Guidelines for TxDOT in Selecting Seal Coat Materials

Cindy K. Estakhri, P.E.
Texas A&M Transportation Institute

Dr. Sanjaya Senadheera, P.E.
Texas Tech University, Center for Multidisciplinary Research in Transportation

0-6747-P1

February 2017

GUIDELINES FOR TXDOT IN SELECTING SEAL COAT MATERIALS

by

Cindy K. Estakhri, P.E.
Research Engineer
Texas A&M Transportation Institute

and

Dr. Sanjaya Sendheera, P.E.
Center Director
Texas Tech University, Center for Multidisciplinary Research in Transportation

Product 0-6747-P1
Project 0-6747
Project Title: Seal Coat Quality: Does Low Cost Mean Low Quality?

Performed in cooperation with the
Texas Department of Transportation
and the
Federal Highway Administration

February 2017

TEXAS A&M TRANSPORTATION INSTITUTE
College Station, Texas 77843-3135

DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation.

This report is not intended for construction, bidding, or permit purposes. The engineer in charge of the project was Cindy Estakhri, P.E. # 77583.

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GUIDELINES FOR SELECTING AGGREGATES FOR SEAL COATS

The aggregate in a seal coat:

- Provides resistance to the abrasion of moving wheel loads.
- Transfers the wheel load to the underlying layers.
- Provides a skid-resistant surface.

Other factors that are related to the stone that affect the performance of a seal coat include:

- Nominal maximum size.
- Gradation.
- Shape.
- Cleanliness.
- Adhesion characteristics.
- Strength and wearing characteristics.

The primary decisions a designer must make when selecting aggregates for seal coat include:

- Aggregate size and gradation.
- Aggregate type.
- Aggregate quality.
- Precoating requirements.

SELECTION OF AGGREGATE SIZE AND GRADATION

Gradation

Aggregates used for seal coats should consist essentially of a single-size stone. When determining binder application rates in the field, achieving an embedment depth of the stone into the asphalt binder of about 40 to 50 percent is the goal. If all of the aggregate particles are about the same size, embedment depth will be about the same for each particle contributing to successful seal coat performance. Very fine particles are likely to become submerged in the asphalt (see Figure 1).

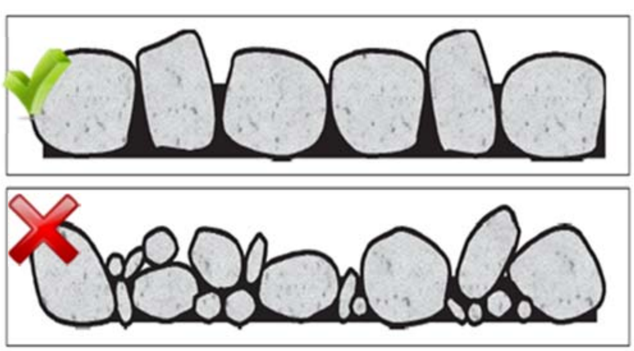

Figure 1. Effect of Aggregate Gradation on Stone Embedment Depth.

For practical purposes, specifications allow some oversized and undersized particles. The Texas Department of Transportation's (TxDOT's) Item 302 seal coat aggregate specifications as shown in Table 1 are designed to provide for a gradation that is as close to single size as economically practical. Those grade designations with an "S" (such as 3S, 4S, and 5S) are required to be even more single-sized. A few districts sometimes require 3S and 4S gradations to achieve a premium seal coat. The most common reason for not using single-size grades is the increased initial cost of these options.

The primary objective in placing a seal coat is to _seal_ the existing pavement surface against the intrusion of air and water, primarily water. The more asphalt binder that is sprayed onto the pavement, the better seal it will provide. Larger stones allow for the placement of more asphalt binder.

Grades 3 and 4 are the most commonly used aggregates for seal coat construction in Texas. These grades are highlighted in blue in Table 1.

Table 1. Item 302 Aggregate Gradation Requirements (Cumulative % Retained[1]) (TxDOT 2014).

