THE UNIVERSITY OF TEXAS AT AUSTIN ✦ COCKRELL SCHOOL OF ENGINEERING

TEXAS PAVEMENT PRESERVATION CENTER

TxDOT **Newsletter**

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Past and Upcoming Events

TPPC Microsurfacing Courses

Microsurfacing training courses will be offered by TPPC.

The course is designed for engineers and inspectors and is entitled "Guidelines on the use of Microsurfacing." The course recapitulates the pavement preservation concepts, specifically with reference to microsurfacing. It focuses on proper mix design selection and application of microsurfacing. TxDOT's experience with microsurfacing is also discussed. This course also includes discussion on the use and applications of cape seals.

TPPC Seal Coat Training Courses

Seal Coat training courses will continue to be offered by TPPC. The course designed for inspectors, entitled "Seal Coat Inspection and Applications," focuses on proper inspection methods and the equipment used during chip seal construction. The other, "Seal Coat Planning and Design," instructs engineers on planning, designing, and constructing chip seals.

Courses for 2012

TPPC has developed two new courses for the new year. One of these courses is titled "Use of Thin Surfacing for Pavement Preservation," and the other is titled "Construction of Thin Hot Mix Asphalt Overlays." Both courses will be taught by Cindy Estakhri, TTI research engineer, and Dr. Yetkin Yildirm, director of the TPPC.

For more information on the Seal Coat and Microsurfacing courses, please contact Dr. Yetkin Yildirim, P.E. at yetkin@mail.utexas.edu or (512) 232-3084.

Our Mission

The mission of 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 TPPC is the Texas Department of Transportation (TxDOT).

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Seal coat

This issue of the TPPC newsletter summarizes the studies performed in the field of seal coat. The newsletter is organized in the following order. First, general information and TxDOT experience about seal coat is presented, which is then followed by select literature review of studies performed on seal coats. The last part of the newsletter summarizes the TxDOT Seal Coat Manual along with additional literature on important factors affecting seal coat operation, materials, equipment and service life of seal coat.

In modern American conditions, where most of the road transportation system is built, transportation engineers face a new challenge: maintaining those roads. As always, engineers attempt to achieve their goals with cost effective solutions. In such a context seal coat is presented as a simple, relatively inexpensive pavement preservation technique that is highly effective if adequate care is taken in the planning and execution of the work. A seal coat is an application of a layer of asphalt binder covered with a layer of aggregate applied to an existing paved surface.

The Texas Department of Transportation (TxDOT) spends about $186 million annually to maintain and preserve about 200,000 lane miles of roadway. Seal coats are an important part of TxDOT's pavement preservation and maintenance program, which applies seal coat to about 20,000 lane miles each year (Senadheera et al).

Seal coat is a surface treatment used to seal an existing pavement with a single application of asphalt covered by aggregate particles. It is used to extend the life of the pavement, but it is not intended as a permanent pavement surface. When seal coats are applied they may be expected to last for about five years, though this depends upon the weather conditions, traffic volume and many other variables. Seal coats provide an impermeable layer of asphalt that protects the pavement by preventing the penetration of moisture and reducing the amount of oxidation.

Other features mentioned in the "Seal Coat Field Manual" (Senadheera et al) are the abilities of seal coat to correct surface deficiencies such as cracks, shelling, bleeding, and lack of skid resistance. Seal coats may be used to seal some small cracks and to prevent water from seeping through narrow surface cracks and mining the pavement or base. In cases where the aggregate particles in the old asphalt surface have broken loose, seal coat cements them and puts new aggregate material in place, preventing additional raveling. At places where the asphalt in the existing pavement has risen to the surface, the skid resistance is almost zero. This is called bleeding and seal coat will often cover these spots with fresh aggregate and hold it in place.

Literature Review

Hasan, S., Meyer, A. H., Fowler, D. W., "Establishment of Acceptance Limits for 5-Cycle MSS and Modified Wet Ball Mill Tests for Aggregates Used in Seal Coats and HMAC Surfaces"

The authors discuss Asphaltic seal coat, which is defined as "a surface layer in which the aggregate particles, precoated or uncoated, are spread over a thin application of asphalt on an existing base." Seal coats are essential in improving deteriorated pavements and in enhancing the restoration of pavement surface. There are three factors that influence the performance of seal coats: micro and macro-texture, angularity and gradation of the aggregate. Initial performance of the surface is dictated by gradation, whereas long term performance of seal coat is dictated by the polish and wear resistance, strength and toughness, and resistance to weathering. The aggregates have direct exposure to traffic loads and environmental conditions and require high quality aggregate. The effects of external loads on aggregates and surface condition should be easy to detect and measure, resulting in good predictive equations for skid resistance.

Abdul-Malak, M. U., Meyer, A. H., Fowler, D. W., "Implication of Aggregates in the Construction and Performance of Seal Coat Pavement Overlays"

The aim of the research was to formulate statistical models that can be used for predicting the frictional performance of seal coat pavement overlays. Fifty-nine seal coat test sections were established in many parts of the state of Texas, and factors that influence performance level were observed, including environmental variables, traffic, and aggregate properties.

Seal coat overlay is a pavement rehabilitation method for all classes of pavements, from low-volume roads to interstate highways, used mostly on rural highways. This method is constructed by applying asphalt to a roadway surface, followed by the spreading of cover aggregate to form an overlay which is less than one inch thick.

The researchers note that in order to make the efficient use of those aggregate sources without records of acceptable field performance, quantitative information on the relationship between properties of aggregates and the performance of seal coat overlays built with them in a particular environment is needed. Moreover, quantitative evaluation of the influence of construction design variables on the performance of seal coat surfaces is also necessary.

The authors aim to formulate statistical models for predicting the frictional resistance of the seal coat overlay in terms of factors hypothesized to have influence on the microtexture and macrotexture components of surface friction. They attempt to establish criteria for evaluating expected aggregate performance, by relating the laboratory properties of aggregates used in seal coat construction to the frictional performance of this rehabilitation method. The researchers also evaluate the effects of various construction spreading rates and gradation of aggregates and determine the influence of environment and other climatic variables on the frictional performance of seal coat overlays, as well as quantitatively study the interaction between traffic and the performance of various aggregate materials.

Seal coat in this study is defined as “an economical method for pavement rehabilitation which involves the application of asphalt and aggregate to an existing bituminous surface”. After the asphalt binder is applied uniformly on the road surface, the cover aggregate is then spread at a specified application rate. According to the research study, the additional thickness provided by seal coats increases the load carry capacity of the pavement and adds little structural strength. Seal coats bridge the cracks and consequently prevent water intrusion into the sub-base of the pavement.

Seal coats are mainly used to improve the frictional resistance of bituminous pavements, and improvements depend largely on the quality of construction and frictional properties of the aggregate used. Moreover, seal coats used to enrich a raveled surface, reduce tire noise, increase pavement visibility at night, improve demarcation of traffic lanes and attain a uniform appearing surface.

For seal coats the main variables controlling the frictional resistance are the microtexture, angularity, and gradation of the individual coarse aggregate particles composing the surface structure. Angularity of the aggregates is produced by rock crushing process, however in order to retain the angularity property mineralogical composition and traffic produced wear play a significant role.

Microtexture or roughness of the coarse aggregate particles in seal coats is an essential property in terms of frictional resistance, but the change in such texture during the service life of seal coats is even more important.

The coarse aggregate in seal coats is in direct contact with the tire. The aggregate is therefore influenced by forces of shear, abrasion and impact, which may break up the aggregate by altering its gradation and reducing the texture of aggregate particles. Thus, the aggregate should provide the mechanical stability and strength to resist those forces over the surface life.

