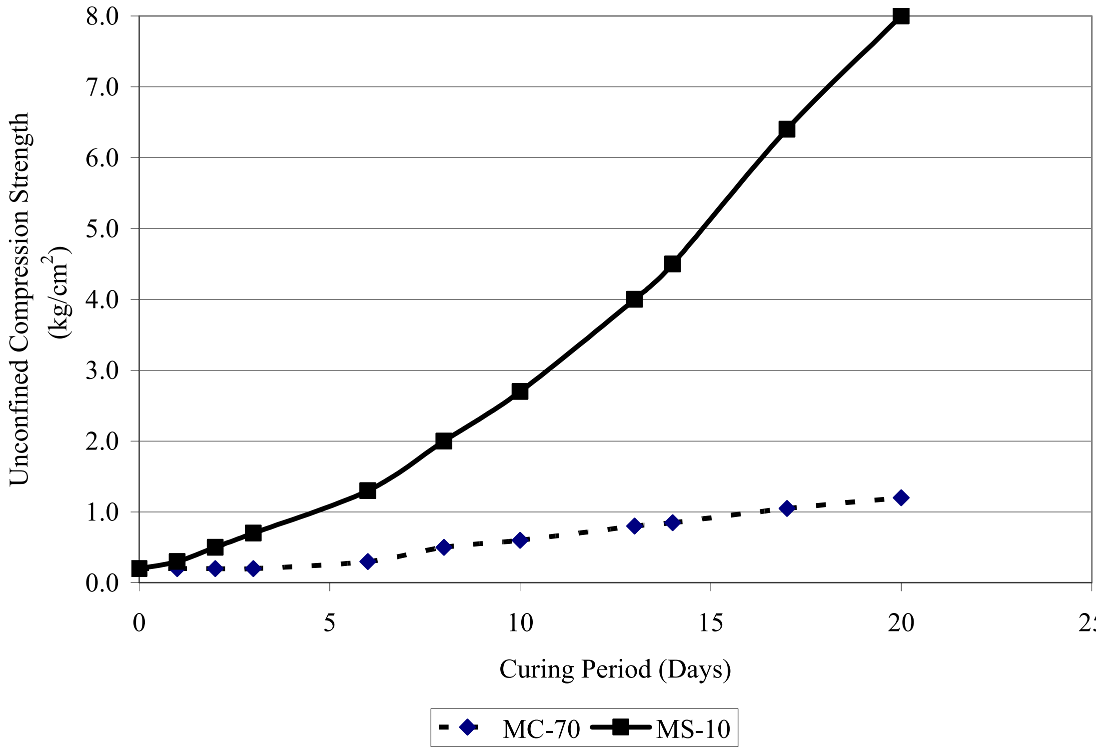

Figure 10. Graph. Relationship between unconfined compression strength of primed, compacted dune sand and curing period [(25)].

Interface Shear Strength

Direct Shear

Both Ishai and Livneh [(25)] and Mantilla and Button [(11)] reported on the direct shear strength of the interface of primed aggregate base and an HMA surface. The results from Ishai and Livneh's study [(25)] are shown in Figure 11. The authors reported that the results clearly demonstrate the superiority of asphalt emulsion prime, with respect to interfacial adhesion, over cutback primed and unprimed surfaces and of the significant role of an adequately specified prime coat [(25)].

Mantilla and Button [(11)] performed direct shear tests on primed samples of aggregate base. Application rates were reported as 1.1 L/m^2 (0.25 gal/yd^2) and a chip seal was placed between the primed base and HMA layer. The prime was allowed to cure for 24 hours at 40°C (104°F) prior to placement of the seal coat. The seal coat was cured for 24 hours at ambient temperatures prior to placing the HMA layer. The results are reproduced in graphical form in Figure 12 [(11)]. The authors reported that MC-30 cutback and AEP samples performed better than unprimed samples and that PEP and low volatile organic compound (LVOC-1) prime performed similarly to the unprimed samples [(11)].

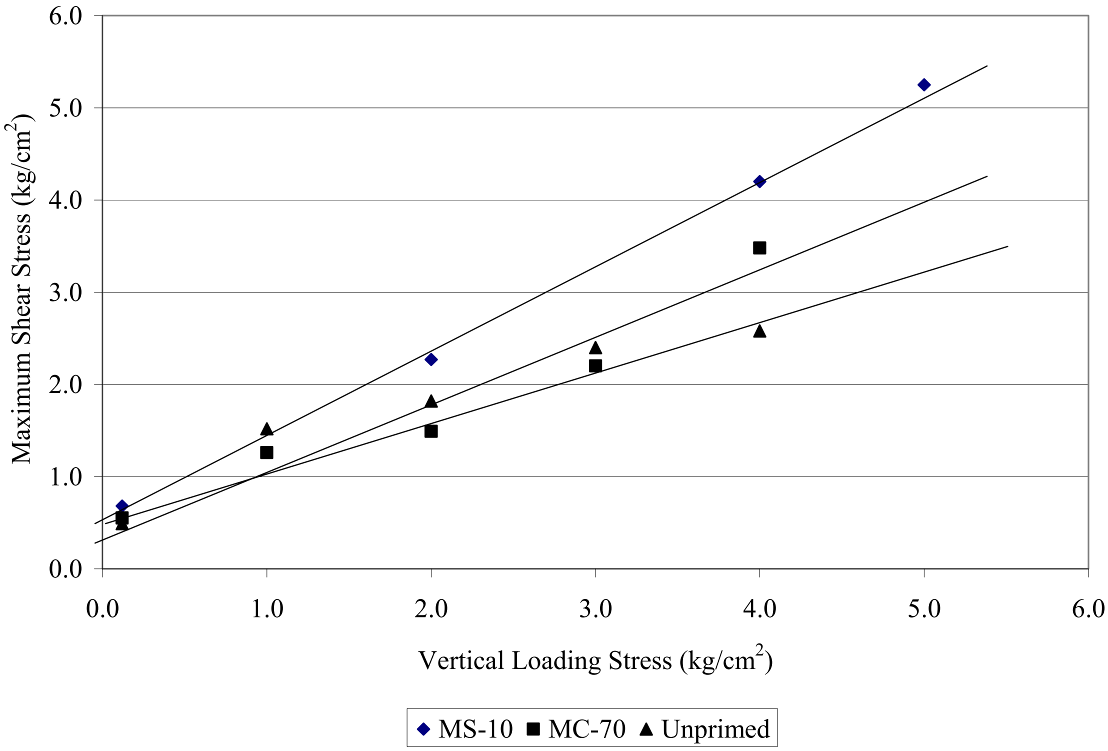

Figure 11. Graph. Maximum shear stress vs. vertical loading stress for compacted crushed-gravel base courses as tested in direct shear test [(25)].

The authors repeated the testing with dust placed between the prime and the seal coat. Some difficulty was reported with the test procedures and limited results were available. However, the authors reported that primed samples had higher shear strengths than unprimed samples when the primed surface was not adequately cleaned [(11)].

Torsional Shear

Mantilla and Button [(11)] determined the torsional shear strength of the primed base interface. The results are reproduced in Figure 13. Although the torsional shear strengths for the different primes evaluated were reported as not being statistically significant, the authors reported that at high normal static stresses, there was little difference between prime coat materials. At lower levels, unprimed samples yielded the lowest torsion shear strength and MC-30, AEP and EPR-1 yielded the highest values [(11)].

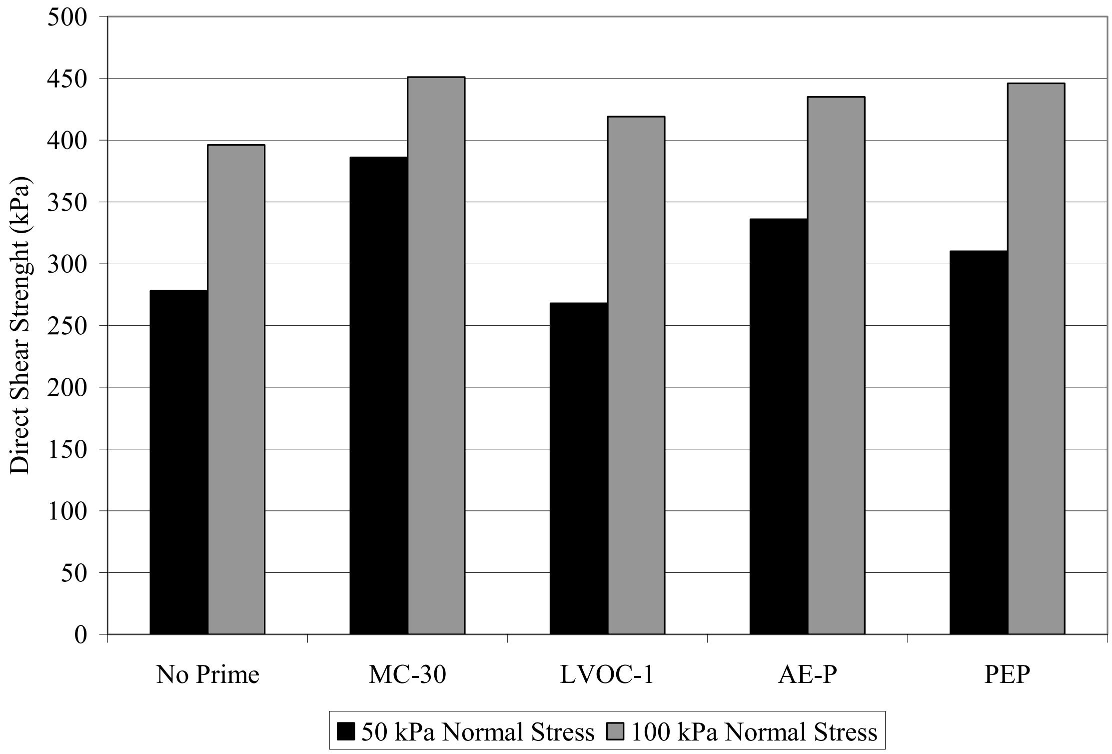

Figure 12. Graph. Direct shear strength for various prime coat materials.