Sieve	Grade								
	1	2	3S[2]	3		4S[2]	4	5S[2]	5
				Non-Lightweight	Lightweight				
1"	-	-	-	-	-	-	-	-	-
7/8"	0–2	0	-	-	-	-	-	-	-
3/4"	20–35	0–2	0	0	0	-	-	-	-
5/8"	85–100	20–40	0–5	0–5	0–2	0	0	-	-
1/2"		80–100	55–85	20–40	10–25	0–5	0–5	0	0
3/8"	95–100	95–100	95–100	80–100	60–80	60–85	20–40	0–5	0–5
1/4"	-	-	-	95–100	95–100	-	-	65–85	-
No. 4	-	-	-	-	-	95–100	95–100	95–100	50–80
No. 8	99–100	99–100	99–100	99–100	98–100	98–100	98–100	98–100	98–100

[1] Round test results to the nearest whole number.
[2] Single-size gradation.

In recent history, a number of districts have moved to the exclusive use of Grade 4 seal coat. While some districts still use both Grade 3 and Grade 4, they are using considerably less Grade 3. The primary reason for moving to the use of more Grade 4 is the initial cost difference and a lack of adequate funding to handle the preventive maintenance needs. A district can simply cover more miles of pavement with a Grade 4 seal than a Grade 3 given the available funding.

Grade 5 seal coats are used by some districts for very low volume roads or on shoulders. Maintenance applications include strip and spot sealing using a Grade 5. It is also sometimes used to restore friction to hot mix pavement surfaces.

Most districts believe that a Grade 3 seal coat will provide from one to several years of performance life over a Grade 4 seal coat. The consensus finding of a statistical analysis of performances of seal coats constructed in three Texas districts by Krugler et al. (2012) is that Grade 3 seal coats should be expected to serve one to two years longer before resurfacing than Grade 4 seal coats, all other roadway and environmental factors being equal. However, as decisions to apply seal coats has in the past been based on age and other non-distress-related factors, this difference in performance life potential may be understated.

Nominal Maximum Size

The nominal maximum size (largest sieve size retaining more than 10 percent of the aggregate) for the different the three commonly used grades is as follows:

- Grade 3 – 1/2 inch.
- Grade 4 – 3/8 inch.
- Grade 5 – No. 4 or 1/4 inch for 5S.

A successful seal coat is more achievable when large size cover aggregate is used. This is because the larger aggregates are less sensitive to small variations in binder application rate than when smaller cover aggregates are used. But larger size aggregates also tend to create more tire/pavement noise and are more likely to cause vehicle damage if dislodged from the surface. Figure 2 shows the On Board Sound Intensity noise measurements of different seal coats around the state.