When selecting the aggregate, attention should be paid to the level of friction to be maintained on the roadway, which is decided upon in view of the estimated traffic volumes and speed limits. Aggregate should be resistant to polish and wear, abrasion, and the deteriorating effects of weathering. Moreover, it should have an ability to transmit traffic loads to the underlying surface. One of the most common problems in Texas, as well as many other states, is the large amount of limestone available for use as an aggregate, which polishes rapidly and leads to low frictional resistance in a relatively short period. Moreover, in Texas problems have been experienced with blends of aggregates used to meet PV or soundness requirements. Size and shape of aggregate particles are also considered as an important element in aggregate selection.

Once aggregate is selected, the asphalt type and the design application rates of asphalt and aggregate are determined. This is based on careful selection of the type of aggregate to be spread on the asphalt layer, as related to the percentages of silica and alkali contents, the climatic region in which the seal coat to be constructed and the limitations on the minimum surface and ambient temperatures.

The performance of seal coats largely depends on the quality of construction. Key factors that contribute to successful construction of high quality seal coat include:
- Proper preparation of the existing surface, upon which the seal coat is planned to be placed
- Satisfactory environmental condition, ideal is when the weather is hot and dry, without rain for the next several days
- Selection of good operating equipment and proper handling during the construction
- Carefully planned sequence and timing of construction operations
- Implementation of good quality plan and field inspection
- Adequate traffic control during construction and for a few hours after.

Research methodology that was carried out in this research study used many coarse aggregate materials and sources for placing seal coats on Texas highways. The major categories include crushed limestone, crushed sandstone, and crushed siliceous gravel. Numerous factors, such as aggregate characteristics, construction variables, traffic volume, and environment, were observed to investigate their effects on the field frictional resistance of coarse aggregates when used in seal coat surfaces. The authors established seal coat test sections in different climatic regions of the state of Texas.

Elmore, W. E., Solaimanian, M., McGennis, R. B., Phromson, C., Kennedy, T. W., “Performance-Based Seal Coat Asphalt Specifications”

Superpave (Superior performing asphalt pavements) Asphalt Binder: final product of SHRP Asphalt Research Program. The major difference between Superpave binder specifications and those now in use is that the new test methods and related specification criteria were developed to be performance based. Therefore, this research study seeks to apply Superpave principles to improving the performance of seal coat binders.

The study discusses the factors TxDOT indentified that influence seal coat performance:

- **Quality design.** The product of a seal coat design is an optimized rate of application of asphalt material and aggregate. According to discussions with TxDOT and other knowledgeable industries, it found that seal coats are seldom rigorously designed in Texas (or elsewhere).
  Aggregate factors that are important for superior seal coat performance are aggregate size, shape, gradation, durability, porosity and cleanliness.
- **Quality and consistency of construction.** Some construction variables and factors that influence seal coat performance include: longitudinal and transverse variation in the rates of material application, variation in materials, type and time of compaction, length of time between application of binder and application of aggregate, environmental condition during and

immediately after construction, length of interval between the end of construction and movement of traffic, and improper embedment of the aggregate.

- **Quality and consistency of materials.**
- **Environmental conditions.** To ensure reasonable environmental conditions, TxDOT specifications require that seal coat construction not occur when the ambient air temperature is 15C and falling. Construction may commence, however, when the temperature is 10C and rising. Evidently, seal coat construction using latex-modified binders is more sensitive to environmental conditions because TxDOT's specifications raise these limitations to 25C and 20C, respectively. An additional TxDOT requirement when using latex-modified binders is that the surface temperature must be greater than 20C.
- **Traffic conditions.**

In this research study the authors determined the existing asphalts used by TxDOT for seal coats; obtained field input for those materials and the user evaluation of their service. Based on the SHRP Recommended Protocol, those asphalts obtained from TxDOT for seat coat used were tested in the laboratory. The test results were then evaluated in accordance with the AASHTO Recommended Guide.

The authors concluded that there was no definite trend in Texas in the type of asphalt binder used for seal coat process. The discontinued use of AC-5 was the only consistent trend found in Texas. Asphalt binders were selected on the basis of good historical performance. On the roadways with high traffic, binders with higher stiffness values at high temperatures were used.

Elmore, W. E., Solaimanian, M., McGennis, C., Kennedy, T. W., "The Use of the Superpave PG Grading System for Selecting Asphalt Binders for Seal Coats"

Advisory group compiled a listing of 37 responders to the questionnaire developed to obtain input on the placement of seal coats. Responders included highway users, consultants, suppliers and one seal coat contractor.

According to the survey, the most critical factors that deliver superior seal coat performance are the amount of asphalt used, condition of the aggregate, environmental conditions and the workmanship. When asked what specific asphalts are used and why, the response was that modified AC-5 or AC-10 coated and held aggregate better than emulsions, and the past experience showed that the certain combinations of materials were needed for successful seal coat. Additionally, the extra cost for polymers was believed to be not justified.

According to the responders' experience about the actual life span, seal coat lasts for the duration of its design life if it is designed and constructed properly. Causes of most short term failures were identified to be rain or low temperatures, no or improper design, condition of existing road surface and improper calibration of equipment.

Transverse Variation of Seal Coats (TVAR) (TTI Projects 0-5833, 5-5833-01)

Transversely Varied Asphalt Rate (TVAR) is the practice of transversely varying asphalt application rates to diminish existing wheel path flushing while retaining chip seal aggregate outside of wheel paths. The project included texture testing of pavements prior to application of seal coats to develop a correlation between difference in the wheel path and outside of wheel path texture and the transverse variation in the asphalt application rates. The pavement texture is determined by three methods: Circular Track Meter (CTR), Outflow Meter Testing and Sand Patch Volumetric Method Testing. The Sand Patch Method has been the most used method in Texas for decades. The standard recommended TVAR Sand Patch Criteria is given in Table 1.

Table 1. Sand Patch Test criteria

Difference in Sand Patch Test Diameters , mm	Use of TVAR with a Single Spray Bar Asphalt Distributor	Use of TVAR with a Dual Spray Bar Asphalt Distributor
Less than 20	No	No
21 to 50	Optional	15%
Greater than 50	Yes (22% to 32%)	30%

Figure 1. Pavement idea for TVAR Application

The Texas Transportation Institute (TTI) tested several seal coats over a period of 2 years (2008-old pavement, 2009 – new seal, 2010 – new seal). Each year a sand patch test was done to determine the texture at wheel path and between the wheel path. TTI concluded from their study of TVAR in various districts across Texas that whether or not TVAR methods were employed with Grade 3 aggregates, Grade 3 aggregates were found to have better results with regard to flushing than Grade 4 aggregate seal coats. When Grade 4 aggregates were used in seal coats, TVAR showed minimal wheel path texture improvement over the pre-existing texture after two years of traffic.

Standard Specification Item 316 allows for transverse variation in asphalt rate. It is necessary to include a plan note defining the use of TVAR in the project, and to clarify the necessary additional distributor calibration procedures. A recommended plan note is included in the TxDOT Guide for Transversely Varying Asphalt Rates. The plan note makes it clear that the engineer, not the contractor, shall be responsible for determining when to transversely vary asphalt rates. Also, it is suggested that the plan note require distributors to be able to provide at least one transversely varied asphalt rate in the range of 22 to 33%. This requirement allows contractors with both single spray bars and dual spray bars to bid on the seal coat project.

Ambarish Banerjee, Andre de Fortier Smit, Jorge A. Prozzi, "Modeling the effect of environmental factors on evaporative water loss in asphalt emulsions for chip seal applications"

Most of the chip seal applications fail due to the underlying reason that aggregates were placed too early or too late after distribution of binder which results in higher embedment of aggregates or inadequate adhesive bond between emulsified binder and cover aggregates, respectively. The aim of the research was to determine the total amount of water loss from emulsion before the aggregates are placed. The amount of water lost in the system decides optimal time for chip placement.