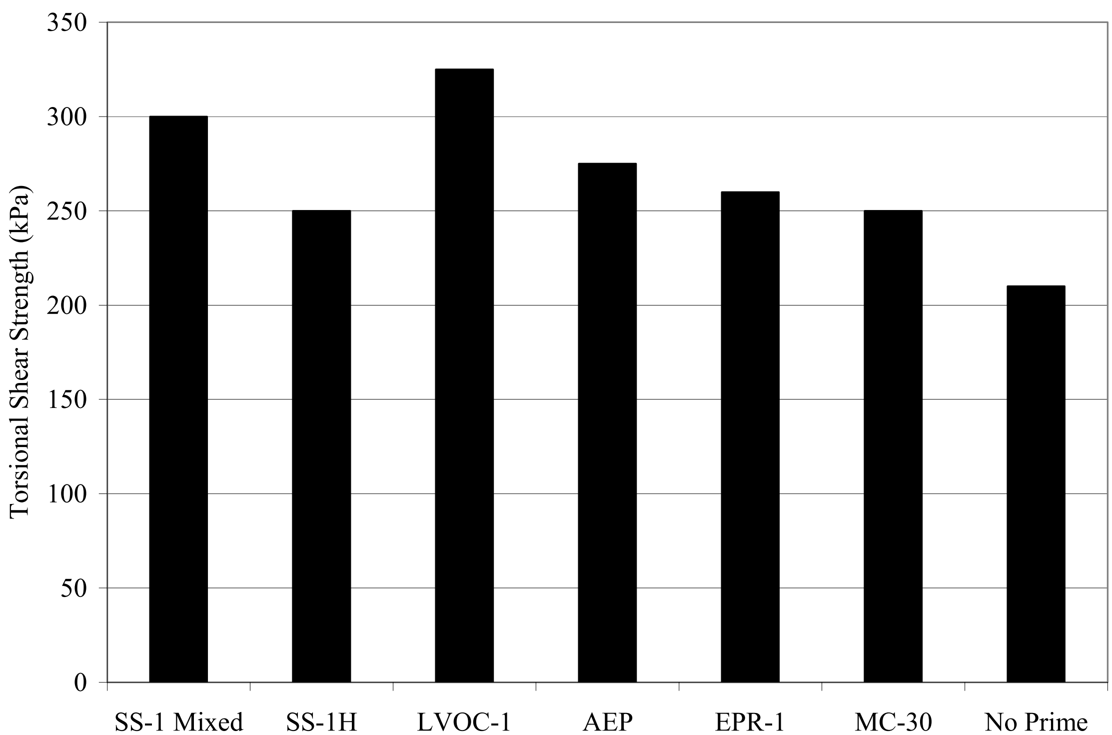

Figure 13. Graph. Torsional shear strength of the interface between the base and the bituminous layer at a normal stress of 410 kPa for different prime materials on limestone base [11].

Need For Prime Coat

Mantilla and Button [11] reported that granular bases should always be primed before application of surface treatments or an asphalt pavement of less than 76 mm (3 in) and that granular base should be primed if construction delays of subsequent layers allow damaged due to weather and/or traffic. Prime is not necessary if the base is asphalt stabilized or if the asphalt pavement is 100 mm (4 in) thick [11]. Ishai and Livneh [25] concluded that the cost/benefit ratio of prime coat is positive when properly formulated asphalt emulsion prime is applied and the benefit/cost ratio of cutback priming should be negative since no functional or structural improvement of the base and adjacent HMA were observed in their study.

TACK COAT

A comprehensive review of literature regarding tack coat was performed. There were 13 papers found, excluding the handbooks reviewed in Chapter 2, which were directly related to tack coat application and performance.

Mechanics of Layer Slippage

Van Dam et al. [26], in a report for the Federal Aviation Administration, and Shahin et al., in two separate journal articles [27,28], reported on the effects of layer slippage on pavement behavior using various mechanistic models. The authors reported that even a slight slippage of an overlay causes a redistribution of stresses and strains within a pavement. Layer slippage of the overlay was reported to cause large tensile strains to occur at the bottom of the overlay rather than at the bottom of the bound layer. The HMA at either side of the slipped surface distorts in different directions, propagating the slipped layer and further destroying the bond between the layers. If slippage has occurred, horizontal loads could only be supported by the slipped layer and the fatigue life of the pavement could become a function of the fatigue life of the overlay only, greatly reducing the fatigue life of the entire pavement [26,27,28].

Uzan et al. [29] used mathematical analysis to show that stress distributions at layer interfaces are affected by interface conditions and that a weak interface bond between pavement layers could result in crescent-shaped cracks in the surface. Hachiya and Sato [30] demonstrated through mechanistic analysis that layer slippage or separation can occur if shear stresses at the interface exceed their shear strength.

Consequences of Layer Slippage

Van Dam et al. [26] reported that a lack of bond between layers in an asphalt pavement shortens the pavement life so drastically that adequate steps should be taken during construction to ensure bonding. Shahin et al. [27,28] has reported that a pavement with a slipped overlay would require removal and replacement rather than a second overlay due to the excessive thickness of additional overlay required to keep the tensile strains below acceptable levels. Dunston et al. [31] reported that inadequate tack coat, perhaps through removal by construction traffic, contributed to tearing of an HMA mat during compaction.

Interface Shear Strength

Factors That Affect Laboratory Test Results

Several papers were found through the literature search where researchers evaluated the influence of tack coat on interface shear strength of HMA layers. The results from these studies provide conflicting conclusions as to the effect of tack coat on interface shear strength. The majority of the testing reported was performed using either custom fabricated devices or devices adapted from other test procedures. The effect of the ruggedness or repeatability of many of these custom fabricated devices is unknown. The variability in test methods and testing conditions makes evaluating the influence of tack on interface shear strength problematic.

Several factors were reported in the literature as having an influence on measured interface shear strength. Magnitude of the normal force (29,30,32), rate of shear (29,30,33) and test temperature (29,30,32,33,34,35,36) were all shown to have an effect on interface shear strength.

Normal Force:

The magnitude of the applied normal force in a direct shear test has an effect on the results. Uzan et al. (29) reported that the higher the applied normal force, the higher the shear strength at failure. Figure 14 shows the effect of applied normal force on interface shear strength for samples with various tack coat application rates tested at 25°C (77°F).

Romanoschi and Metcalf (32) reported that normal force did not have a significant effect on shear strength for tacked interfaces but did have a significant effect on untacked surfaces. The researchers reported that an increase in normal stress would increase the contact area of the interface, thus increasing the interface shear strength. With a tack coat, the researchers reported that interface voids are filled with the tack coat so the increase in normal stress does not increase the contact surface (32).

Rate of Shear:

The rate of shear has an effect on shear strength with increased rate of shear resulting in increased shear strength (29,30,33). A typical relationship between rate of shear and shear strength is shown in Figure 15 (30).

Test Temperature:

The temperature of the test sample at failure had an effect on shear strength. Shear strength results are also a function of joint construction type or interface condition. For similar interface condition, increased test temperature resulted in reduced interface shear strength (29,30,32,33,34,35,36). Crispino et al. (36) evaluated a new dynamic test apparatus to test layer strength. They reported that test temperature had a considerable effect on shear strength, affecting the viscous-elastic properties of the tack coat binder and of the asphalt concrete. Figure 16 shows the typical effect of test temperature on interface shear strength.