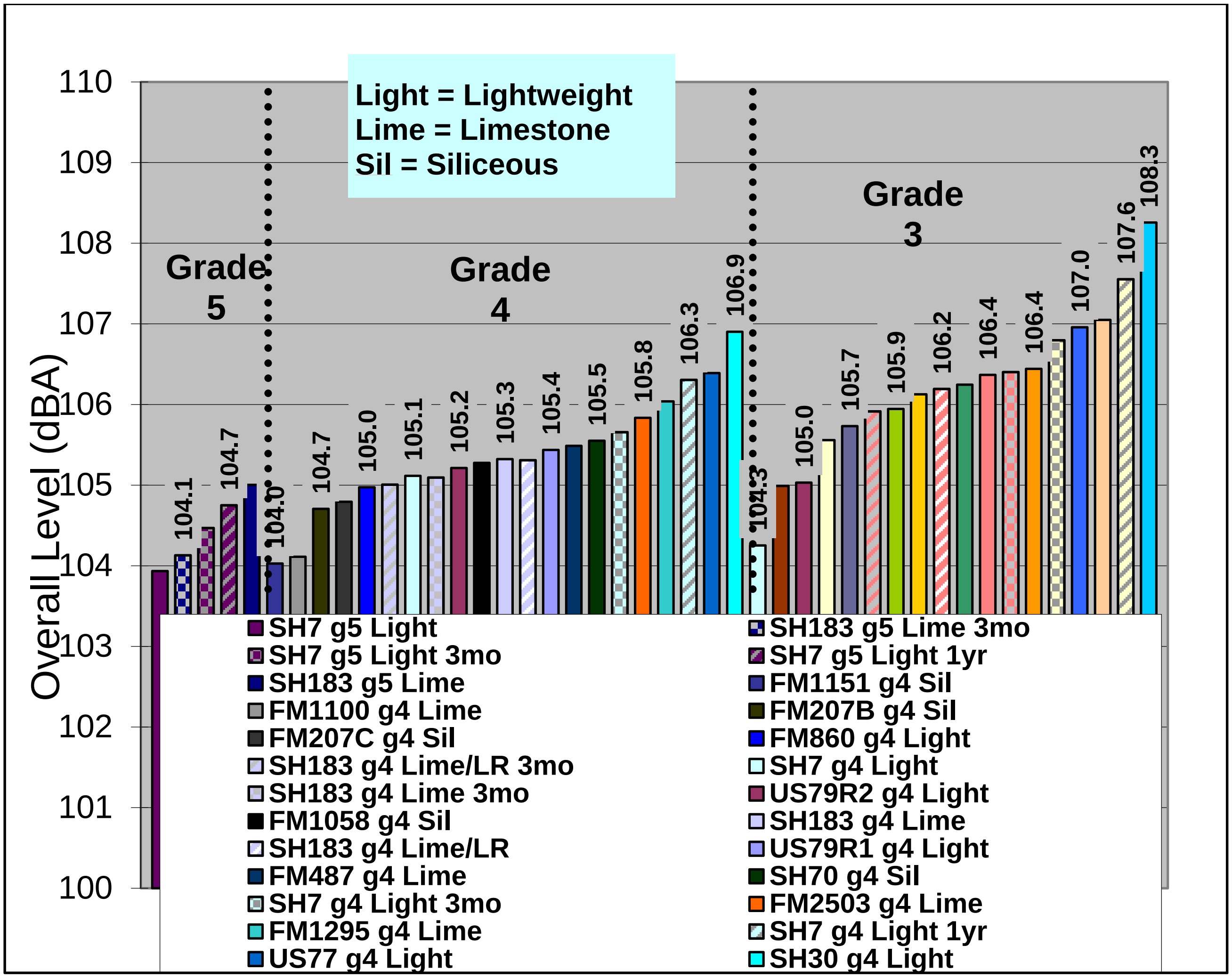

Figure 2. Grades 3, 4, and 5 Seal Coat Tire Pavement Noise Sound Intensity Measurements Collected by TxDOT Research Project 0-6496 Test Sites.

Other Considerations

High Traffic Volume Considerations

Seal coats are used in Texas routinely and effectively on both low and high-traffic volume roadways. When asphalt and aggregate application rates are applied correctly, there should be little to no loose stones. Stone loss is most likely to occur within the first few or hours or days after construction. This may happen if stones are not embedded properly, if the aggregate application rate was excessive, sweeping was inadequate, or if fast traffic is allowed on seal too soon. Concern for vehicle damage caused from dislodged aggregate may be the primary reason for not using seal coats on high-traffic volume roadways. Damage can occur to windshields, headlights, radiators, and vehicle paint.

To minimize the potential for vehicle damage, a small aggregate may be used (Grade 4 as opposed to Grade 3) and/or consider the use of lightweight aggregate.

Aggregate Type and Quality

Table 2 shows aggregate types allowed by TxDOT specifications. Type B is commonly specified and includes most of the crushed aggregates available to TxDOT (crushed limestones, crushed gravels, crushed igneous, crushed sandstones). Type D includes the same as Type B but excludes limestone rock asphalt (LRA). Types A and C allow uncrushed instead of crushed gravel as an option. Uncrushed materials are not usually desired for a final surface since better friction and interlocking can be obtained from the crushed faces as shown in Figure 3.

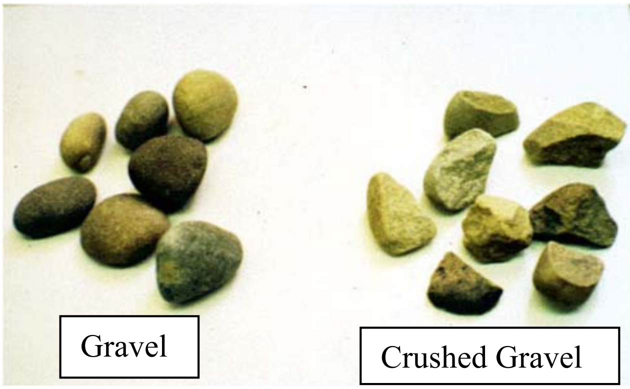

Figure 3. Types of Gravel.

LRA is commonly used in southern and central portions of the state, and it is only produced near Uvalde, Texas. It is a unique material that comes from a limestone formation that is infused with naturally occurring asphalt. This aggregate is also used to produce a commonly used cold mix for maintenance paving and patching applications (Item 330).

