THE UNIVERSITY OF TEXAS AT AUSTIN ✦ COCKRELL SCHOOL OF ENGINEERING

TEXAS PAVEMENT PRESERVATION CENTER

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Our Mission

The mission of the TPPC, in joint collaboration with the Center for Transportation Research (CTR) of the University of Texas at Austin and the Texas Transportation Institute (TTI) of Texas A&M University, is to promote the use of pavement preservation strategies to provide the highest level of service to the traveling public at the lowest cost. The executive sponsor for the TPPC is the Texas Department of Transportation (TxDOT).

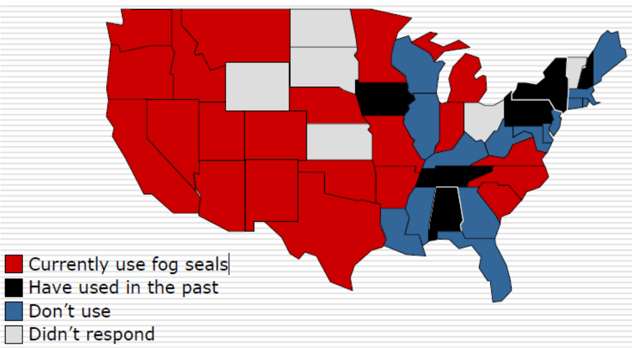
Next Issue: Summer 2013

The Transportation Research Board's (TRB) 92nd Annual Meeting attracted nearly 12,000 transportation professionals from around the world to Washington, DC January 13-17, 2013. The TRB Annual Meeting consisted of over 4,000 presentations in nearly 650 sessions. Summaries of selected seminar papers related to pavement preservation will be included in this upcoming newsletter.

The Transportation Research Board is a division of the National Research Council, which serves as an independent adviser to the federal government and others on scientific and technical questions of national importance. TRB's mission is to promote innovation and progress in transportation through research.

Fog Seals

Highway agencies are facing increasing demands to maintain and preserve their road networks. Historically, agencies have focused on new construction of roadways, however the focus has been shifting towards finding better methods of preserving existing roadways from distress caused by traffic. Preservation techniques allow for a more economically efficient way of extending the life of roadways. Pavement conditions deteriorate with time and preventative maintenance practices are designed to stall the formation of significant distress and ensure a low life-cycle cost. Fog seals have been utilized as a cost effective method of preventative maintenance in Texas and many other states in varying degrees for several years. Fog seals are designed to provided a layer of asphalt coat to help protect the existing asphalt binder. They are specifically intended for delaying weathering and providing a waterproof layer to keep water from penetrating into the subgrade of a pavement structure.



Fog Seal Usage by State

Fog seals have been used for pavement preservation purposes for many years. Fog seals are referred to as enrichment treatments since fresh asphalt is added to an aged surface to lengthen the pavement surface life. Fog seals, sometimes called flush coats, are also used in some seal coat applications successfully to hold the aggregate in place in a fresh seal coat. This method is intended to reduce windshield damage to cars on the roadways due to flying rocks.

What is a Fog Seal

Fog seals are a light application of a slow-setting, water diluted asphalt emulsion which is applied directly to an existing pavement surface in spray form. Fog seals are intended to seal the pavement, lengthen the pavement surface life by enriching hardened or oxidized asphalt, provide some pavement edge-shoulder delineation, and prevent raveling. Fog seals are also used during seal coat applications as a flush coat.

Unlike other spray application treatments, fog seals require no aggregate cover. Because no aggregate is used, the emulsion rate is kept very low to guard against tackiness and major decrease in skid resistance. Emulsion application rates usually range from 0.45 to 1.00 L/m2, but vary depending on pavement texture, local conditions, and traffic.

Shoulder Fog Seal

Dilution allows for better control of fog seal application rates. There are various concentrations of fog seal emulsion, some as low as one part emulsion to five parts water. However, in most cases, a one to one dilution ratio is used. The grades of asphalt emulsion usually used in fog seals are SS-1, SS-1h, CSS-1, or CSS-1h. A spraying temperature of 21˚C to 60˚C and surface temperature of 15˚C or above is recommended for this type of sealing.