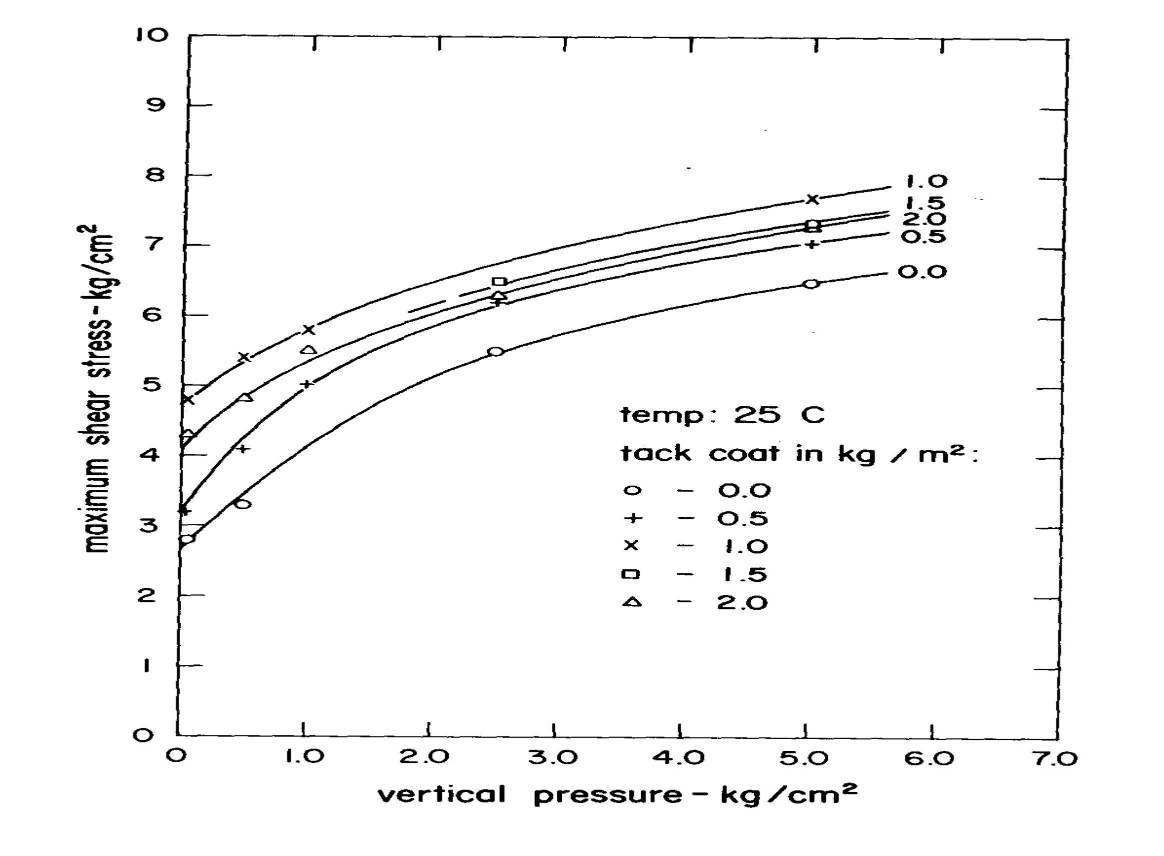

Figure 14. Graph. Maximum shear stress vs. vertical pressure at 25° C (29).

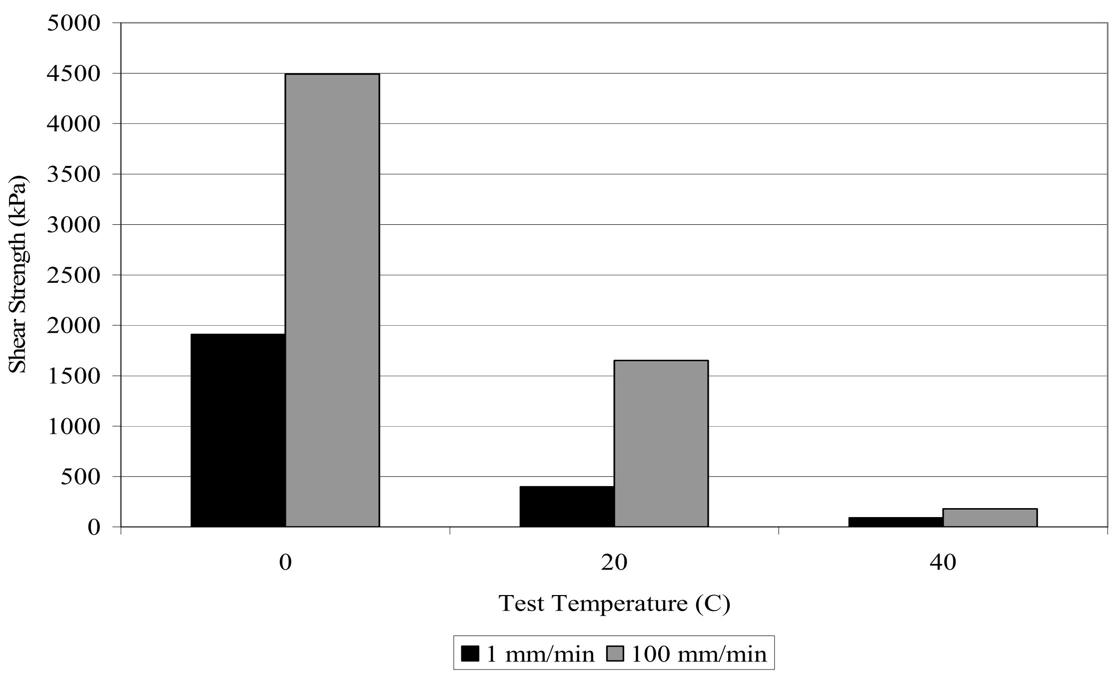

Figure 15. Graph. Rate of shear vs. direct shear strength.

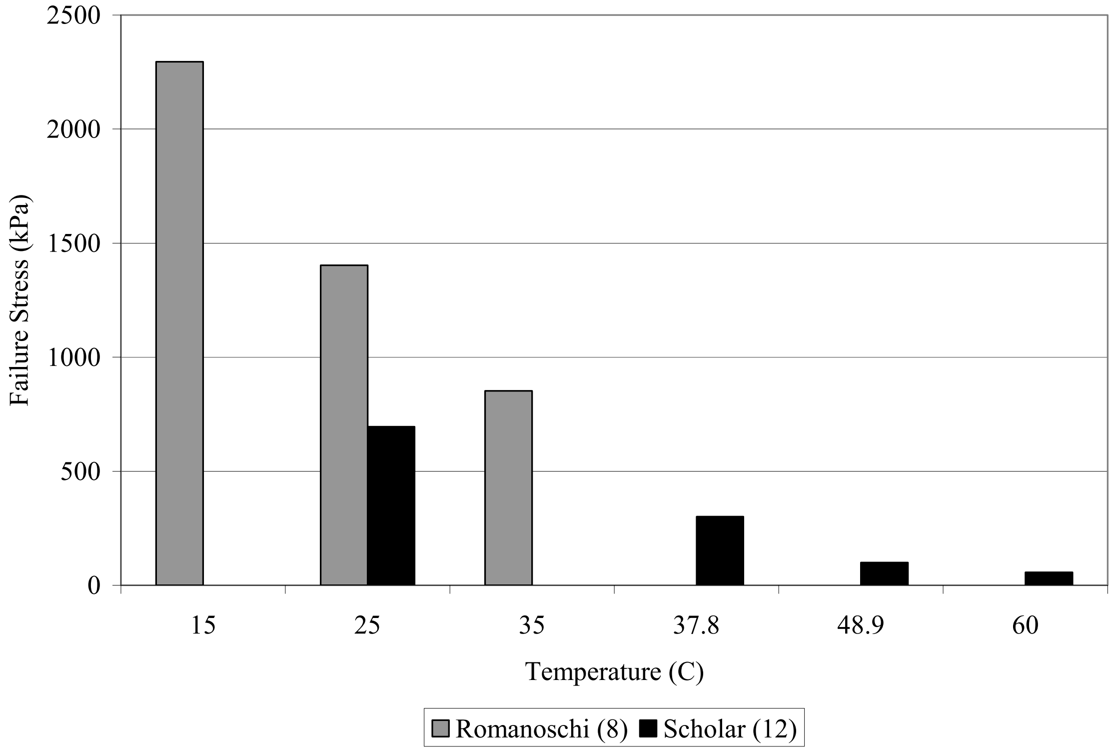

Figure 16. Graph. Effect of test temperature on interface shear strength.

Hachiya and Sato [(30)] evaluated the effect of joint construction method and test temperature on interface shear strength. The researchers evaluated four different joint conditions; hot joint, cold joint, tacked joint and monolithic joint construction. For the hot joint, the upper layer was compacted when the temperature of the lower layer dropped to 60°C (140°F). The results, shown in Figure 17, indicate that increased test temperature results in decreased interface shear strength. The effect was most dramatic for the cold joint samples [(30)].

Type of Joint Construction

The results of shear strength tests found in the literature were a function of joint construction and surface condition. Paul and Scherocman [(37)] reported that almost all state DOTs used tack coat before laying a new asphalt layer over an old existing asphalt layer. However, the review of the handbooks and results from the phone survey indicated that some agencies were deleting tack between new lifts of HMA.

One of the more comprehensive studies performed on tack coat was by Hachiya and Sato [(30)] where they evaluated the effect of tack coat on bonding characteristics at the interface between HMA layers. The researchers used emulsified asphalt for tack coat to provide the bond between two asphalt layers and evaluated the bond strength using tension and flexural tests. The researchers compared four joint construction types, monolithic, hot joint, tacked and cold joint.