Type L aggregate is a lightweight aggregate that is a popular choice by many TxDOT districts for seal coat construction. There is currently only one producer located in Fairfield, Texas. It is produced by introducing the raw material (highly siliceous clay, shale, or slate) into a rotary kiln, similar to the type used in the Portland cement industry. As it passes through the kiln, the material reaches temperatures greater than 1800°F and begins to turn plastic. Internal gases cause the material to expand and create a mass of small air cells retained after the material cools and solidifies. After leaving the kiln, the material is cooled, crushed, and graded. The cellular structure and texture gives the aggregate good frictional properties (Figure 4). Lightweight aggregate weighs approximately half as much as natural aggregates.

Figure 4. Lightweight Aggregate for Seal Coat.

Table 2. Item 302 Aggregate Types (TxDOT 2014).

Type	Material
A	Gravel, crushed slag, crushed stone, or LRA
B	Crushed gravel, crushed slag, crushed stone, or LRA
C	Gravel, crushed slag, or crushed stone
D	Crushed gravel, crushed slag, or crushed stone
E	Aggregate as shown on the plans
L	Lightweight aggregate
PA	Precoated gravel, crushed slag, crushed stone, or LRA
PB	Precoated crushed gravel, crushed slag, crushed stone, or LRA
PC	Precoated gravel, crushed slag, or crushed stone
PD	Precoated crushed gravel, crushed slag, or crushed stone
PE	Precoated aggregate as shown on the plans
PL	Precoated lightweight aggregate

The aggregates selected for use in seal coats or surface treatments should provide sufficient friction to satisfy the frictional demands of the roadway. The TxDOT Wet Weather Accident Reduction Program (WWARP) provides methods to ensure that pavements with good skid-resistant characteristics are constructed. The guidelines address three separate but interrelated aspects of pavement friction safety: accident analysis, aggregate selection, and skid testing.

For complete details on aggregate selection, refer to the TxDOT WWARP in the *Pavement Design Manual*. The designer should consider the guidelines presented in the WWARP and, using engineering judgment, determine the overall frictional demand of the roadway surface. TxDOT Standard Specification Item 316, Surface Treatments, states "…. unless otherwise shown on the plans, furnish aggregate with a minimum 'B' (i.e., A or B is permitted) surface classification."

A listing of surface aggregate classifications by source is contained in the Bituminous Rated Source Quality Catalog maintained by the Construction Division. These classifications are based on a combination of friction and durability properties of the aggregate. For example, a surface aggregate classification (SAC) of A is assigned to an aggregate that has high frictional and durability properties.

SAC A sources typically include igneous rocks, sandstones, most gravel sources, and lightweight. The most commonly available aggregates to much of the state are the limestone quarries, which are for the most part SAC B classifications. One of the complaints often heard about some seal coats constructed of limestones is that their life is shorter due to wearing down of the aggregate surfaces by traffic. While the limestone quarries produce SAC B materials, there is still a range of quality that exists within the SAC B classifications, particularly for durability as measured by Los Angeles Abrasion and Soundness.

Researchers measured the wear characteristics of different types of seal coat aggregates (Figure 5). Based on the data from this study, researchers determined that the wear characteristics for LRA was significantly greater than other limestones; however, even the limestones with poor soundness performed as well as those with much better soundness values in terms of wear.