The total amount of water lost to evaporation before aggregates are spread occur in two stages: first while emulsion cools down from application temperature to the ambient condition which is then followed by normal evaporation due to convective heat transfer from the ambient air. The mass lost in the first stage is modeled by incremental time steps in which each succeeding time step consists of decreasing temperature and decreasing amount of water in the system. The amount of water lost in first stage depends on the convective heat transfer coefficient (k) of the air. The rate of change of temperature is worked out using Newton's law of cooling. The mass lost in the second stage depends on the vapor pressure deficit (VPD) and the wind velocity. VPD is defined as difference between ambient vapor pressure and the saturated vapor pressure. The threshold values of moisture lost for aggregate placement were proposed as 19.8% and 3.0% for cationic and anionic emulsions respectively.

It was concluded that for the first stage the rate of moisture loss drops as the square of residual water in the emulsion. The loss in the second stage depends on temperature, relative humidity and wind speed. Thus it is concluded that the optimal time for placing the aggregates depends on the curing characteristics of the emulsified binder because the rate of development of adhesive forces depend upon the curing property of the emulsion.

Seal coat damage evaluation due to superheavy loads (TTI Project 0-5270)

Seal Coat Damage has become a prevalent problem for TxDOT due to rapid increase in the movement of superheavy loads (SHL). The number of permitted SHL moves has increased from over 100 in FY04 to over 1800 in FY09.Currently, TxDOT performs a pavement review of the SHL route if Gross Vehicle Weight (GVW) is over 500 kips or the tire loads exceeds 5 kips. Considering a large seal coat placement of approximately 20,000 miles/year in Texas, the guidelines for the movement of SHL has to be developed.

Figure 2. Seal Coat Damage due to SHL movement

Researchers at TTI have developed a mechanistic approach to determine the extent of damage by SHL movement subjected to different temperatures and time conditions. Failure occurs when tensile strength (σt) is less than the fracture pressure.

$\sigma t <= [\ ft/t + F/(t.w)*(\sin \Phi - u \cos \Phi)$, where (Refer to Figure 3)

ft = tire traction force per tire width

t = seal coat thickness

w = tire width

F = wheel load

u = coefficient of friction between the seal coat and the underlying existing layer

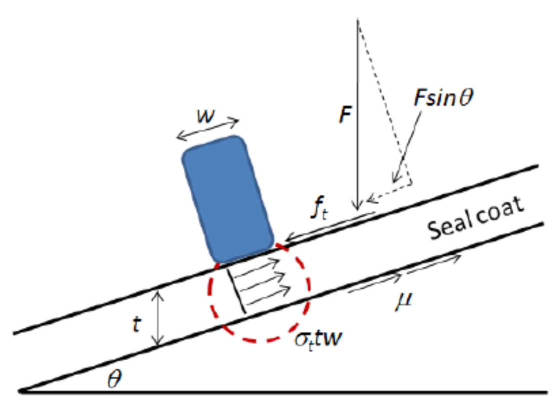


Figure 10. Free Body Diagram of Seal Coat Damage.

Figure 3. Mechanistic Approach to assess Seal Coat Damage due to SHL movement

Since it is not feasible to measure the tensile strength of the seal coat mixture from laboratory testing, researchers used fracture mechanics to find the tensile strength as a function of surface energy, crack density, crack length, asphalt mixture modulus properties and the film thickness. Researchers conducted pilot field testing in the Bryan and San Antonio Districts to validate the proposed mechanistic model. The mechanistic model was recalibrated to account for different levels of temperature, curing period, texture depth, and seal coat type.

Supplemental Maintenance Effectiveness Research Program (SMERP)
(TTI Projects 7- 2908, 7-1981, 0-4040)

The SMERP study was done by TTI to establish the effectiveness of typical and promising maintenance treatments used in Texas to prolong the life of asphalt pavements. Twelve districts decided to participate in this study and a total of 20 sites were constructed across these districts. Each site included a total of seven 700 foot sections. The seven sections included a micro-surfacing, fog seal, and control section and four seal coat types: asphalt rubber, latex modified, polymer modified, and conventional. These sections were monitored until failure in order to achieve the objective of SMERP. The data collected during construction was as follows: target and actual application rate of binder, pavement and air temperature, relative humidity, application temperature of asphalt, and temperature of asphalt when aggregate was spread. A total of nine post construction surveys (6, 12, 24, 36, 48, 60, 72, 84, and 96 months) were done. In preliminary surveys all seven sections at a site were judged with respect to increasing or decreasing alligator cracking, bleeding, block cracking, long/trans cracking and raveling. These results were questionable except when a more comprehensive study was done in the successive surveys.

Based on all the post construction survey data, the analysis and recommendations were made by TTI [TTI: 0-4040]. Distress propagation (alligator cracking plus patching, other cracks, bleeding) and PCI (Pavement Condition Index) were measured and used as performance criteria. A longitudinal statistical study was done on the data collected. The data had a multivariate nature (consisting of three distresses and the derived PCI). These data were treated as four univariate responses and the following 5 steps were implemented for each variable: exploratory data analysis and simple curve fitting, imputation, site curve fitting with imputed values, multiple comparisons to group the treatment at different pre-construction conditions, and family curve fitting. Performance curves as a function of months since construction for all four variables were produced as a result of statistical analysis.

The following conclusions and observations were reached by the researchers: seal coat treatments performed well in reducing cracking. Although microsurfacing reduced bleeding, it did not reduce long term cracking. Polymer modified emulsion treatment performed better in terms of reduced bleeding, for PCI all treatments performed similarly with microsurfacing slightly better and polymer modified emulsion slightly worse than others, to reduce the effect of bleeding TVAR can be followed as per TxDOT seal coat manual. The treatment selection based on predominant distress type was made as a conclusion of the study. Table 2 below summarizes the findings of this research project.

Table 2. Summary of results

Best Treatment	Predominant distress
Asphalt Rubber	Cracking
Micro-Surfacing	Bleeding
Asphalt Rubber	Alligator Cracking plus patching
Micro (if PCI >70) , Latex (PCI < 70)	PCI

Cindy K. Estakhri and Miguel A. Gonzalez, "Design and Construction of Multiple Seal Coats"

The objectives of the report were to establish design and construction guidelines for multiple seal coats for the Texas State Department of Highways and Public Transportation. A multiple seal coat is a bituminous surface that results from two or more successive alternating applications of bituminous binder and cover aggregate to an existing paved surface, usually with smaller aggregates sizes used in each successive layer. The calculation of the void spaces between the aggregates is the most important design requirement to accurately calculate the amount of binder required for a pavement. A portion of these voids is lost due to embedment, wear and tear of aggregate because of traffic conditions. Moreover, a sufficient amount of voids should be left to ensure minimum macrotexture for a good skid resistant surface.

Claude P. Marais integrated the research findings of various engineers and results of several experiments done by NITRR (National Institute for Transport and Road Research). He concluded that voids in a loose volume of stone were a function of Average Least Dimension (ALD) and the shape of the stone (Flakiness Index).He developed a practical spread rate of aggregates in terms of ALD and void volume. In order to calculate the optimum binder quantity, Marais first derived an equation for void volume as a percentage of ALD volume taking into account factors such as embedment, wear and tear and minimum texture of aggregates.

The NITRR study revealed a low correlation factor for Marais calculated values. The NITRR devised the test called Modified Tray Test in order to determine the true void content and Effective Layer Thickness (ELT) of the aggregate layer. The binder quantity and aggregate spread rate are also determined from this test. The Modified Tray Test was evaluated in the laboratory by Texas Transportation Institute (TTI). The test was also used to determine the true void content and ELT of double seals made up of different combinations of aggregates. A very good correlation was found between the ELT of double seal and the sum of ELTs of the bottom and top layers.

Using the same previous aggregate combinations, multiple seal coats were fabricated in the laboratory to evaluate the design procedure. Ten different combinations of aggregate gradings and two different binder application rates (design and low) were used as variables in the study. The aggregate retention, surface texture depth and embedment depth of seal coats were compared to evaluate the procedure. The design procedure suggested higher binder application rates in comparison to the results of this study. The following modifications were incorporated into the design procedure:

1. Required surface texture of seal coat was increased from 0.64 mm to 1.0 mm.
2. The percentage of minimum voids which must be filled with binder in order to prevent initial stone loss was decreased from 65% to 55%.