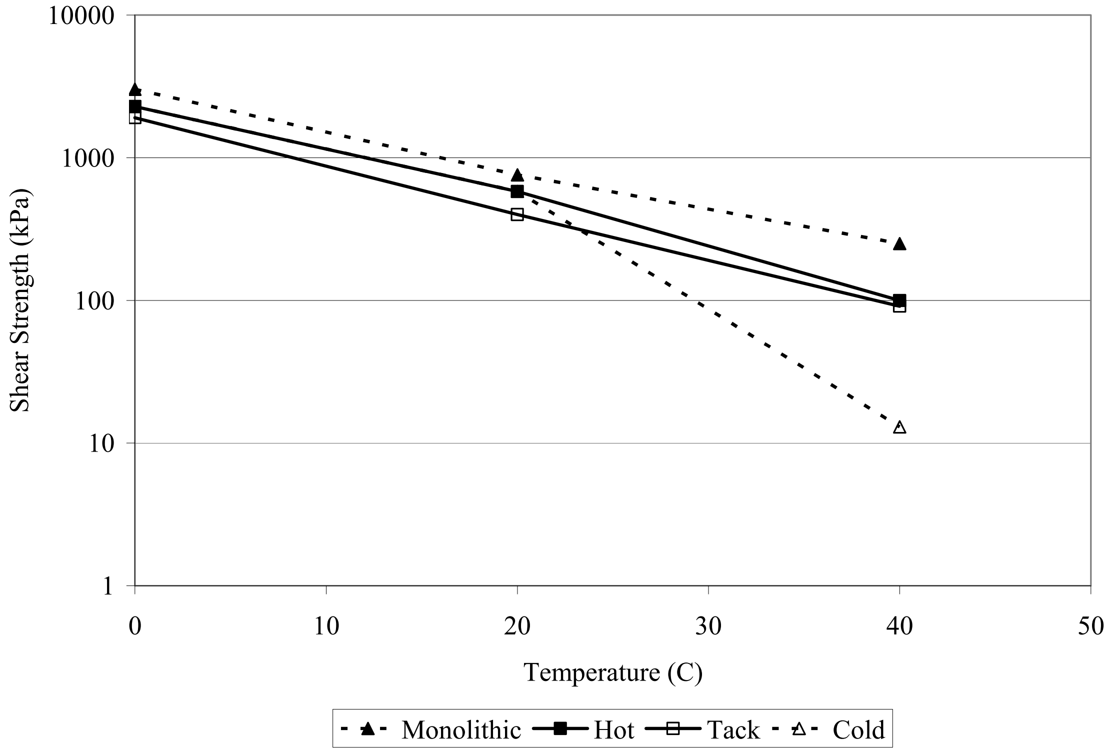

Figure 17. Graph. Shear strength at 1 mm/min vs. various joint construction procedures [30].

For monolithic construction, a 100-mm (4 in) thick layer was constructed in one lift. In hot joint construction, the upper layer was constructed when the lower layer temperature dropped to 60° C (140°F) while the cold joint construction was constructed at ambient temperature. In tack coat construction, 0.4 L/m^2 (0.09 gal/yd^2) of tack coat was spread over the lower layer and the upper layer was constructed after curing the tack for 24 hours. The tests were conducted at 0° C, 20° C and 40° C (32°F, 68°F and 104°F), at a loading rate of 1 and 100 mm/min (0.04 and 4 in/min) [30].

The shear strength results for these four construction joints, at a rate of shear of 1 mm/min (0.04 in/min), were shown in Figure 17. The test results for 100 mm/min (4 in/min) rate of shear are shown in Figure 18. From the plots, it can be seen that monolithic construction has the highest shear strength at any temperature range, followed by hot joint. The shear strength of tacked construction joints was lower than cold joints during low and intermediate temperatures. As the temperature increased above 20°C (68°F), the shear strength of the cold joint decreased rapidly. At 40° C (104°F) shear strength of the tack coated joint, at a loading rate of both 1 mm/min (0.04 in/min) and 100 mm/min (4 in/min), was 8 and 3 times greater than that of cold joint, respectively [30]. Mohammad et al. [35] also reported that flexible pavements constructed in multiple layers using optimum application of CRS 2P as the tack coat produce only 83% of the monolithic mixture shear strength. Other joint construction methods were not reported.

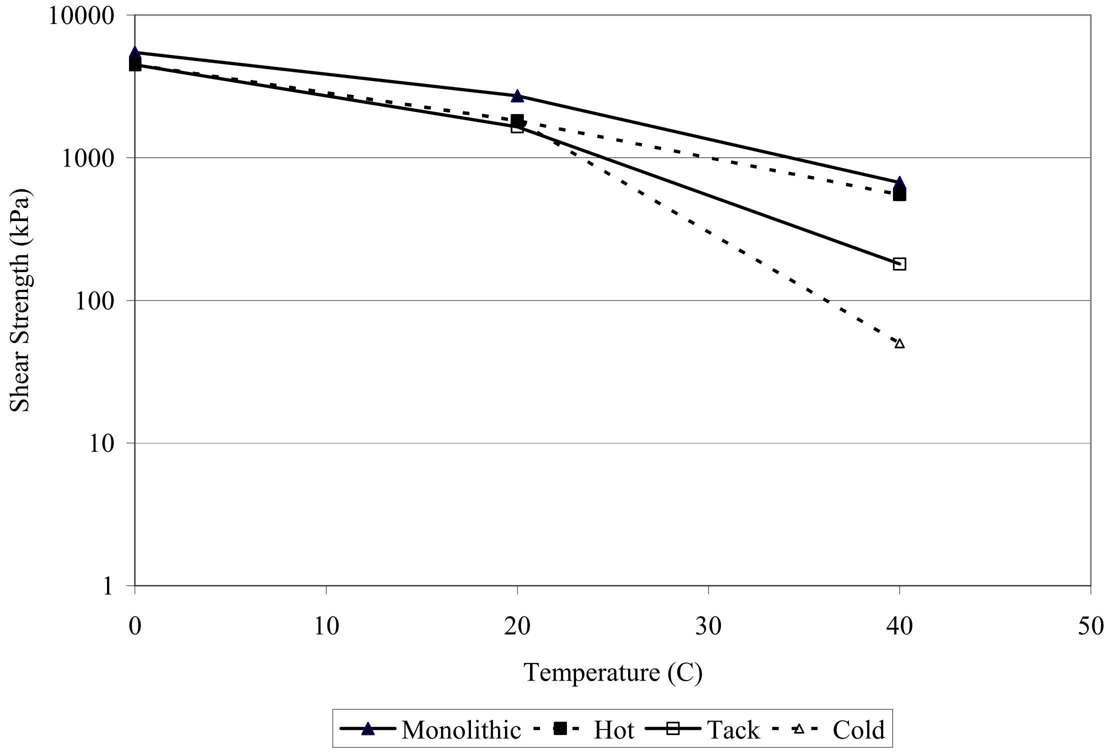

Figure 18. Graph. Shear strength at 100 mm/min vs. various joint construction procedures [(30)].

Romanoschi and Metcalf [(32)] conducted research to analyze the characteristics of HMA layer interfaces. Three parameters were identified by the researcher to describe interface behavior. They were interface reaction modulus (K), shear strength (S_{max}) and friction coefficient after failure (μ). Core samples were obtained from the Louisiana Research Facility site from areas with a 0.1 L/m^2 (0.02 gal/yd^2) tack coat and from areas without tack coat. Results from Romanoschi and Metcalf's direct shear testing at a normal force of 276 kPa (40 psi) are shown in Figure 19 [(32)]. The researchers reported that shear strength (S_{max}) was higher in samples with tack coat than samples without tack coat. Similarly, shear strength of both samples (with and without tack coat) was affected by temperature [(32)].

Mrawira and Damude [(38)] evaluated interface shear strength using a test apparatus adapted from ASTM D 143 for testing shear strength in wood. The shear strength was evaluated using tack versus no tack samples of new HMA compacted on top of existing pavement cores. The tack coat was an SS-1 asphalt emulsion applied at a rate of 0.2 to 0.3 L/m^2 (0.04 to 0.07 gal/yd^2). The results are shown in Figure 20.

Mrawira and Damube reported that non tacked overlays seem to exhibit slightly higher ultimate shear strength compared with tack coated overlays. The difference was reported as not statistically significant. The tests were performed after soaking the samples in a water bath at 22±1^{o}C (71.6±1.8^{o}F) for 30 minutes [(38)].