In order for fog seals to work properly, they should only be used on sufficiently porous surfaces that are capable of absorbing a substantial amount of emulsion. Furthermore, fog seal use is restricted on heavily trafficked roads as the pavement friction may be reduced until traffic wears some of the asphalt from the surface. It may, however, be used on both low- and relatively high-volume roads, as long as the initial low friction values do not present a risk. Harsh weather conditions can hinder road use after an application of fog seal. Despite minor obstacles such as the above, a fog seal is a temporary but cost-effective pavement preservation treatment.

Fog Seal Uses

Fog seals are used as a method to deter surface aging, and a method to hold aggregate in place. Thus, they are intended to treat raveled and aged roads. However, sometimes there is no way to determine to what extent the pavement has deteriorated and if it is qualified for a fog seal treatment. Also, different asphalts will age at different rates. At present, engineers are relying largely on visual inspection to determine appropriate candidates for fog sealing.

Fog seals can realize their expected effect only when proper penetration can be achieved. That makes aged and raveled hot mix surfaces, chip-sealed surfaces, and open graded asphalt surfaces proper candidates for fog sealing.
Fog seals have three main goals: prevention of raveling, preservation and protection of road conditions, and sealing and treatment of cracking or surface defects. The first, prevention of raveling, appears frequently on high-volume roads. On a high-volume road, fog seal use is limited because the spray application may reduce friction. Therefore, the primary use of fog seal on heavily trafficked roads has been restricted to prevention of raveling on open-graded friction courses. Raveling, or aggregate loss, could

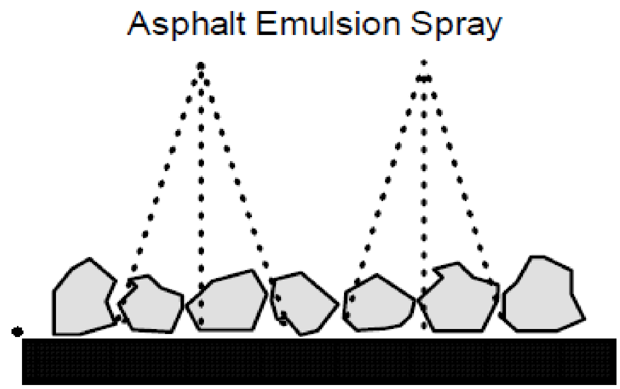
be inhibited or reduced when fog seal is used as a flush coat. Flush coats, formed by combining fog seal with a sand blotter coat, keep aggregate in place during seal coating to prevent future aggregate loss. Similarly, fog seals protect hot mix asphalt or chip seals on low-volume roads. Currently, eleven states use fog seal to protect open graded friction courses from raveling.

Seal Coat Four Years after Construction
Left Lane = No Fog Seal
Right Lane = With Fog Seal

The second main function of a fog seal is the preservation and protection of road conditions. Fog sealing is intended to preserve and protect roads by providing a waterproofing surface membrane that both enriches the oxidized dry, brittle areas and reduces pavement aging vulnerability by locking moisture and air out. To successfully preserve and protect roads, fog sealing must have low viscosity. Emulsions with too high a concentration may break before fully entering the surface voids. This will result in slippery, excess surface asphalt and will decrease pavement friction. The third function of a fog seal is sealing and treatment of cracking and surface defects. Some texts argue that fog seals are inadequate for treatment of surface voids and do not improve roughness or surface friction. However, if the surface damage is minor, a fog seal could provide an inexpensive, short-term relief to longitudinal, transverse, and block cracking.

A fog seal is designed to coat, protect, and/or rejuvenate the existing asphalt binder. The addition of asphalt should also improve the waterproofing of the surface and reduce its aging susceptibility by lowering permeability to water and air. To achieve this, the fog seal material must fill the voids in the surface of the pavement. Therefore, during its application it must have sufficiently low viscosity so as to not break before it penetrates the surface voids of the pavement. This is accomplished by using a slow setting emulsion that is diluted with water. Emulsions that are not adequately diluted with water may not properly penetrate the surface voids, resulting in excess asphalt on the surface of the pavement after the emulsion breaks, which can result in a slippery surface.