Field tests were conducted at four locations in Texas. Initial field tests confirmed the laboratory results that the design binder quantities were very high. The last two test roads incorporated the above mentioned changes and performed successfully in the future.

Jon A. Epps, Bob M. Gallaway and Mark R. Brown, “Guidelines for application of synthetic aggregate seal coats “

Synthetic aggregate seal coats improve skid resistance of surface and reduce windshield damage. However, problems were encountered regarding the proper design, materials and construction. The Texas Highway Department initiated a study at TTI to develop design and construction guidelines. Field trial sections were designed to study the effects of the following variables: environment, traffic, asphalt type, asphalt quantity, aggregate type, aggregate quantity, aggregate moisture content and simulated rainfall. Techniques recommended to construct a satisfactory synthetic aggregate surface are summarized below:

1. Avoid construction or detour traffic if rainfall is likely to occur in 24 hours.
2. Limit light weight aggregate usage to a limit such that sufficient bond is developed between asphalt and aggregate before heavy traffic is allowed.
3. Use pneumatic rollers.
4. Remove excess aggregate by brooming.
5. Use harder and satisfactory quantities of asphalt to provide deeper embedment of aggregate.
6. Do not use synthetic aggregate where heavy vehicle turning movements are expected.
7. Reevaluate freeze – thaw test requirement for synthetic aggregates.

William D. Lawson, Michael Leaverton and Sanjaya Senadheera, “Maintenance Solutions for Bleeding and Flushed Pavements Surfaced with a seal coat or Surface Treatment “

Flushing/bleeding typically occurs from a combination of factors such as over-application of binder, poor quality or dirty aggregate, poor surface preparation prior to placing of seal coat, construction during periods of inclement weather, inexperienced contractors, inexperienced inspection personnel and traffic conditions. Based on an extensive literature survey and interviews of experts inside and outside of TxDOT, researchers presented maintenance solutions to three specific issues: bleeding pavements, flushed pavements, and intersections. The findings are summarized in Table 3.

Table 3: Maintenance solutions for bleeding and flushing.

Solution Type	Concerns
Bleeding	
Apply layer of Grade 5 aggregate , Apply coarse sand/stone screenings	Small rocks occupy voids and displaces asphalt to higher level
Apply layer of Grade 4 or 3 aggregate	Larger Aggregate not sticking to asphalt
Sandwich seal	Relatively complicated method
Apply lime water	Kills reflectability of markings , some asphalts are not amenable to lime
Remove bleeding pavement and replace	Used in total failure of seal coats
Flushing	
Cold Milling	Leaves surface more susceptible to water penetrations
New Seal Coat	Adding more asphalt may worsen bleeding
Microsurfacing	Migration of excess asphalt through surface
Thin asphaltic concrete overlay	Blade Level up techniques may create patches
Ultra high pressure water cutting	Environmental pollution

Nazimuddin M. Wasiuddin, Amanda Marshall, Nibert E. Saltibus, Aziz Saber , Christopher Abadie and Louay N. Mohammad, "Use of Sweep Test for Emulsion and Hot Asphalt Chip Seals: Laboratory and Field Evaluation"

The objective of this study was to determine the sensitivity of sweep test for both emulsions and hot asphalt with respect to the aggregate mineralogical types, aggregate precoating, aggregate moisture content, asphaltic material type and application rates of asphalt. Sweep test, as shown in Figure 4, is done in following sequence:

1. Bituminous asphalt is applied to the asphalt felt disk.
2. Aggregate is applied and rolled over asphalt surface.
3. Sample is conditioned at a prescribed temperature and time before curing.
4. Brooming is performed over surface using nylon brush.
5. After some time the percentage of aggregate loss from the sample is calculated.

Figure 4. Preparation of sweep test samples

The field tests were done with three asphaltic materials (CRS-2P, PAC-15 and AC20-5TR) and five aggregate types (precoated expanded shale lightweight, uncoated, expanded shale lightweight, crushed limestone, crushed granite and expanded clay lightweight aggregates). A total of 15 chip seal test sections were prepared at the parking lot of a stadium. In the sweep test one asphalt type (CRS-2) and one aggregate type (gravel) were added to see the extra results. These combinations were not tested in the field. The aggregate size, curing time and temperature for this study were ¼ inch, 48 hours and 28° C, respectively.

The sweep test results were evaluated on the basis of amount of aggregate loss from the sample. Figure 5 shows that expanded shale light weight aggregate performed best with 4.9% aggregate loss, while expanded clay light weight aggregate performed worst with 16.4% aggregate loss. Moreover, the pre-coating in expanded shale lightweight aggregate increased the percentage of aggregate loss from 4.9% to 20.3%. Aggregates were also compared with PAC-15 and AC20-5TR asphalt types. For PAC-15, gravel performed the best, while lightweight expanded clay aggregate performed worst. For AC20-5TR, gravel performed the best, while limestone and lightweight expanded clay aggregate performed worst.

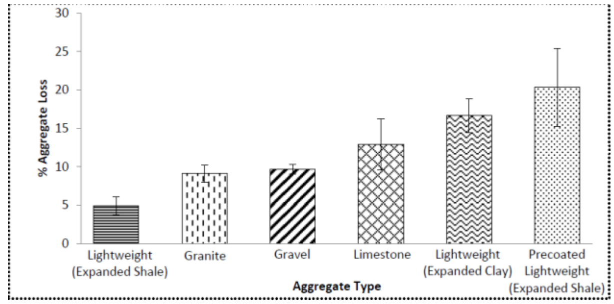


Figure 5. Effects of aggregate type on percent aggregate loss for CRS-2P

The effect of asphalt type on the percentage aggregate loss was also measured. Figure 6 shows that for limestone hot asphalts (PAC-15 and AC20-5TR) performed better than emulsion (CRS-2P) .For gravel, CRS-2P performed better than PAC-15 but CRS-2 performed poorly.

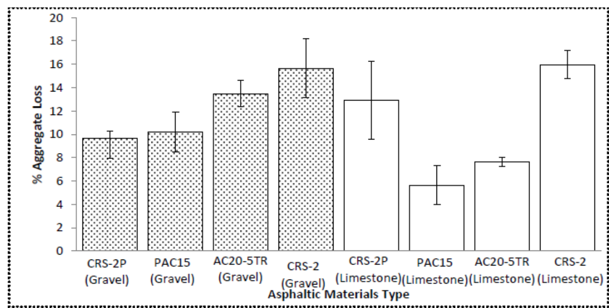


Figure 6. Effects of asphaltic materials type on percent aggregate loss

When asphalt rates were increased to 1.33 times the original, it was found that the aggregate loss decreased considerably. The effect of moisture on aggregates was also observed. The aggregate loss decreased with increasing moisture content for CRS-2P chip seals, while it was reverse in the case of PAC-15 chip seals for both limestone and gravel.

The field test distress results in fifteen chip seal test sections were compared with the sweep test results. Overall field distress test rating correlated well with the sweep test results. Only 2 test sections (precoated shale lightweight on CRS-2P and granite on PAC-15) did not match the laboratory results. All AC20-5TR sections matched well with the sweep test results. The results of this study confirmed that performance of the seal coat depends highly on the aggregate-binder compatibility.

Andrew J. Hanz, Petrina Johannes and Hussain U. Bahia, "Development of an Emulsion Residue Testing Framework for Improved Chip Seal Performance"

The objective of this study was to develop an emulsion testing framework, inspired by the PG grading system used for hot binders, and to see the effects of modification type and emulsifier chemistry on the performance of emulsions. Several tests were conducted on recovered and PAV-aged residue at various stress levels and temperature to see the effects of climate, traffic speed and aging. The testing protocols were applied to recovered and PAV-aged emulsion residues from six emulsions widely used in Wisconsin that are inclusive of two emulsifier chemistries and two types of modification. Emulsion residues were recovered using the thin film evaporative method specified in ASTM D7497 Method B. During this method, emulsion is drawn down to a film thickness of 380 microns and subject to curing in a forced draft oven at 60°C for six hours. These emulsion residues were long term aged in the Pressure Aging Vessel (PAV) at the temperature and pressure specified in AASHTO R28.