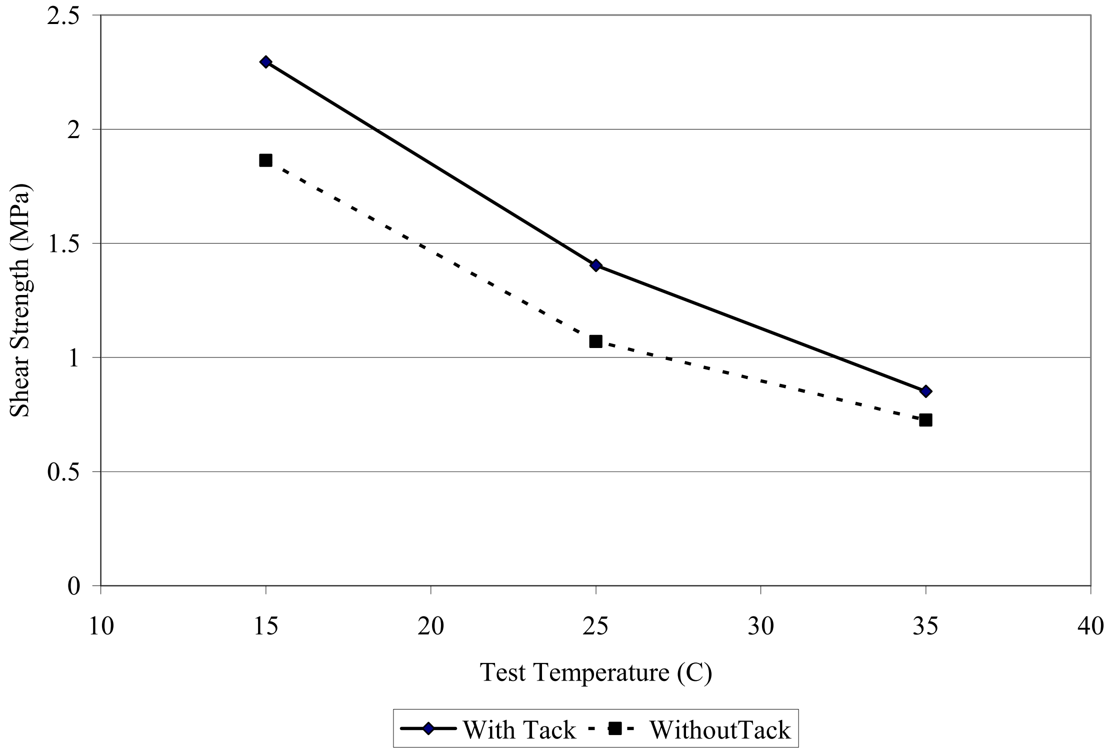

Figure 19. Graph. Effect of tack coat on direct shear strength.

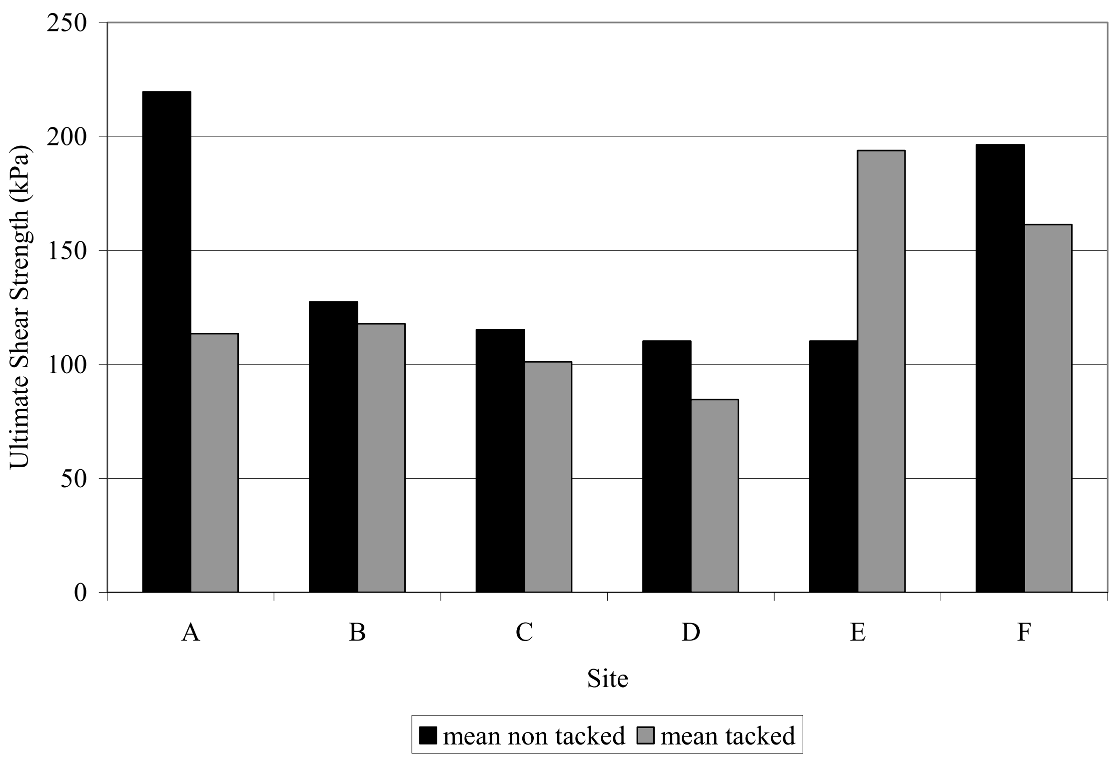

Figure 20. Graph. Comparison of mean ultimate shear strength of tack coated and non tack coated overlays [(38)].

Uzan et al. (29) performed direct shear tests on samples having a 1.0 kg/m^2 (1.84 lb/yd^2) tack coat of 60-70 penetration asphalt cement. Tests were performed at 25°C (77°F) and 55°C (131°F) at normal stress levels of 0.05, 0.5, 1.0, 2.5 and 5.0 kg/cm^2 (0.7, 7.1, 14.2, 35.5 and 71.1 psi). The results are shown in Figures 21 and 22. Samples with tack coat had higher shear strength than samples without tack, regardless of test temperature or normal stress level (29).

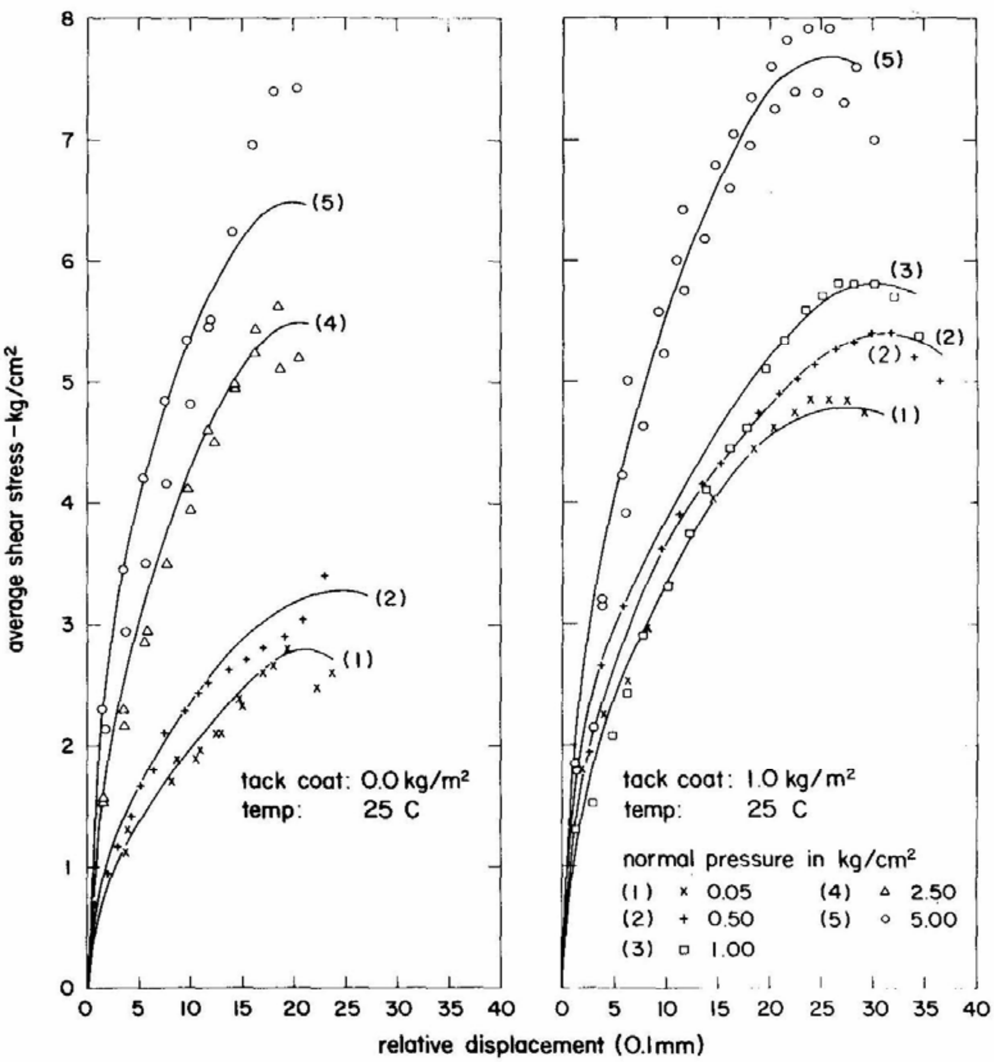

Figure 21. Graph. Shear test results at 25°C (29).