During application, the emulsion wets the surface of the aggregate and the existing binder film. Cationic (positively charged) emulsions can displace water from the surface of an aggregate or aged asphalt film. The emulsion then breaks by loss of water and chemical action, forming a film of new binder on the aggregate and existing binder film. The rate at which the emulsion breaks is dependent on several factors with weather conditions being dominant factors. For anionic (negatively charged) emulsions, there is no surface specific interaction with most aggregates. The emulsion breaks due to water loss by evaporation and absorption of water by the aggregates and surface voids of the pavement.

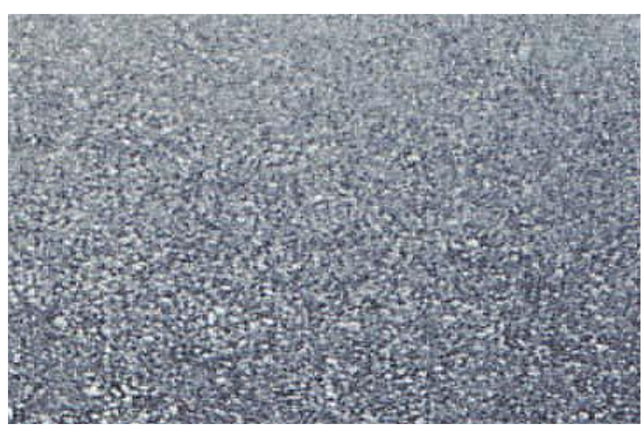


Auxiliary uses of fog sealing include frequently appearing on shoulders, dikes, dig outs, blankets, patches, and gores. Fog seals are also often used to provide delineation between the mainline pavement and the shoulder of the road. Additionally, during construction on milled or ground HMA surfaces, fog seals can also keep dust down and prevent rock loss before a new surface is placed.

Existing Pavement Condition

Before applying a fog seal, it is important to ascertain that the existing pavement condition will allow the seal to work properly. Fog seals should only be used on structurally sound pavements with minor defects. Rutting should be less than 3/8 inch and raveling must be very limited. If used on a shoulder, the surface should exhibit a good cross section and a good base. Surfaces with poor skid resistance should be avoided as a fog seal will further decrease the resistance.

A fog seal should only be placed on a pavement surface that is porous enough to absorb most of the asphalt emulsion. Another element to take into account is the age of the existing pavement. Fog seals are more effective if started early in the pavement's life with reapplication at appropriate intervals.



Open Graded Surface - Suitable for Fog Sealing

Dense Graded Surface - Not Suitable for Fog Sealing

If the pavement condition meets the above requirements, the surface must then be properly prepared for application. Right before applying a fog seal, the pavement surface must be cleaned with a road sweeper or a power broom or flushed with water to remove dust, dirt, and debris. If flushing is required, it should be completed 24 hours prior to application to allow for sufficient drying.

Fog Seal as a Rejuvenating Seal

All asphalts harden as they age, primarily due to oxidation, volatile loss and other aging mechanisms. Asphalt aging takes place at different rates according to weather conditions and the access of air in the pavement. Permeable pavements or pavements with higher void contents tend to age faster. The penetration of water into the pavement will carry dissolved oxygen that may promote aging. This indicates that pavements with open surfaces tend to age faster than those with closed surfaces.

Aging results in more brittle binders. These binders eventually experience cohesive binder failures under traffic loads and stone loss or raveling. In some cases, the asphalt produces oxidized compounds that are acidic and bond well to the aggregate; however, these compounds may also react with water causing adhesive failure or stripping.

Rejuvenating emulsions (e.g. Reclamite (oil emulsion), PASS (asphalt, oil and additives) and Topien C (asphalt, oil and additives)) have oils that soften the existing binder, thus reducing its viscosity. These also improve the flexibility of the binder, which reduces the likelihood of cohesive failure. This may be beneficial in situations where the surface has an open texture and the existing binder is brittle from age. As with conventional emulsions, if these types of emulsion do not penetrate the surface, they may create a slippery surface after they break.