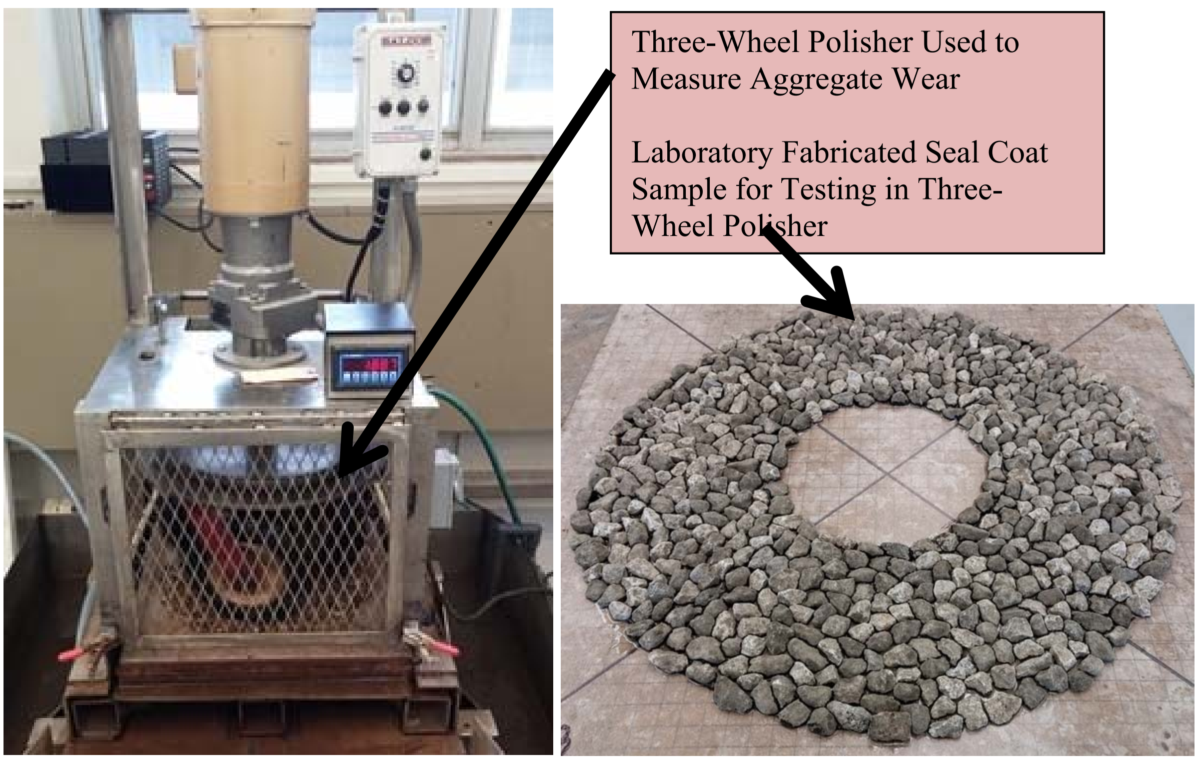

Figure 5. Seal Coat Aggregate Wear Testing Using Three-Wheel Polisher.

PRECOATING REQUIREMENTS

Precoating versus Not

The decision on whether to precoat the aggregate or not depends on the binder selected for the seal coat. If an emulsion is used, then the aggregate should be left uncoated. If a hot asphalt binder is used, then precoating is recommended. Sometimes, situations may arise such as the following real life scenario:

> We are using an [asphalt cement] AC-20-5TR for our districtwide program but fall is approaching and the weather is beginning to get cool. We want to switch to an emulsion, but we have all of this precoated aggregate on hand. Can it be used with the emulsion?

The answer to the above question is yes. However, keep in mind that it may take a little longer for the emulsion to break and traffic may need to be kept off longer. Emulsions lose their water by evaporation but also by water being absorbed into the aggregates. Precoating will prevent the water from absorbing into aggregate surfaces.

Precoating Materials and Quantity

Precoating is typically accomplished in a hot mix plant using either hot asphalt cement (such as AC-10 or AC-20) or emulsions (such as MS-1 or SS-1). LRA aggregates are precoated with a flux oil.

Around 1 percent of residual asphalt is a common quantity for precoating aggregate. According to Item 302, the engineer may require trial batches to assist in selecting a target value for the precoating material. This is recommended to ensure that adequate coating is achieved. TxDOT does not require a minimum percent coating, but the aggregate must be visually evaluated and shall be coated uniformly and adequately to the engineer's satisfaction. Research has shown that best performance is achieved when the level of coating is 90 percent or greater (such as that shown in Figure 6). LRA aggregates that are coated with a flux oil will have a different appearance as shown in Figure 7.

Figure 6. Uncoated and Acceptably Precoated Limestone.

Figure 7. LRA Aggregate Precoated with Flux Oil.

Item 302 allows the use of antistripping additives when shown on the plans. Aggregates, such as limestone, may not benefit from the use of an antistripping additive since the precoat material will absorb into the surface of the limestone and form a good bond. On the other hand, when igneous and gravel aggregates are used, an antistripping additive is recommended. These are non-absorptive materials and are prone to stripping in the presence of moisture. Several seal coat failures have occurred recently where all aggregate was lost when a rainstorm occurred within a few days of construction. These were projects that were constructed with AC-20-5TR and precoated igneous or gravel aggregates. If the precoat is not bonded well to the aggregate surface, then the aggregate will not be bonded well to the seal coat asphalt.

The quantity of dust present in the aggregate at the time of precoating is also a very important factor. Research has shown that when the quantity of dust is 3 percent or more at the time of precoating, seal coat aggregate loss increases significantly. Item 302 accounts for this by only allowing 1.5 percent dust in the decantation test (Tex-406-A) and requires that aggregates meet all of the quality requirements prior to precoating.