The emulsion performance was judged on four factors: resistance to bleeding, resistance to raveling, elastic recovery in the DSR test and resistance to cracking. Bleeding occurs at high temperature or high stress condition when binder is viscous enough to flow to the chip seal surface. Multiple Stress Creep and Recovery (MSCR) test was selected to simulate field bleeding conditions. The non-recoverable creep compliance (J_{nr}) and its variation according to stress and temperature were studied. The results are presented in Table 4.The five of the six emulsion types performed similarly as per Jnr values at both 52°C and 64°C but HFRS-2 performed unsatisfactory. Four of the six emulsions performed similar behavior as the temperature increased. With regard to stress sensitivity, the modified emulsions were more sensitive than conventional which indicates that there is a critical stress level at which network developed by polymers breakdowns for these formulations.

Table 4 - MSCR Results for Recovered Emulsion Residues and RTFO – aged Base Binders

Material	Jnr @ 3.2 kPa^{-1}		Grade (AASHTO MP-19)		Temp. Sensitivity		Stress Sensitivity (1.0 kPa^{-1} – 10 kPa^{-1})		
	52°C	64°C	52°C	64°C	Slope	Rank	52°C	64°C	Rank (64°C)
HFRS-2	1.02	6.32	H	N/A	0.44	5	50%	24%	N/A
HFRS-2L	0.27	3.95	E	S	0.52	6	42%	60%	2
HFRS-2P	0.29	2.28	E	S	0.28	3	75%	138%	5
CRS-2	0.26	2.42	E	S	0.31	4	18%	24%	1
CRS-2L	0.41	2.16	E	S	0.22	1	32%	91%	3
CRS-2P	0.32	2.37	E	S	0.29	2	65%	107%	4
Base Binder Properties									
PG 58-28 (RTFO)	0.43	6.48	E	N/A	0.50		33%	39%	
PG 76-28 (RTFO)	0.09	1.38	E	V	0.11		44%	120%	

The resistance to raveling is measured using the Bitumen Bond Strength (BBS) test and application of a strain amplitude sweep test to evaluate strain tolerance. The strain associated with a 65% reduction in the G*sinδ parameter was selected as the criterion to evaluate materials. The dry strength is a representation of the cohesive strength as most binders fail within the binder film rather than at the interface. The wet strength is a combination of adhesive and cohesive strength as most binders will only partially strip from the aggregates, with stripping dependent on conditioning time. Figure 7 presents graphically the results of the test conducted. The unmodified emulsions have higher modified strength in both wet and dry conditions with most significant difference for cationic emulsions. The effect of emulsion modification is more prevalent in the measure of strain tolerance, as both polymer and latex modification demonstrate a higher failure strain.

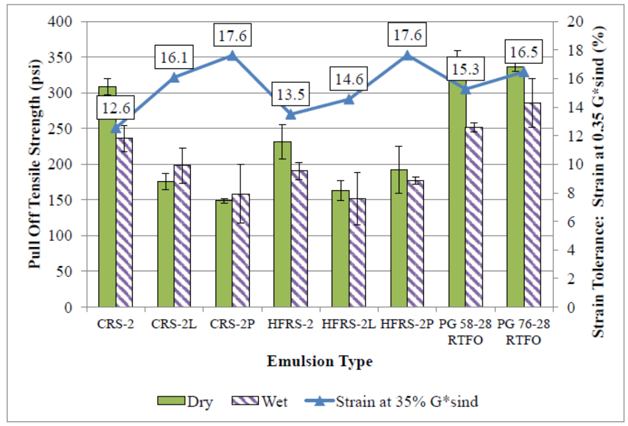
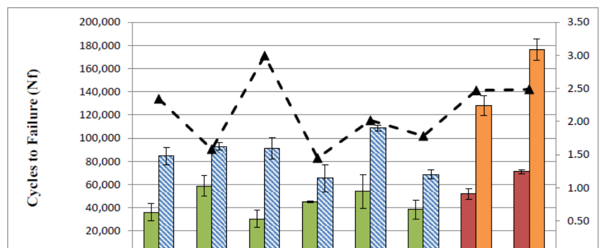


Figure 7. Evaluation of Raveling Resistance - Effect of Emulsion Type on Cohesive Strength, Adhesive Strength, and Strain Tolerance (Wet conditioning was performed at 40°C for 24 hours)

The elastic recovery in the DSR test indicates that the polymer modified exhibits a greater increase in elastic recovery than the latex modified.



	CRS 2	CRS 2P	CRS 2L	HFRS 2	HFRS 2P	HFRS 2L	PG 58-28	PG 76-28
Recovered Residue	36,080	58,642	30,435	45,011	53,864	38,580	51,890	70,959
PAV Aged Residue	84,484	92,728	91,067	65,222	108,667	68,707	128,049	176,258
Aging Index	2.34	1.58	2.99	1.45	2.02	1.78	2.47	2.48

Figure 8. Resistance to Fatigue Cracking - Cycles to Failure at 2.5% Strain and Sensitivity of Performance to Aging as Measured by the Aging Index

The cycles to failure at 2.5% strain, estimated from the fatigue law developed from LAS test protocol, was used to evaluate the fatigue performance of materials. Results are presented in Figure 8; the effect of aging is also included as measured by the aging index which is defined as the ratio of cycles to failure of the PAV aged material to the cycles of failure of the recovered residue. The current research has evaluated the materials in the laboratory; a full scale field test may be required to justify the findings of this research.

Shuo Li, Todd Shield, Samy Noureldin and Yi Jiang, "A Field Evaluation of Surface Friction Performance of Chip Seals in Indiana"

This research was initiated by INDOT to evaluate the field performance of seal coats, particularly, the friction properties. A total of 18 test sections were constructed and the friction properties were measured during 12 months of service. The effects of aggregate type, traffic volume and existing pavement condition on the seal coats' frictional properties were also studied. Out of 18 test sections, 10 sections were made up of conventional chip seals and 8 were fog seals. The section division is shown in Table 5.

Table 5 – Chip seal and fog seal test sections.

(a) Chip Seals

Category	Road	Agg. Type	Length	AADT	Truck %	Year Sealed
1	SR-32	Crushed Stone	8.3 mi.	732	8.9	08/2008
	SR-14	Crushed Stone	14.9 mi.	1,530	18.3	07/2008
	SR-10	Crushed Stone	6.3 mi.	3,372	47.2	07/2007
	US-421	Crushed Stone	9.0 mi.	4,527	23.5	08/2007
	SR-129	Crushed Stone	6.5 mi.	5,892	4.8	07/2007
	SR-19*	Crushed Stone	8.9 mi.	6,129	9.7	07/2007
2	SR-341	Crushed gravel	12.9, mi.	955	8.1	07/2009
	US-150	Crushed gravel	12.7, mi.	2,450	6.4	07/2009
3	SR-246	Crushed	4.0, mi.	902	8.5	06/2010
	SR-159	Natural	4.0, mi.	2,467	9.7	06/2010

(b) Fog-chip Seals

Road	Agg. Type	Location (RPs)	AADT	Truck %	Year Sealed
SR-9	Crushed Stone	121.6-127.6	3,161	10.8	08/2009
SR-11	Crushed Stone	0-18.44	1,656	4.5	09/2009
SR-48	Crushed Stone	0-6.96	1,410	8.5	08/2009
SR-67	Crushed Stone	190.8-199.3	2,110	39.6	05/2009
SR-101	Crushed Stone	34.41-36.52	1,047	19.4	08/2008
US-36	Crushed Stone	0-7.66	2,085	15.8	10/2008
US-52(a)	Crushed Stone	27-37.29	6,307	7.2	10/2008
US-52(b)	Crushed Stone	137-145.7	1,531	9.8	09/2009

Friction tests were performed following the construction and twice a year after the construction. The surface friction decreased after opening to traffic and showed the greatest decrease after 12 years of service for all the test sections. After that surface friction increased and fluctuated over time. It is observed that after approximately 30 months of service, the surface friction tends to decrease.