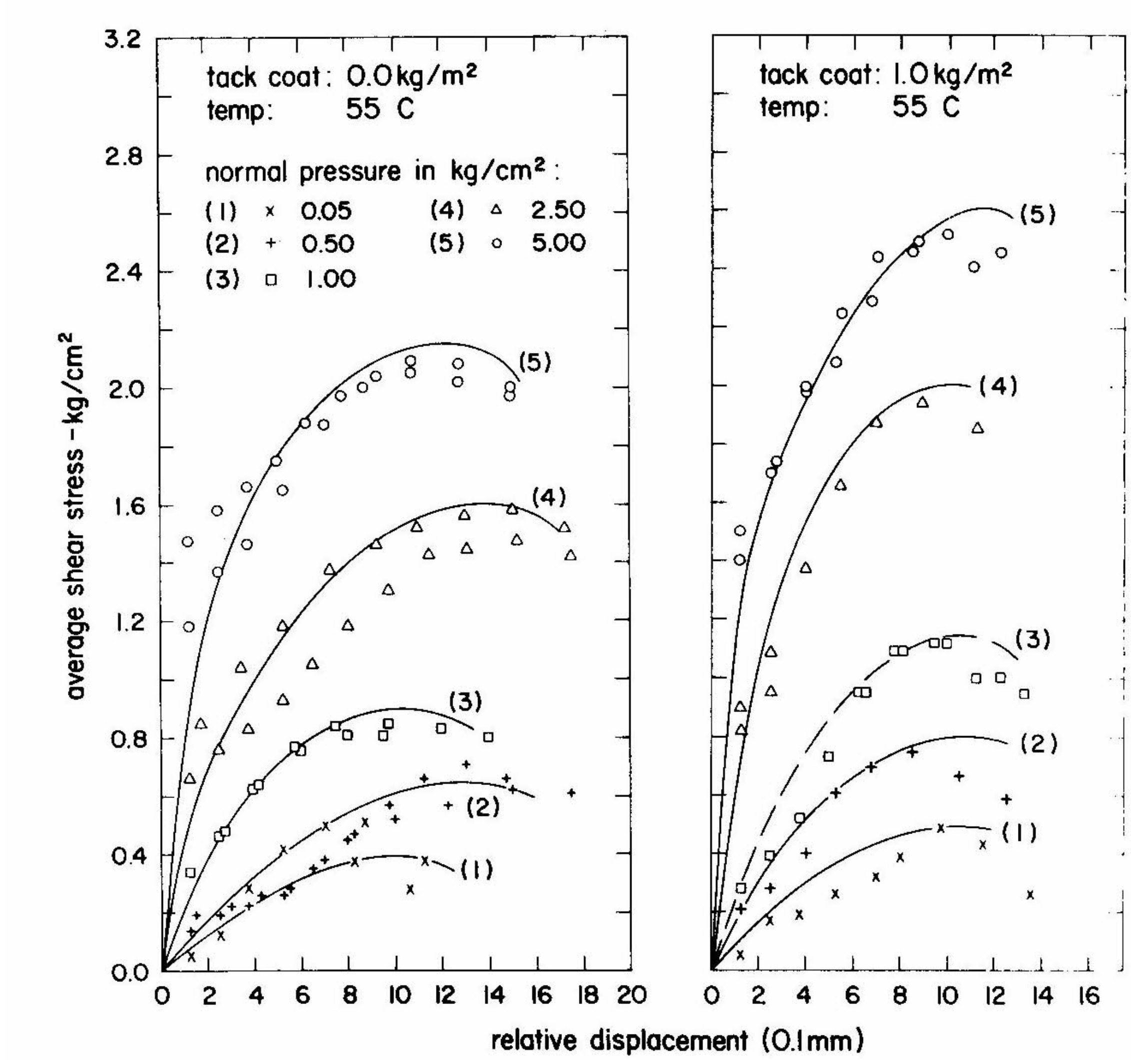

Figure 22. Graph. Shear test results at 55°C (29).

Sholar et al. (33) evaluated direct shear strength of tack coat from field cores. The tests were performed at 25°C (77°F) and at a rate of loading of 50.8 mm/min (2 in/min). The field cores were obtained from test sections with no tack and the minimum, midpoint and maximum Florida DOT specified tack coat application rate. Milled as well as conventional overlay sections were evaluated. The lower application rate of 0.091 L/m^2 (0.02 gal/yd^2) was reported to have slightly higher direct shear strength than the no tack section, for sections with a fine 12.5 mm (0.5 in) Superpave mixture. For test projects consisting of a coarse graded 12.5 mm (0.5 in) Superpave mixture, the benefits of tack were less noticeable. For the milled interface project, tack coat was reported as not being effective in increasing interface shear strength (33).

Materials

Paul and Scherocman (37) surveyed the 50 state DOTs and the District of Columbia about their tack coat practices. Based on 43 survey responses, they reported that almost all states used slow-set asphalt emulsions for tack. Only Georgia was reported to use hot asphalt (37). Cooley (39) reported on an experimental procedure where millings were used as tack coat material. In a mill and overlay project, the fine millings remaining on the pavement were not swept off the milled surface prior to overlay. The heat from the asphalt overlay was sufficient to melt the fine millings left on the surface and provided sufficient tackiness to bond the overlay to the existing milled surface. Preliminary finding indicated that the procedure was successful (39). Follow-up reports are not available at this time.

A more comprehensive study of the effectiveness of tack coat materials was performed by Mohammed et al. (35) where they evaluated simple shear strength of two types of performance graded asphalt cements (PG 64-22 and PG 76-22) and four types of emulsified asphalts (CRS-2P, SS-1, CSS-1, and SS-1h). Simple shear strength was determined using the Superpave Shear Test (SST) at a constant rate of shear of 222.5 N/min (50 lb/min). The researchers reported that at a test temperature of 55°C (131°F), there was no significant difference in simple shear strength between the tack materials evaluated. At a test temperature of 25°C (77°F), CRS-2P had significantly higher shear strength than the other tack materials (35). Typical test results at optimum application rate, which corresponds to maximum shear strength, are shown in Figure 23. The authors reported that test results with the same letter indicate no significant difference in simple shear strength.

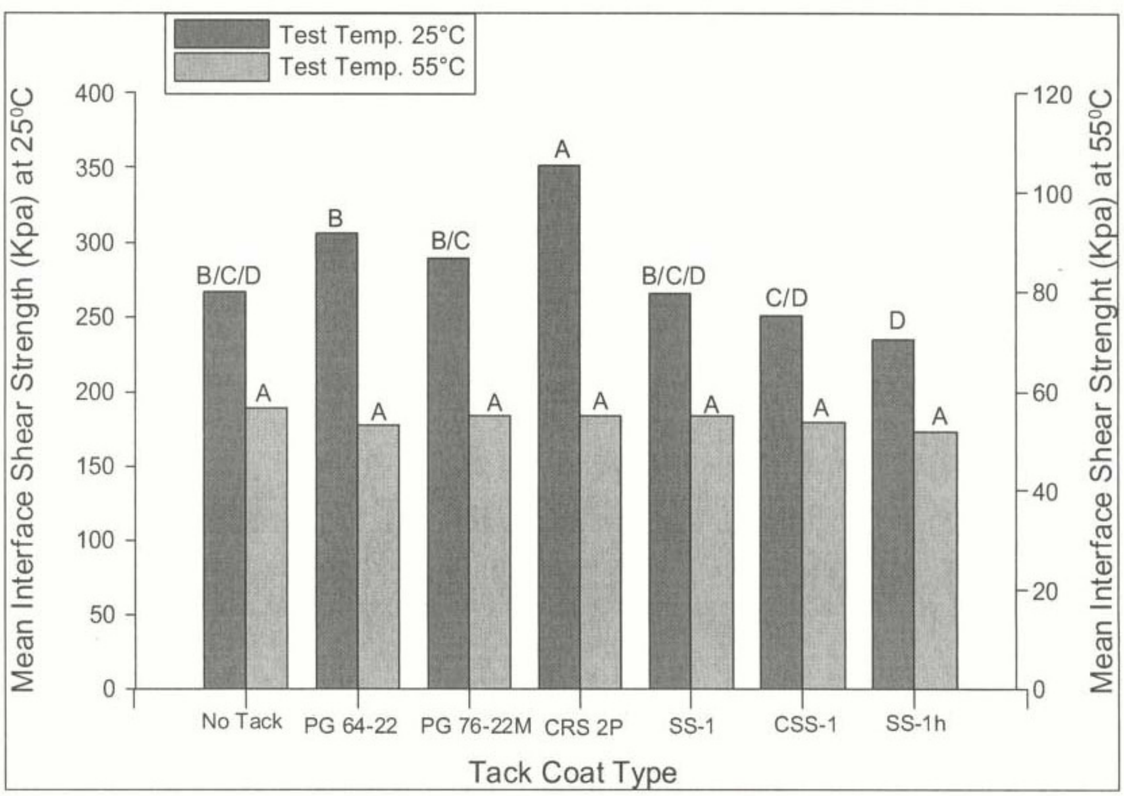

Figure 23. Graph. Mean shear strength vs. tack coat type (35).

Mohammad et al. (35), Crispino et al. (36), and Tschegg et al. (34) all reported on the influence of tack coat binder viscosity on interface shear strength. All reported that the higher the viscosity of the tack coat binder, the higher the interface shear strength.

Application Rate

Paul and Scherocman [37] conducted a survey of tack coat practices. From their survey of state DOT materials engineers, they reported that the residual application rate of tack coat typically varies from 0.06 to 0.26 L/m^2 (0.01 to 0.06 gal/yd^2). Different application rates were used depending on the type of surface.

One of the more comprehensive studies on application rates was by Mohammad et al. [35]. The researchers evaluated the use of tack coats through laboratory simple shear strength testing using the SST at a constant rate of shear of 222.5 N/min (50 lb/min) to determine the optimum application rate. Two types of performance graded asphalt cement and four asphalt emulsions were used. The application rates, based on residual asphalt content, were 0.00, 0.09, 0.23, 0.45 and 0.9 L/m^2 (0.00, 0.02, 0.05, 0.10 and 0.20 gal/yd^2). The tests were conducted at 25°C (77°F) and 55°C (131°F).