GUIDELINES FOR SELECTING ASPHALT BINDERS FOR SEAL COATS

According to the Asphalt Institute, asphalts for seal coats should have the following characteristics:

- When applied, the binder should be fluid enough to spray and cover the surface uniformly, yet viscous enough to remain in a uniform layer and not puddle in depressions or run off the pavement.
- After application, it should retain the required consistency to wet the aggregate.
- It should develop adhesion quickly.
- After rolling and curing, the binder should hold the aggregate tightly to the roadway surface to prevent dislodging by traffic.
- When applied in the proper amount, it should not bleed or strip under traffic or with changing weather conditions.

Binders used for seal coats must conform to Item 300 of TxDOT's Standard Specifications (2014), and Item 300 lists many binders that may be used for surface treatments; however, the most commonly used and those recommended for summertime seals are discussed below.

ASPHALT RUBBER BINDERS

Asphalt-Rubber (A-R) binders are mixtures of asphalt cement and reclaimed tire rubber, which have been reacted at elevated temperatures. This reaction occurs in a blending plant that is often portable and set up on site. The blending of the hot asphalt cement and the rubber particles occurs at an elevated temperature over several hours causing the rubber particles to swell. The viscosity of the material is monitored in the field using a handheld viscometer (Figure 8) to determine when the desired result is achieved. This high-viscosity material has a consistency similar to oatmeal, which requires that the tips of the spray bars be enlarged to accommodate the material. A-R binders contain a minimum of 15 percent crumb rubber modifier, and there are two A-R types allowed by the specification: A-R Type II and A-R Type III. The Type III binder is softer than the Type II and may be better suited to the northernmost regions of the state.

Figure 8. Field Viscosity Testing of A-R Binder.

For a given aggregate, A-R binders can be shot at a higher application rate than conventional ACs without contributing to flushing problems. This higher application rate provides for better sealing capability on cracked pavements, and the tire rubber modifier is thought to provide increased flexibility to withstand the movement of the cracks. A-R binders have been used successfully by many districts as a stress-absorbing membrane interlayer between an old pavement and new overlay to reduce the rate at which reflection cracks reappear. A-R binders also have good adhesion and have been used to successfully seal Portland cement concrete pavement and bond subsequent layers to the concrete.

ASPHALT CEMENT

Hot-applied AC is the most common type of binder used for districtwide seal coat construction in Texas, and a precoated aggregate is usually required. Two types of polymer-modified asphalt cements have been used extensively for seal coats: AC-20-5TR and AC-20 XP. The AC-20 5TR contains 5 percent tire rubber while the AC-20 XP contains another type of polymer but both products are comparable to each other. Softer asphalts with less polymer modification include AC-10 2TR, AC-15P, AC-5 w/2%SBR, and AC-10 w/2% SBR, and these products may be better suited to the northern districts.

Unmodified asphalt cements that can be used for seal coats include AC-5 and AC-10 but are reserved for use on low volume facilities. Performance of seal coats is highly dependent on workmanship and correct application rates for binder and cover stone. However, the use of polymer-modified binders can be like buying insurance against workmanship issues. Rock loss typically occurs in the first few weeks after construction, and polymer modified materials aid in holding rock even when too little asphalt may have been applied. Flushing/bleeding is usually caused by application of too much asphalt, but polymer modified binders can minimize the severity of the flushing. The polymer-modified materials help to ensure better adhesion to the aggregate and existing pavement.

EMULSIONS

Asphalt emulsions consist of AC droplets suspended in water. This dispersion, under normal circumstances, would not take place, since oil and water do not mix. If an emulsifying agent is added to the water, the asphalt cement will remain dispersed. In the production of asphalt emulsion, water is mixed with an emulsifying agent and is pumped to a special mixer called a colloid mill along with the asphalt. The colloid mill breaks the asphalt into tiny droplets less than 5 microns in diameter, as shown in Figure 9. The emulsifying agent migrates to the asphalt-water interface and keeps the droplets from coalescing, because the asphalt droplets all carry the same electric charge.

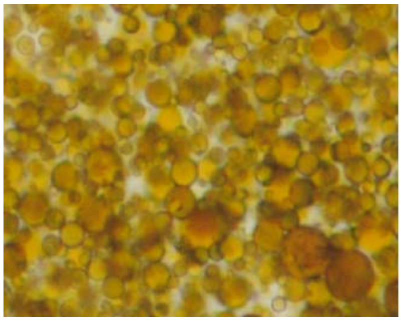

Figure 9. Greatly Magnified Asphalt Emulsion.