Residential Fog Seal Application

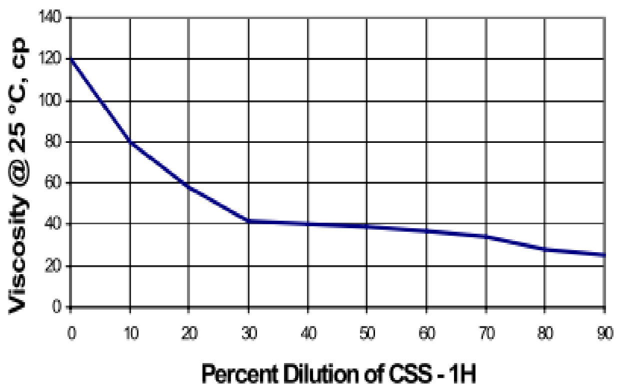
Materials

Fog seals consist largely of a diluted asphalt binder that can be applied directly over the surface of the pavement. There are three main types of asphalt binders used in fog seals: cutbacks, emulsions, and polymer modified emulsions. Cutbacks are asphalts that are dissolved in some kind of petroleum solvent. Typical solvents include naphtha (gasoline) and kerosene. Cutbacks have a higher residual asphalt content over emulsions. However, due to health and environmental concerns, the use of cutbacks have declined. Emulsion binders are binders that have been diluted with water in order to achieve a proper consistency, so as to get adequate coverage of the roadway. The common emulsion types for fog seals may either be cationic or anionic. The most common types are CSS-1h and SS-1h. Typically, fog seal materials used in Texas span a wide range of properties. Most are asphalt emulsion materials. Sometimes polymer-modified asphalt material with a 60ºC low shear rate viscosity can also be used.

Rejuvenating emulsions may take several forms and should only be used on pavement showing significant age related distress associated with stiffening of existing binder. They may be emulsions of rejuvenating oils and may include asphalt, polymer latex and other additives. These are defined in manufacturer's literature and are covered by SSP 37-600 and SSP 37-600_M. For such products, the manufacturer should be consulted to ensure correct handling.

Material Preparation

Asphalt emulsions contain up to 43 percent water but must be diluted, generally, to 50 percent before further use. This additional dilution reduces viscosity and allows the application of small amounts of residual binder to be adequately controlled.



Dilution water must be potable and free from detectable solids or incompatible soluble salts.

Application Rates and Spraying

Properly calibrated distributor trucks must be used to apply the emulsion. Spray nozzles with 4 to 5 mm (1/8" to 3/16") openings are recommended. Emulsion is generally sprayed at ambient temperature. The emulsion is sprayed at a rate that is dependent on the surface conditions. A test section representative of the entire surface should be chosen to approximate application rates. Typical application rates for diluted emulsion (1:1) range from 0.15 to 1.0 L/m2 (0.03 to 0.22 gal/yd2) depending on the surface conditions. A 1:1 diluted emulsion is an emulsion that has been subsequently diluted with equal parts water.

AEMA Recommendations for Application Rates

% Original Emulsion	Dilution Rate	Tight Surface*		Open Surface**	
		(l/m^2)	(gal/yd^2)	(l/m^2)	(gal/yd^2)
50	1:1	0.15 - 0.5	0.03 – 0.11	0.4 - 1.0	0.09 – 0.22

* A tight surface is of low absorbance and relatively smooth.
** An open surface is relatively porous and absorbent with open voids. (Recommended Performance Guidelines, AEMA)

Fog Seal Performance

Very little regard is given to performance evaluations for particular conditions and circumstances. Some states select binders according to viscosity values. There are, however, several binder properties that generally lead to more successful surface treatment. First, the emulsion should have sufficient viscosity for uniform application on the pavement surface and the binder should be able to resist stripping caused by traffic. Performance graded specifications for asphalt emulsions are performed using existing laboratory techniques. A study done by the Texas Transportation Institute investigated fog seals when applied to laboratory-molded samples. The objective of the study was to determine the effectiveness of fog seals at reducing the rate of age-hardening in asphalt concrete mixtures. Mixture stiffness was measured according to ASTM standard D412382 using a Mark III Resilient Modulus Device. In addition, the indirect tension test was also utilized. The results showed that all mixtures including fog seals showed an increase in stiffness after aging.