Mohammad et al. [35] found that the best tack performer was CRS-2P emulsion with an application rate of 0.09 L/ m^2 (0.02 gal/ yd^2). At the lower test temperature, an increase in tack coat application rate resulted in a decrease in interface shear strength. However, at a higher temperature, shear strength was not sensitive to application rate [35]. Their results for CRS-2P and SS-1h are shown in Figures 24 and 25, respectively.

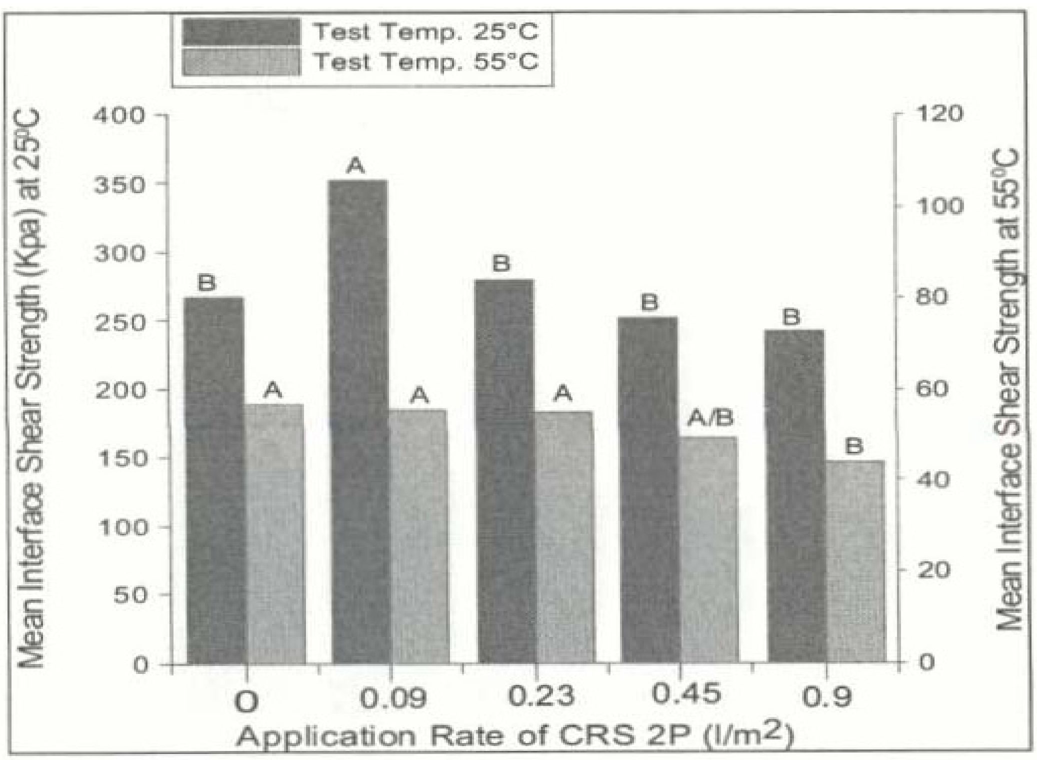

Figure 24. Graph. Interface shear strength with varying application rates of CRS 2P [35].

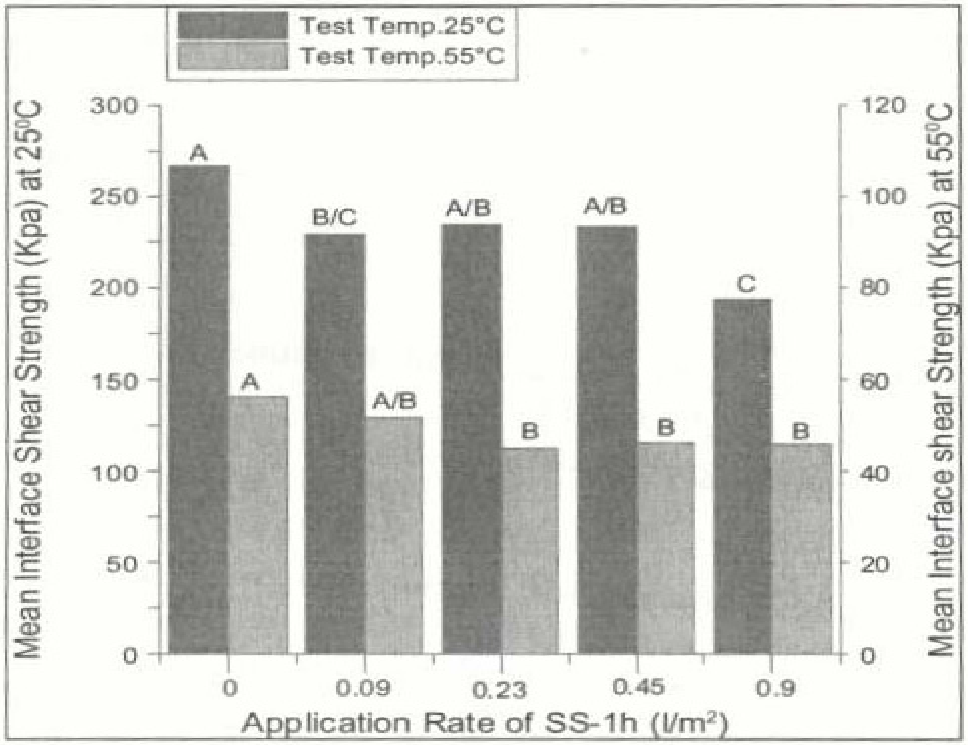

Figure 25. Graph. Interface shear strength with varying application rates of SS-1h (35).

Uzan et al. (29) reported that high application rates of tack results in an increased film thickness of bitumen, resulting in decreased adhesion and interlocking resistance. Results from their study are shown in Figure 26. The researchers concluded there is an optimal amount of tack coat at which the shear resistance is maximum, but the influence of tack coat rate on shear resistance of fresh HMA is slight (29).

Sholar et al. (33) evaluated application rates of tack coat from field cores using direct shear. The tests were performed at 25°C (77°F) at a rate of loading of 50.8 mm/min (2.0 in/min). Three application rates were evaluated; the minimum, midpoint and maximum Florida DOT specified application rates, 0.091, 0.226 and 0.362 L/m^2 (0.02, 0.05 and 0.08 gal/yd^2), respectively. The application rate was reported to have a slight effect on shear strength. Shear strengths were slightly higher at higher application rates. As weeks passed, shear strengths were reported to equalize, regardless of application rate (33).

Weather

Sholar et al. (33) evaluated the effect of rain falling on a cured tack coat prior to application of the HMA overlay. The direct shear strength was determined from field cores tested at 25°C (77°F). Partial test results from the US-90 project are shown in Figure 27. The authors concluded that water applied to the surface of tack coat, to represent rain water, reduced shear strength when compared to equivalent sections without water applied. As weeks passed, shear strength of both sections increased, but the rain water sections never reached the strength of the sections without water. Sections with higher application rates, 0.362 L/m^2 (0.08 gal/yd^2) performed better than sections with lower application rates, 0.091 L/m^2 (0.08 gal/yd^2).

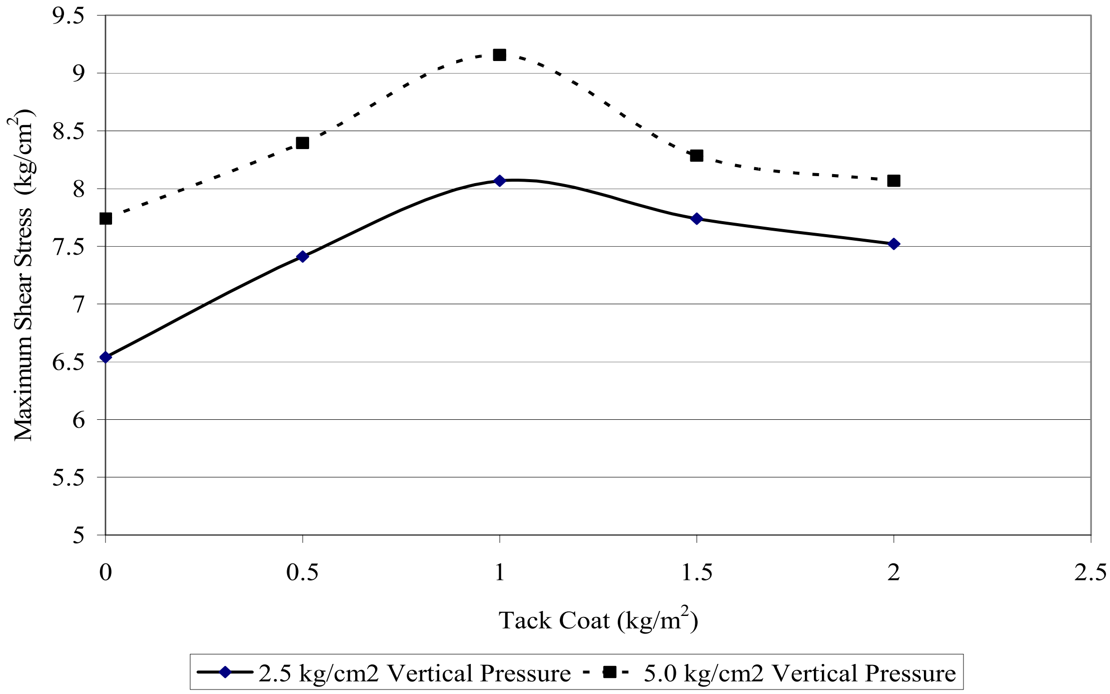

Figure 26. Graph. Tack coat application rate vs. maximum shear stress.