Emulsions are produced for ease of application and safety for field personnel. Emulsions enable much lower application temperatures of 120° to 160°F. Conventional asphalt cements are applied between 275° and 350°F. Emulsions are comprised of about 35 percent water, and at ambient temperature have the consistency and color of chocolate milk (Figure 10).

After emulsion and aggregate have been applied to the road surface, the emulsion breaks leaving the asphalt cement holding the aggregate. The rate of breaking is controlled by the type and concentration of emulsifying agent and atmospheric conditions.

Figure 10. Spray Applications of Emulsion.

There are two general types of emulsions used for seal coat applications: cationic and anionic. The cationic emulsions include:

- CRS-2 (Cationic Rapid Set with no polymer modification).
- CRS-2H (Cationic Rapid Set with no polymer modification. The "H" means it has a harder base binder).
- CRS-2p (includes polymer modification).
- CHFRS-2p (Cationic High Float Rapid Set, polymer-modified).

The anionic emulsions include:

- HFRS-2 (High Float Rapid Set).
- HFRS-2P (High Float Rapid Set, polymer modified).

The advantage of emulsions over asphalt cement is that they are applied at much lower temperatures (140°F versus 300°F+) and can be more forgiving and easier to work with. They can readily coat damp aggregates, and because they are composed of 30 percent water, the aggregate has an initially higher embedment depth. As the emulsion breaks, the residue is deposited up on the sides of the aggregate particles, which can minimize the propensity for shelling or rock loss, as illustrated in Figure 11. Aggregates used with emulsions should not be precoated.

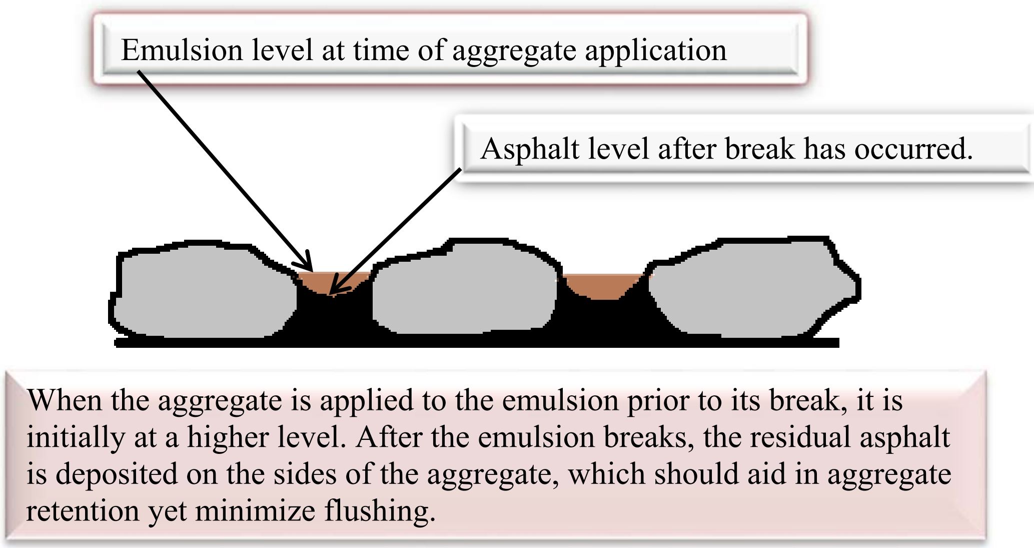

Figure 11. Illustration of Emulsion Seal Coat after Break Has Occurred.

Cationic emulsions break quicker than anionic, are generally attracted to the rock more than anionic, and can be opened to traffic sooner. Cationic emulsions are a good choice in high humidity areas and if the aggregate is clean. Anionic emulsions, though slower to cure, are a good choice if the aggregate is excessively dusty and is in a low humidity area. The slower cure allows time for the binder to wick its way through the dust on the aggregate and achieve a good bond.

The residual asphalt used in high float emulsions is resistant to flow. In theory, high float products should not be as prone to flushing and should be less likely to migrate through an overlay when used in underseals.

POLYMER MODIFICATION

Polymers are added to improve adhesion, shorten return to traffic times, and reduce the temperature susceptibility the binder may see in-service, translating to less propensity for flushing in high temperatures and better cracking resistance and rock loss at low temperatures.