Troubleshooting

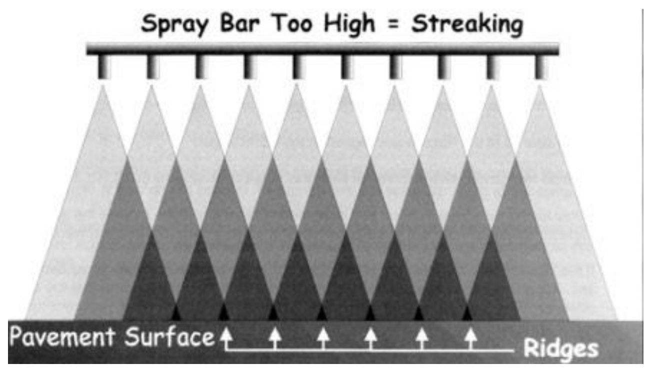
The Federal Highway Administration (FHWA) in collaboration with the Foundation for Pavement Preservation (FP2) developed a Pavement Preservation Checklists for fog seals that includes a trouble shooting section that aims at solving problems after fog seal application.

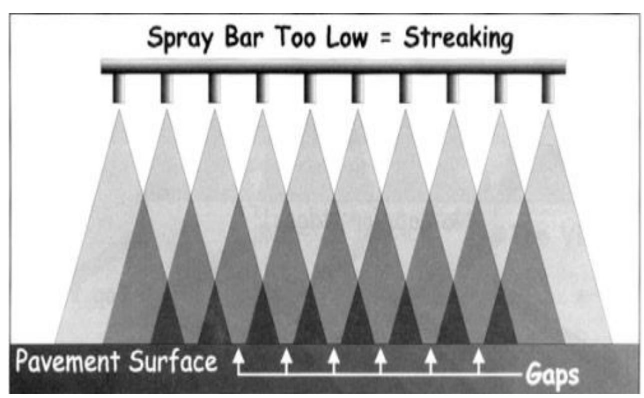
The checklist notes that if there is excessive splattering of the emulsion, there might be three possible reasons:

1. Emulsion has been diluted too much
2. Bar is incorrectly set
3. Spray pressure is too high

When streaking or drill marks are appearing in emulsion:

1. Emulsion is too cold
2. Viscosity of the emulsion is too high
3. All nozzles are not at the same angle
4. Spray bar is too high
5. Spray bar is too low
6. Spray bar pressure is too high
7. Nozzle is plugged





If Emulsion bleeding or flushing occurs:

1. Emulsion application is too high.

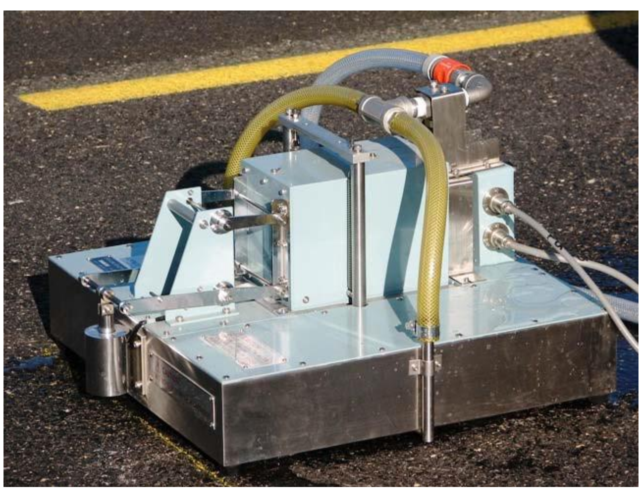
When to Apply Fog Seal

Fog seals are a relatively simple method intended to treat and rejuvenate pavements. In addition, fog seals are inexpensive compared to other surface treatments. The equipment required to perform a fog seal application is very minimal. In most cases, only a distributer truck would be required. It is best used on pavements that have yet to exhibit signs of significant distresses, low to moderate weathering or raveling. While the low cost is an attractive incentive, fog seals have a shorter expected life compared to other surface treatments, and therefore are sometimes used to preserve a pavement until a longer lasting surface treatment is applied. Also, if applied too heavily, a fog seal could potentially reduce friction on the pavement, making it hazardous to traffic. In addition, weather conditions are an important factor in the field when applying fog seals. Finally, fog seals do not work well when applied to pavements with large cracks, low skid resistance, rutting, shoving, or structural deficiencies. For the most part, fog seals are recommended for low to medium volume roadways because the time necessary for the emulsion to cure can severely disrupt traffic.