In the fog seal test sections, the friction number tends to decrease after of the application of asphalt emulsion. As the asphalt dried, surface friction increased over the first 6 months after which it decreased. The average friction value was 51 after 12 months in service, and 37 after 24 months of service. The average friction value after 12 months of service was almost the same as that in chip seals after 24 months in service. The above observations indicate that a fog-chip seal does not necessarily outperform a standard chip seal in terms of surface friction.

Crushed aggregate chips produced greater friction values than the naturally formed aggregate chips. Successful chip seals occurred on high traffic volume roads. A laser scanner was used to measure the macrotexture mean profile depth (MPD). Based on the MPD tests the authors drew the following conclusions. Successful chip seals had a MPD of greater than 0.60mm, with no noticeable differences in MPD values for aggregates between No.11 and No.12. Chip seals having low MPD values were found to produce a low friction value.

Jaejun Lee, Y. Richard Kim "Evaluation of Performance and Cost-Effectiveness of Polymer Modified Chip Seals"

This study shows that chip seals are a cost effective method to extend the service life of the current degraded pavements. The author proved, through laboratory experiments, that the polymer-modified emulsions (PMEs) provide better initial and long term performance than those with the unmodified emulsions. For this study, two types of chip seals, double and triple, were constructed in the laboratory. Two types of emulsions, CRS-2 (unmodified) and CRS-2L (latex modified), and two types of aggregate, granite 78M and lightweight, were used for the chip seals. To simulate the traffic load conditions, a one-third scale model mobile loading simulator (MMLS3) was used.

Bleeding performance is evaluated using MMLS3 on double chip seals using the two emulsion types: CRS-2L and CRS-2. The test temperature of 122°F was used for this study and the time schedules for two types of emulsions were different. The MMLS3 provided traffic loading for 1 hour for CRS-2 and for 4 hour for CRS-2L. The bleeding was measured using digital image processing (DIP). During the test it was evident that emulsion did not come from bleeding but rather from aggregate loss. The results of the DIP showed that bleeding of the CRS-2 emulsion was three times higher than that of CRS-2L with large aggregate loss, three times higher than what occurred with CRS-2 emulsion. This suggests a strong relationship between bleeding and aggregate loss in the double seal.

Figure 9 shows the bleeding test results. White diamond and triangle symbols indicate the percentage of bleeding and colored in symbols indicates the percentage of aggregate loss.

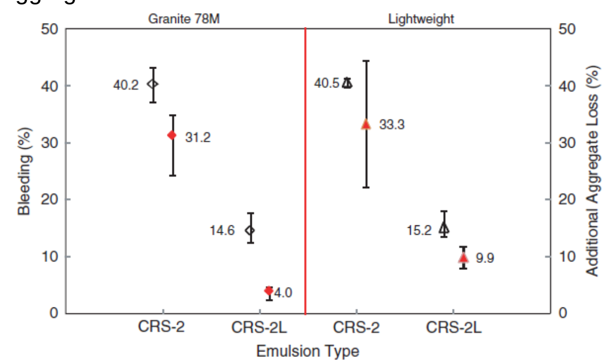


Figure 9. Calculated bleeding rates of double seals and aggregate loss of double seals during bleeding test

The MMLS3 rutting test was conducted for the triple seal at three test temperatures: 68°F, 104°F and 129.2°F.A linear relationship is observed between average rut depth and number of wheel passes in the semilog scale, except for the CRS-2L emulsion at 68°F.Figure 8 shows the comparison of initial rut depth in two emulsions after 990 wheel passes. Rutting in chip seals is caused both by densification and the shear flow of aggregate particles. It is evident from Figure 10 that CRS-2L emulsion resists the shear flow of aggregate particles much better than unmodified emulsion and thus result in less rutting.

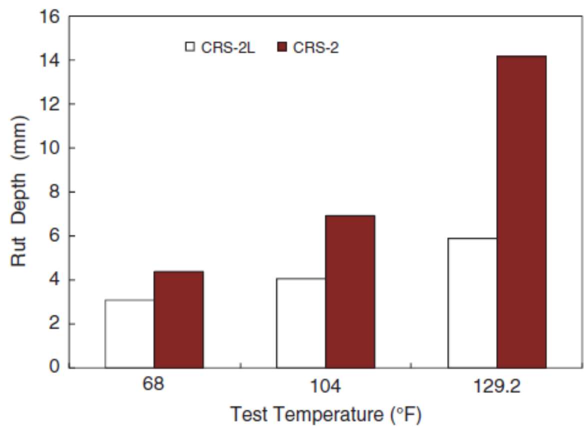


Figure 10. Comparison of initial rut depth growth after 990 wheel passes

Lastly, Life-Cycle Cost Analysis (LCCA) was performed to establish the effectiveness of PME. The life span for a typical unmodified chip seal is generally assumed to be 5 years. Real Cost software recommended by FHWA was used in the LCCA. It found that the present value of the polymer modified chip seal becomes lower than that of conventional one when the pavement has at least 7 years of life span. Results from the bleeding and rutting test of this research indicates that life span of a PME can be extended by at least 2 years.

Md Shahidul Islam and Mustaque Hossain, "Chip Seal with Lightweight Aggregates for Low-Volume Roads"

This study attempted to determine the optimum aggregate and emulsion application rates for lightweight aggregate embedment of almost 70% and to identify the optimum combination of light-weight aggregate and emulsion so that aggregate loss in service can be minimized. The aggregates selected for the study were expanded shale and clay from Colorado(Agg-1T), a lightweight aggregate from Oklahoma(Agg-2C), expanded slate from Kansas(Agg-3M) and expanded shale from Missouri(Agg-4N).The emulsion used for study were CRS-1HP and CRS-2P. Chip seals were applied on 29.8x26.0x4.1 cm slabs made with a 9.5 mm nominal maximum aggregate size Superpave mix with finer gradation. The quantity of aggregates and emulsion were determined from current Kansas DOT construction manual procedures and the modified Kearby method. Optimum binder requirements were quite different from current Kansas DOT procedure. Both methods were able to achieve an embedment between 50-70% of seal depth. A modified sand circle method was used to estimate the embedment of the aggregates after rolling. The complete chip seal application procedure can be summarized in the following steps:

1. Compacted slab was heated to 70°F.
2. Measured quantity of emulsion was applied at 150°F over slab surface.
3. A thin plate used to make the surface even.
4. Aggregates were applied carefully to avoid overlapping.
5. A concrete cylinder was used to compact aggregates.
6. After 3 hours each sample was swept to remove loose aggregates (initial loss).

Statistical Analysis System (SAS) software was used to perform the analysis of variance (ANOVA) to find the significant factors that affect embedment depth, aggregate retention, rut depth, and the number of wheel passes and to compare the population means of these factors. The rutting of the asphalt surface was measured by the Hamburg wheel-tracking device. The steel wheel (71.67 kg) was rolled onto the asphalt slab immersed in hot water (at 50°C). The rut depth and number of passes to a pre-specified rut depth (failure criteria) was determined. The aggregate retention test was done by the sweep test method in which mechanical energy is applied to access the bond between aggregate and asphalt. Based on analysis of the results it was concluded that Agg-1T performs better in rutting test but not in sweep test and the opposite is true for Agg-4N. Aggregate loss was found to be largely a function of aggregate-emulsion compatibility.