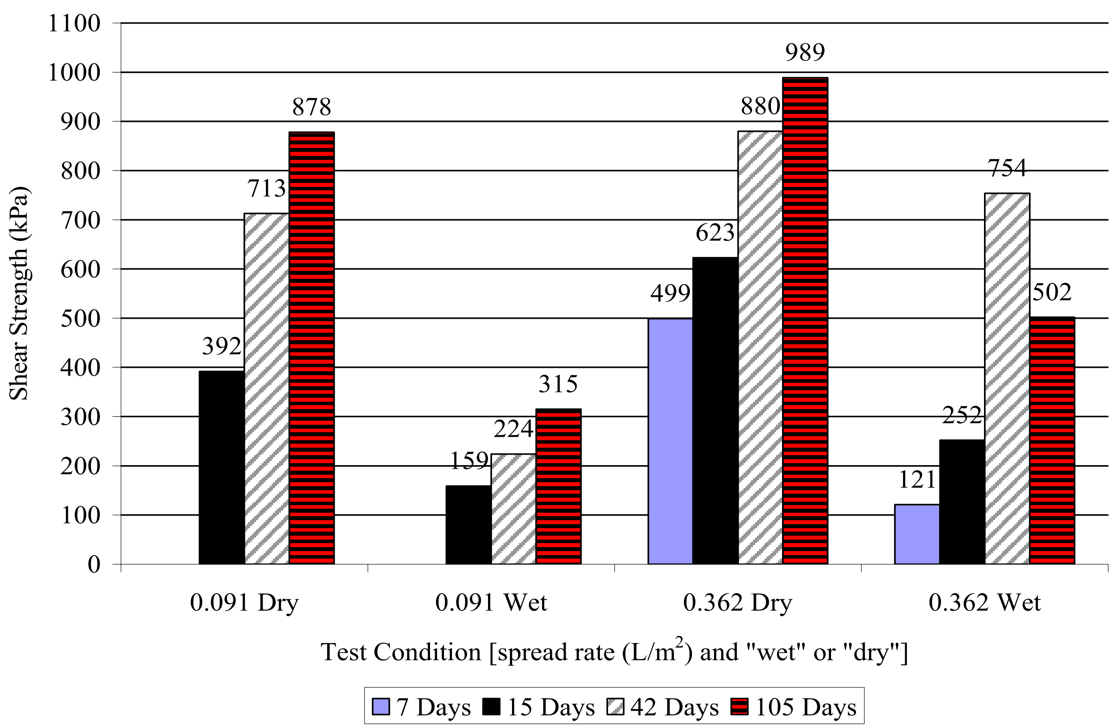

Figure 27. Graph. Shear strength test data for US-90 project [33].

Curing

Paul and Scherocman [37] found from their survey of state DOTs on tack coat practices that cure time between tack coat application and paving was typically after the asphalt emulsion had broken. They also reported that tack coat materials exposed for more than 24 hours were required to be retacked.

Sholar et al. [33] evaluated the effect of cure time on direct shear strength of tack coat from field core samples. The tests were performed at 25°C (77°F) at a rate of loading of 50.8 mm/min (2.0 in/min). Tack coat application rates included no tack and the minimum, midpoint and maximum Florida DOT specified application rates, 0.091, 0.226 and 0.362 L/m^2 (0.02, 0.05 and 0.08 gal/yd^2), respectively. Cure times were up to 100 days. Typical results are shown in Figure 28. The researchers concluded that shear strength increased slightly with time and that shear strength equalized with time, regardless of application rate [33].

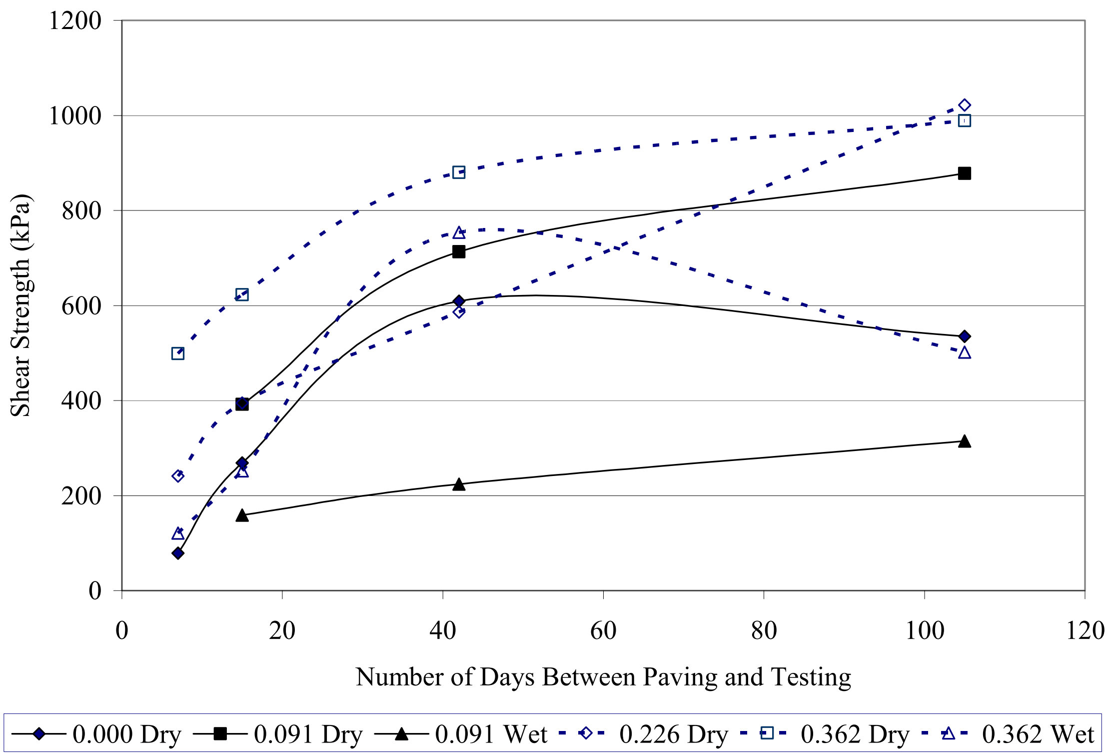

Figure 28. Graph. Shear strength test data vs. time for US-90 project [33].

Hachiya and Sato [30] evaluated the importance of curing tack coat. The researchers measured the change of mass of emulsified asphalt after being exposed to the environment. At an application rate of 0.2 L/m^2 (0.04 gal/yd^2) and laboratory exposure conditions, the mass of an emulsified asphalt tack coat decreased to a nearly constant value after six hours. For an application rate of 0.4 and 0.6 L/m^2 (0.09 and 0.13 gal/yd^2) the mass did not become constant, even after 24 hours of curing. The study also compared the evaporation process between indoor (laboratory) and outdoor conditions at an application rate of 0.4 L/m^2 (0.09 gal/yd^2). When the emulsion was exposed in a natural outdoor environment, the mass of emulsified asphalt became constant after one hour. The difference in weather (fine or cloudy) did not influence the process significantly [30].

Another important finding of Hachiya and Sato's research was the influence of dirt on tack coat strength. The authors reported that dirt did not influence the strength of interface bond if the curing was conducted fully, as there was little reported difference in interface strength [30].

SUMMARY

Prime Coat

Based on the review of research data and reports, the following conclusions are warranted:

1. Prime coat increased the bond strength at the interface between a compacted base and asphalt layer over that of no prime coat. The reported differences were not always statistically significant.
2. At higher static normal stresses, shear strength at the interface is not appreciably affected by the type or even the presence of a prime coat.
3. Medium cure cutback asphalts penetrated deeper than conventional emulsified asphalts. Dilution of emulsified asphalts with water helped penetration but did not provide acceptable penetration.
4. Some emulsified asphalt primes were essentially emulsified asphalt cutbacks and were no less polluting than medium cure cutback asphalts.

Tack Coat

1. A loss of bond between HMA layers can cause crescent shaped slippage cracks or debonding to occur, leading to reduced pavement life.
2. Many factors were shown to affect laboratory interface shear strength, including rate of shear, magnitude of normal force, temperature and joint construction.
3. Monolithic construction provided the highest shear strength followed by hot joint construction. Neither of these construction methods is always feasible.
4. In a few studies, tacked surfaces were shown to have slightly lower interface shear strengths than untacked surfaces. However, in these studies the statistical significance of the difference in interface shear strength was not reported. In reports where the statistical significance of the differences in interface shear strength was evaluated, tacked interfaces were either stronger or not significantly different from untacked interfaces.
5. The higher the viscosity of the bituminous binder in the tack the higher the reported interface shear strength.
6. At typically specified application rates, application rate had little effect on interface shear strength. Higher than typically recommended application rates resulted in slightly lower interface shear strengths.