Fog Seal Limitations

Fog seals are versatile: they perform well in all climatic conditions and they can be used on nearly any road if needed. However, there are factors that limit the performance of fog seals by inducing weathering and raveling of bituminous surfaces. The biggest limitation of the fog seal is that it typically has a short service life. Therefore, other types of surface treatments should be considered for pavements requiring a more long-lasting solution.

Fog sealing is often not recommended for medium- and high-volume roads because it requires a lengthy period of time without traffic for slow setting emulsions to break. A fog seal should not be applied to any pavement with existing low skid numbers, as the emulsions of a fog seal often reduce surface friction immediately after application. Performing a permeability test on the pavement surface before applying fog seal is recommended to ensure that the surface is porous enough to absorb the treatment's emulsions.



Friction Testing After Fog Seal Application

Fog seals are not useful as seal coats on tight surfaces without the addition of aggregates as they will reduce surface texture and may create a slippery surface. Fog seals should not be used on Rubberized Asphalt Concrete (RAC) or polymer modified mixes unless the pavements are over five years old as these binders age at a different rate.
The application of fog seals is also limited by weather. A cutoff date in the Fall (approximately September 1st) will ensure that rain will not be a factor and that the emulsion will fully cure before freezing conditions are encountered. In addition, seal coats applied in the winter have less time to penetrate the pavement and are more prone to cause slick surface conditions. Fog seals are best applied during warm or hot, dry weather. Cold temperatures require a longer curing period before the road can be opened to traffic. Time is another factor that limits fog seal use. A fog seal should be placed four years after an asphalt overlay. Further, sealed cracks should undergo two seasons of oxidation before a fog seal is applied to the pavement.

Estimating Service Life and Cost

The service life of a fog seal varies due to a number of factors. The type of seal applied, the original pavement conditions, the geometry of the road, and the amount of traffic all affect the length of time a fog seal could remain intact and functional. Most research estimates a fog seal service life to be about 1 to 3 years, while others approximate the duration to be from 1 to 2 years.

Like most treatments, the cost of fog seal varies depending on materials used and location. Different sources report different pricing for a fog seal. However, cost can be estimated at an average of $0.36 to $0.54 per square meter ($0.30 to $0.45 per square yard) of pavement surface area. In some situations the cost could be as low as $0.15 to $0.20 per square meter ($0.18 to $0.24 per square yard), while some applications could cost as much as $0.50 to $1.25 per square meter ($0.60 to $1.49 per square yard).

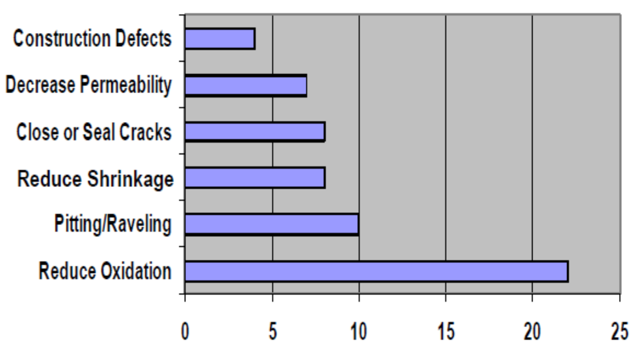
Binders Used in Fog Seals

The binders used in fog seal materials in Texas span a wide range of properties. Most are asphalt materials, but much lighter coal-tar aromatic materials are also used. The polymer-modified surface sealer (PASS) material was a polymer-modified asphalt with a 60˚C low shear rate viscosity of approximately 1000 poise. The medium-set emulsion (MS-2) and asphalt emulsion materials had 60˚C low shear rate viscosities of 2000 and 3000 poise, respectively. The COS-50 60˚C low shear rate viscosity was much higher at 30,000 poise, approximating that of a newly placed pavement binder. Thus, this binder may be expected to better withstand traffic stresses at the surface and to protect against raveling, provided that adhesion to the aggregate is adequate. The coal-tar materials used on airfield pavements seem to serve well to darken pavement surfaces.