Issac L. Howard, Scott Shuler, Walter S. Jordan III, James M. Hemsley Jr. and Kevin McGlumphy, "Correlation of Moisture Loss and Strength Gain in Chip Seals"

This study focused on the curing rate of emulsions and percentage of aggregate loss as a function of loss of moisture after the chip seal construction. Three methods were used for laboratory testing: sweep test I (ASTM D7000), sweep test II (modified) and frosted marble test. Multiple emulsions and aggregates with different combinations were selected for the three tests. The FMT results are plotted as a function of cure time and moisture loss. Up to 80% moisture loss, a moderate gain in strength is achieved. Between 80% and 90%, the strength rises sharply. Full strength is achieved after 90% moisture loss. The results indicated that moisture loss is a more appropriate parameter than cure time for the opening of traffic after chip seal construction. Sweep test I results indicated a strong correlation between aggregate loss and moisture loss. The same emulsion combined with different aggregates was observed to be both the best and worst performing product in terms of aggregate loss. In sweep test II, the emulsion-aggregate combination was tested at both 40% and 80% moisture loss. Chip loss with dry aggregates averaged approximately 70% and 15% at 40% and 80% moisture loss, respectively. Chip loss with SSD aggregates averaged approximately 65% and 10% at 40% and 80% moisture loss, respectively. The SSD aggregates showed less aggregate loss than dry aggregates because damp aggregates allow the emulsion to wick into the aggregate pores and provide improved adhesion and cohesion properties. Comparison of data collected from each test showed differences in four key areas: (a) ability to validate aggregate properties and chemistry effects on chip seal systems, (b) ability to validate binder properties and emulsion chemistry on chip seals, (c) ability to address variables that affect performance achievement within the test, (d) ability of the methods to affect design, quality control and quality assurance methods for improved chip seal performance.

Scott Shuler, "Chip Seals for High Traffic Pavements"

This research study focused on problems related to applying chip seals on high traffic volume pavements and possible solutions for these problems. The first problem in chip seal application on high traffic volume pavements is the short term aggregate loss or loose chips. Solutions to this problem include the following:

- Reduce aggregate quantities such that there is only a layer thick aggregate cover.
- Apply choke stone (smaller aggregates) to fill the voids of first layer.
- Apply double seal.
- Sweep pavement after rolling to remove excess chips.
- Adjust binder quantity.
- Raise the application temperature of the asphalt if the binder is too cold.
- The minimum temperature of the substrate should be 50°F.
- If cool or cold weather was not anticipated after construction, a fog seal may be used to retain the aggregate.

The second problem in the chip seals is the long term effective aggregate loss which results in the short life expectancy of the seal coats. This loss may be attributed to the loss of adhesion between the binder and aggregate or the decreased cohesion within the binder. The possible solution for this problem can be summarized as follows:

- Reduce asphalt hardening by adding certain antioxidative additives.
- Improve long term resiliency of binders by using polymer modified binders.
- Reduce the water susceptibility of chip seals by adding antistripping agents to asphalt or hydrated lime to aggregates.

The major problem with the construction of chip seals on high traffic volume pavements is the prolonged traffic control. These can be overcome by using emulsified binders. Emulsified binders can reduce the breaking time of emulsion and thus reduce both traffic delays and early aggregate loss.

Types of Seal Coats

Under different cases and conditions, different types of seal coats are used. The types are differentiated from each other mainly from the construction sequence, number of courses sealed, and variations in aggregate nominal size. NCHRP classifies these types of seal coats (chip seals) in the "Chip Seal Best Practices" report.

Single Chip Seal - It is constructed from a single application of binder followed by a single application of uniformly graded aggregate, as shown in Figure 11.

Figure 11. Single Chip Seal

Double Chip Seal - A double chip seal is constructed with two consecutive applications of both the bituminous binder and the uniformly graded aggregate, as shown in Figure 12.

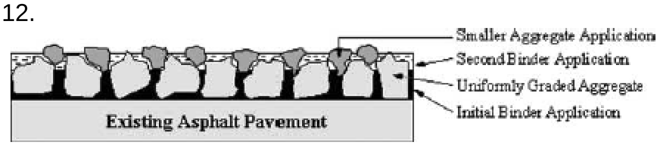


Figure 12. Double Chip Seal

Racked-in Seal is a special seal in which a single-course chip seal is temporarily protected from damage through the application of choke stone that becomes locked in the voids of the seal.

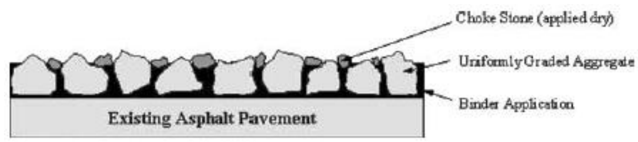


Figure 13. Racked-in Seal

Cape Seal, named after the area in South Africa where it was invented, is basically a single chip seal followed by a slurry seal (Figure 14).

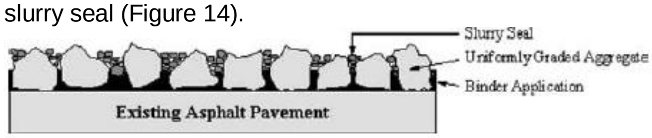


Figure 14. Cape Seal

Inverted Seal - Figure 15 shows how an inverted seal is constructed. It is called an inverted seal because the larger-sized aggregate goes on top of the smaller-sized aggregate and is therefore an inverted double seal.

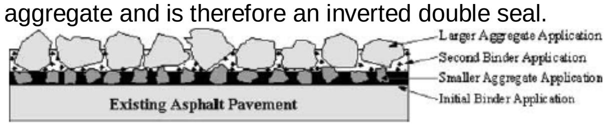


Figure 15. Inverted Seal

Sandwich Seal- As shown in Figure 16, sandwich seal is a chip sealing technique that involves one binder application sandwiched between two separate aggregate applications.

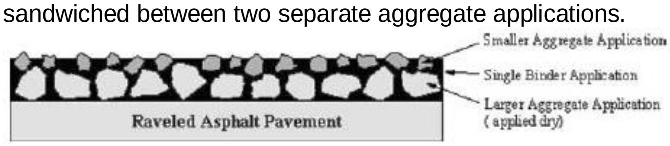


Figure 16. Sandwich Seal

Geotextile-Reinforced Seal- Reinforcing a chip seal with geotextile products can enhance the performance of a conventional chip seal over extremely oxidized or thermal cracked surfaces.

Figure 17. Geotextile-Reinforced Seal

Factors to consider before seal coat

Weather conditions

The field practice shows that the ideal conditions to apply seal coat are when hot weather is present, with relatively low humidity, and little or no wind. The best condition for humidity is if the humidity is 50 percent or lower when the asphalt is shot. The period from June to September tends to be the best time for seal coat work in the United States. During cool weather, or in areas where the aggregate might be damp, emulsions are thought to be more appropriate and that asphalt cement should be avoided (Griffith and Hunt 2000).

Traffic conditions

What engineers aim is an opening of the road to the traffic as soon as possible. The curing time that a seal coat should be left untouched, before allowing traffic to pass, is different from one case to another, and it is dependent upon different conditions. Estakhri & Saylak et al developed a TTI Cohesion Test method to identify the curing time of asphalt emulsions in seal coat operation.

The first condition to be taken into consideration is traffic volume. If the road being sealed has a low volume of traffic, it can be opened as soon as the rollers have finished rolling. On the other hand, a high traffic volume normally should be held off the fresh seal coat longer.

Existing pavement condition

It is clear that seal coat does not improve any structural deficiency of the pavement structure. Its main purpose is to rejuvenate and extend the life of an existing road by restoring skid resistance and other features lost during the road's lifetime. Seal coat cannot be applied over pavements that demonstrate any structural problems. Any repair work that the pavement needs must be done well ahead of the beginning of seal coat work.

All potholes must be repaired. This entails cleaning them out, trimming around the edges, sealing them with liquid asphalt and patching them with hot or cold mix asphalt. Large cracks must be sealed with liquid asphalt. If they are excessively large, it may be necessary to cut them out and apply a hot or cold mix patch. When the number of cracks is large, crack sealing in the described manner is impractical. The area should be squeegee sealed.