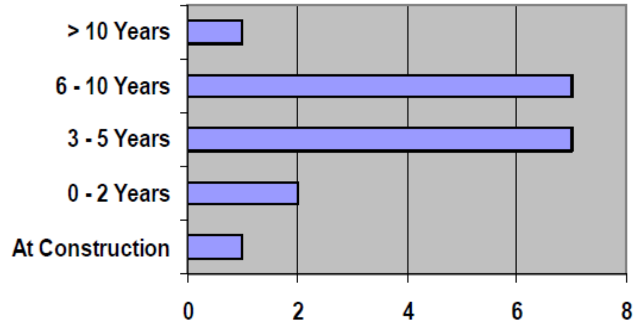
TxDOT Fog Seal Research and Development

A study was performed by the Texas Transportation Institute (TTI) and TxDOT to determine the effectiveness of fog seals and rejuvenators at performing their intended functions in preventative maintenance and thereby evaluate the economic effectiveness of these maintenance treatments. Fog seals have been used for maintenance purposes in Texas with varying degrees of success for several years. Rejuvenators have been used to a limited degree in the state. Application of fog seals and rejuvenators appears to be economically attractive method of pavement preservation. Many highway districts in Texas routinely use these products and techniques and believe they are cost effective. Information on the value of these treatments is not well documented; however, considering the widespread use of fog seals, it is obvious that a number of knowledgeable people feel that they have a significant economic value. The study concludes that for a fog seal to be cost-effective, it would need to be capable of delaying further rehabilitation for approximately 18 months based on an annualized cost analysis. Fog seals applied at residual rates of 0.05 gallons per square yard are not effective at sealing the surface to reduce the rate of aging in the mix. They can be used more effectively to correct specific surface problems such as raveling or loss of surface fines. There is insufficient information in this study to conclude when and how much fog seal to apply on asphalt to reduce aging.

In pursuit of developing a better understanding of fog seals, further investigation has been made into the effectiveness of fog seals in Texas. A more recent study has been completed by TTI and TxDOT that extensively analyzed the cores of many pavement structures. Replicate cores of both treated and untreated highway and general aviation pavement sections were analyzed in this study. Whole cores were assessed by water permeability and by susceptibility to permanent deformation. Replicate cores were sawed into approximately one-quarter-inch slices that were individually analyzed for total air voids, accessible (or interconnected) air voids, binder content, oxidative aging and rheology, and the presence of fog seal material. The fog seal materials used in this project were emulsions of asphalt materials and coal tar type materials typically used by TxDOT. No assessments were made of the effect of the treatment on raveling of a recently placed seal coat or to the appearance of the pavement. Fog seals are used routinely by TxDOT to stop the further raveling (sometimes called shelling) of a recent seal coat. While this use of fog seals was not studied in this project, the surveys of TxDOT personnel that were conducted during this study indicated that this was an effective use of the treatments.



TxDOT Survey: Why Use Fog Seal?



TxDOT Survey: Pavement Age at Fog Seal Application

Fog seals and rejuvenators are also used to restore the dark surface of the pavement and help delineate and sharpen the contrast between the travel lane and shoulder. This attribute of fog seals was not explicitly studied in this project; however, the pictures taken during the project, especially on the airfield pavements, demonstrate the effectiveness of the treatments in providing this benefit. Due to the types of treatments used on airfield pavements, the darkening effect of the treatment is long lasting.

Fog Seal Atop Seal Coat Application

The study focused instead on fog seal's use in reducing permeability of the surface, its ability to protect and seal against binder oxidation, and its use as a treatment to rejuvenate pavement binders. In regards to permeability, the study found that for the untreated cores, fog seals and rejuvenators had little to no effect on the permeability for the materials tested in this study. For binder oxidation, the study found that the tested fog seals and rejuvenators showed very little to no ability to reduce or retard binder oxidation. Finally, in testing of rejuvenating pavement binders, the study found that the tested fog seals and rejuvenators had very little, or no, ability to rejuvenate in-situ binders. The fog seal materials studied in this project were of two basic kinds: asphalt emulsions and coal-tar type materials. This study did not cover all different types of fog seal materials available in the market. The asphalt materials in the emulsions typically were 1,000 to 3,000 poise, approximately AC-10 to AC-30 viscosity grade, but one was quite high at 30,000 poise.