Materials and specifications

Seal coat is comprised of two main materials: cover aggregate and asphalt binder. The aggregates can be natural or crushed, and the most widely used asphalt binder is the asphalt emulsion. In this section information and specifications about these two materials will be discussed.

Asphalt Binder

According to TxDOT specifications, asphalt binders should demonstrate a number of properties when used in seal coat, such as:

- The binder should be fluid enough that it can be sprayed uniformly, and also it should be viscous in order to remain in a uniform layer.
- After being applied, it should have the designed consistency in order to wet the aggregate.
- It should develop adhesion quickly, and prevent any dislodging of the aggregates from the traffic.
- Also, it should not bleed or strip under traffic.

Cover Aggregate

TxDOT classifies the aggregates used in Texas for seal coats in two major categories: natural and synthetic.

Natural aggregates include crushed gravel, crushed stone and natural limestone rock asphalt. Crushed gravel is natural gravel which has been crushed in order to change the shape of the gravel from round to angular and the surface from smooth to rough. Crushed stone is achieved by applying a number of crushing processes on large stones or pieces of bedrocks. Natural limestone rock asphalt is a limestone that is naturally impregnated with asphalt.

Synthetic Aggregates, on the other hand, include lightweight aggregate and crushed slag. Lightweight aggregates are mainly expanded shale, clay, or slate produced by a rotary kiln method. It also has excellent skid-resistant properties. Crushed slag is produced as a by-product of steel production.

For a better performance of seal coat, it is advised to use one size of aggregate, as the depth of the embedment in this case will be the same for each particle. TxDOT Standard Specification Item 302, Aggregates for Surface Treatments, describes the size and gradation requirements for aggregates used in seal coats. A successful seal coat is more generally achieved when larger size cover aggregate is used, because the larger aggregates are less sensitive to small variations in binder application rate than smaller cover aggregates.

Precoated aggregates are aggregates which have been coated with emulsions or asphalt cement. Precoated aggregates have a greater adhesion of the aggregate to the asphalt cement binder. They are used to reduce the accumulation of dust on the surface of the aggregates and to improve the color contrast between striping and roadway surface. Precoated aggregates are mainly used when the seal coat binder is to be an asphalt cement. But, if the seal coat binder is an asphalt emulsion, the use of precoated aggregate is not recommended.

Seal coat design

Seal coats should be designed to ensure that the proposed materials are of sufficient quality and have the desired properties required for a successful seal coat project. In addition, the design will determine the proper amount of cover aggregate and bituminous binder to apply. The available seal coat design method includes the McLeod Design Procedure and Kearby Design Method.

Equipment

Seal coat quality is highly determined by the availability and proper usage of appropriate equipment.

Understanding the capabilities and limitations of each piece of equipment helps to attain a quality seal coat product. The following types of equipment are used in a seal coat construction project:

- Asphalt distributor
- Aggregate spreader
- Haul trucks
- Rollers
- Rotary broom
- Front-End Loader
- Heater and storage unit

Asphalt distributor
An asphalt distributor is a truck-mounted, insulated tank, with numerous special purpose attachments. A typical asphalt distributor is shown in the Figure 18.

Figure 18. Asphalt Distributor

The major components of the asphalt distributor are: asphalt tank, heating system, circulating and pumping system, filter screens, spray bar, hand sprayer, controls and gauges.

Aggregate spreader
The aggregate spreader, sometimes called the "spreader box" is used to distribute aggregate evenly over the film of asphalt sprayed by the asphalt distributor. The specifications require aggregate spreaders to be self-propelled and have a continuous feed feature. The type most commonly seen on a seal coat project is shown in Figure 19.

Figure 19. Aggregate Spreader

The major components of the aggregate spreader are: truck hitch, receiving hopper, belt conveyors, spreading hopper, discharge gates, discharge roller.

Haul trucks
The trucks used to transport the aggregate and dump it into the spreader box are usually of the end-dump variety. They are normally either tandem-axle or single axle trucks like the one shown in Figure 20.

Figure 20. Haul truck

The size of the truck bed is an important factor and is expressed in cubic yards. The single-axle trucks normally carry 6 cubic yards of aggregate. The bed capacity for tandem-axle trucks is usually 12 or 14 cubic yards.

Rollers
After aggregate is placed on the asphalt, rollers orient the aggregate in its flattest dimension and seat it firmly into the asphalt binder. A pneumatic roller is recommended for all seal coat and surface treatment work. A steel-wheeled roller is not recommended because the flat, steel drum will tend to crush the aggregate, especially on the high spots. Pneumatic rollers operate on rubber, air-inflated (pneumatic) tires. Figure 21 shows a pneumatic roller typical of those used for seal coat and surface treatment work.

Figure 21. Pneumatic roller

Rotary broom

The pavement must be adequately broomed before asphalt is applied. A finished seal coat will also be broomed to remove excess aggregate particles. Power rotary brooms are used for these purposes. An example of a rotary broom is shown in Figure 22. A vacuum sweeper is another type of broom which may also be used to clean the pavement.

Figure 22. Rotary broom

Front-End loader

Front-end loaders are used to move aggregate from the stockpile into the haul truck. Figure 23 shows a typical front-end loader. Loaders, like all equipment, must be in good mechanical condition. There are no particular components or adjustments that inspectors should monitor. More important than the machine itself, is the way it is operated.

Heater and Storage Unit

Sometimes the contractor will set up a heater and storage unit for large projects. The asphalt is hauled from the source by truck and pumped into the heater and storage unit. When it is used, it is pumped either into another transporter or directly into the asphalt distributor.

Figure 23. Front-end loader

Application process

In order for the seal coat or surface treatment to be applied as planned, it usually requires three inspectors. The application of the seal coat is a fast-paced process, and requires alert inspectors to ensure that it is done properly. The inspectors must work together as a tightly knit team, because it is difficult to monitor every detail. If one inspector misses a detail, one of the others must pick it up. Communication and coordination must be excellent. For detailed application process, the TxDOT Seal Coat Manual should be closely followed.

Estimated Service Life

The service life of a sealcoat is generally expected to be five years. Sealcoat performance depends primarily on the underlying gravel which carries the traffic loads. A sealcoat surface also degrades more quickly under a high volume of heavy trucks, snowplowing, and at locations where traffic frequently makes turning maneuvers.

Surface maintenance generally involves patching failed areas, wedging raveled edges, and improving drainage. By making a timely application of a new sealcoat surface before the old one deteriorates completely, we can extend service life and maintain a good riding surface. A single sealcoat is often applied three years after the initial double sealcoat. After that a three to five year resealing cycle is common. When a road has received multiple treatments, the sealcoat layer may be several inches thick. These roads look and perform more like an asphalt pavement road, and crack sealing can be an effective maintenance technique on them.

Transverse Variance of Asphalt Rates (TVAR)

Transverse Variance of Asphalt Rates (TVAR) is the seal coat practice of varying the amount of seal coat asphalt across the width of the roadway in order to better address the needs of the existing pavement surface. TVAR can improve the performance of seal coats on pavements with flushed surfaces by adjusting the asphalt application rates to account for the difference between the wheel paths and the rest of the pavement. TVAR allows more asphalt to be put on the road without causing flushing in the wheel paths, resulting in a better seal overall.

Standard Specification Item 316 allows for transverse variation in asphalt rate. It is necessary to include a plan note defining the use of TVAR in the project, and to clarifying the necessary additional distributor calibration procedures. A recommended plan note is included in the TxDOT Guide for Transversely Varying Asphalt Rates. The plan note makes it clear that the engineer, not the contractor, shall be responsible for determining when to transversely vary asphalt rates. Also, it is suggested that the plan note require distributors to be able to provide at least one transversely varied asphalt rate in the range of 22 to 33%. This requirement allows contractors with both single spray bars and dual spray bars to bid on the seal coat project.

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