Based upon the whole-core and one-quarter inch slice data, it appears that if the tested fog seals are penetrating into the pavement, they are not doing so at a detectable level (the material is either draining off the side of the pavement or is draining through the pavement and away from the surface of the pavement). What's more, the permeability of the pavement is not significantly reduced for the tested materials.

The project evaluated several possible effects of the fog seal treatments on the pavement. The effects of the treatments that were primarily of interest were rejuvenation of the binder and retardation of binder aging. Researchers reached the following conclusions:

- Generally, the dynamic shear rheometer (DSR) map plots of binder recovered from the several slices of the pavement showed no clear effects. By comparing the DSR map to SEC chromatograms, the differences between the untreated and treated slices seem more likely due to original binder variability with depth than to the fog seal treatments. The one exception seems to be for the coal-tar treatments, which appear to harden the top layer.
- No effect of the tested fog seal treatments on hardening susceptibility was observed.
- A paired t-test statistical analysis of recovered binder stiffness showed that the only significant effect on the rheology of the in situ binder was by the EB44 coal-tar type material, in that it stiffens the binder, and that this effect is primarily restricted to the top one-quarter inch or so of the pavement.

Conclusions drawn from this study suggest that the tested fog seals do not in fact achieve many of the goals of their application. Little evidence exists to support claims of the tested fog seals' ability to protect pavements from moisture penetration or in rejuvenating brittle binders. Despite being unable to reinforce these expected performance characteristics of fog seals, the study does concede that fog seals could still be effective as a coat atop a recent seal coat, and as a method of maintaining roadway appearance. These results and other conclusions from this study were summarized in the following table:

Treatment Material	Example Grades	Solvent	Application Rate* (Gal/SY)	Residual Viscosity* (Poise) @ 60 C, 0.1 rad/s	Field Performance		Remarks
					Advantage	Disadvantage	
Slow Setting emulsion	- CSS-1 - SS-1	Water	0.09 - 0.1	2,200[a]	- Low cost - Easily applied	- No pavement penetration detected - No water sealing effect detected	- Slow-set emulsions typically are better for coating dust or fine aggregate; the faster setting the emulsion, the cleaner the surface should be
Medium Setting Emulsion	- MS-2 - CMS-2	Water	0.15	2,000[b]	- Low cost - Easily applied	- No pavement penetration detected - No water sealing effect detected	- Most commonly used product for both seal coats and HMAC - Slow-set emulsions typically are better for coating dust or fine aggregate; the faster setting the emulsion, the cleaner the surface should be
Hard Residual Emulsion	- COS-50 - SS-1H - CSS-1H	Water	0.14	30,000[c]	- May possibly be more durable, unlikely to bleed or flush	- In some cases, it may provide a less skid resistant surface - No pavement penetration detected - No water sealing effect detected - Cost may be higher	- For COS-50, only used experimentally - Slow-set emulsions typically are better for coating dust or fine aggregate; the faster setting the emulsion, the cleaner the surface should be
Polymer Modified Emulsion	- PASS (CMS-1P) - SS-1P - CSS-1P	Water	0.10 - 0.16	1,100[d]	- Break rapidly after application	- No pavement penetration detected - No water sealing effect detected - Cost may be higher	- Used often, especially on HMAC - Most common rejuvenator used - Slow-set emulsions typically are better for coating dust or fine aggregate; the faster setting the emulsion, the cleaner the surface should be
Coal-Tar Sealer	- PDC - EB44	Naphtha / Antracene	0.04 - 0.1	< 1,000[e]	- Hard, fuel-resistant surface; retains black color for longer	- Environmental concerns with runoff/solvent - No pavement penetration detected - No water sealing effect detected	- Used extensively on airports

* Approximate Values From Field and Laboratory Data
[a] Viscosity Measured From CSS-1
[b] Viscosity Measured From MS-2