Any of the seal coat binders that have a designation of p, TR, or XP in their nomenclature or any of the A-R binders have the effect of polymer modification. These binders should improve both the low and high in-service temperature performance of seal coats.

SEAL COAT BINDER SELECTION GUIDELINES

For several years, TxDOT has used the Seal Coat Material Selection Table (SCMST) either as a mandate or as a guideline. The SCMST shown in Figure 12 uses a tiered approach to binder selection based on the type of traffic on the section that is to be sealed. In Tier I roads (Heavy Use), stiffer binders such as A-R, AC-20 5TR, AC-20 XP, and AC-15P are included. For Tier II roads (moderate use), softer base asphalt cements and emulsified asphalts modified using block co-polymers or tire rubber are recommended. In Tier III roads (low use), unmodified softer asphalt cement binders such as AC-5, AC-10, and emulsified asphalts were included. At a time when availability of preventive maintenance funds is limited, this binder selection procedure appears to be rational.

However, the service conditions of roadways with seal coat surfaces have changed over the years. With higher speed limits even in minor collector roadways where seal coats are commonly used, one can see heavy trucks using them. Even though the truck traffic volumes are not as high as on other major collectors and arterials, these minor collectors such as farm-to-market roads do take a beating from even low volumes of heavy traffic. This is further accentuated by the changes in climate patterns resulting in drought conditions for extended periods such as during summer 2011. This flushing performance even on low volume roadways is evident from Figure 13 where the Surface Condition Index (SCI) for flushing is plotted against estimated cumulative truck traffic during its service period until the date of survey in July 2014. Figure 13 shows that unacceptable levels of flushing, as evidenced by SCI values below 60, was present on highways that had a wide range of truck volumes from very low to very high. In low truck volume roadways, the softer asphalt binders recommended in the SCMST are not able to withstand even low numbers of heavy traffic.

The non-recoverable creep compliance values calculated from the Multiple Stress Creep Recovery (MSCR) test for commonly used seal coat binders such as AC-10, AC-10 2TR, AC-15P, AC-20 5TR, AC-20 XP, and A-R showed significantly different performances from binders tested at 64°C (Estakhri and Senadheera, 2016). Softer asphalt cement binders such as AC-10 and softer but modified binders such as AC-10 2TR showed significant non-recoverable strain build-up during the 10 cycles of MSCR test for both un-aged and RTFO-aged binder. The stiffer binders such as A-R, AC-20 XP, AC-20 5TR, and AC-15P showed much improved performance for flushing behavior as indicated from lower non-recoverable creep compliance values. This shows that using low-cost softer binders in low ADT highways is not likely to reduce flushing of the seal coat and will lead to wet-weather traffic safety problems.

Texas Department of Transportation

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Seal Coat Material Selection Table		
Tier I: Heavy Use - Use only the selected materials.		
Type	Asphalt Rubber (A-R) A-R Only	Asphalt Cement (AC) AC Only
Asphalt	A-R Ty II A-R Ty III SP 300-	AC-20-5TR AC-20XP AC-15P SP 300-
Tier II: Moderate Use - Use these materials or any selected Tier I material combinations of the allowed types.		
Type	Asphalt Cement (AC) AC Only	Asphalt Emulsion Emulsion Only
Asphalt	AC-10-2TR AC-15P AC-20XP AC-10 w/2%SBR AC-5 w/2%SBR SP 300-	CHFRS-2P HFRS-2P CRS-2P SP 300-
Tier III: Light Use - Use these materials or any selected Tier I or Tier II material combinations of the allowed types.		
Type	Asphalt Cement (AC) AC Only	Asphalt Emulsion Emulsion Only
Asphalt	AC-10 AC-5 SP 300-	CRS-2 CRS-2H HFRS-2 SP 300-
Districtwide Seal Coat Project Seasons: Refer to Item 316 for temperature and weather restrictions.		
Season 1: AMA, CHS, LBB		May 15 to Aug 31
Season 2: ABL, ATL, BWD, DAL, FTW, LFK, ODA, PAR, SJT, TYL, WAC, WFS		May 1 to Aug 31
Season 3: AUS, BMT, BRY, ELP, HOU, SAT, YKM		May 1 to Sept 15
Season 4: CRP, LRD, PHR		Apr 1 to Sept 30
Note: Seal coats on routine maintenance contracts must be completed by August 31 unless otherwise shown on the plans.		

Figure 12. TxDOT SCMST.

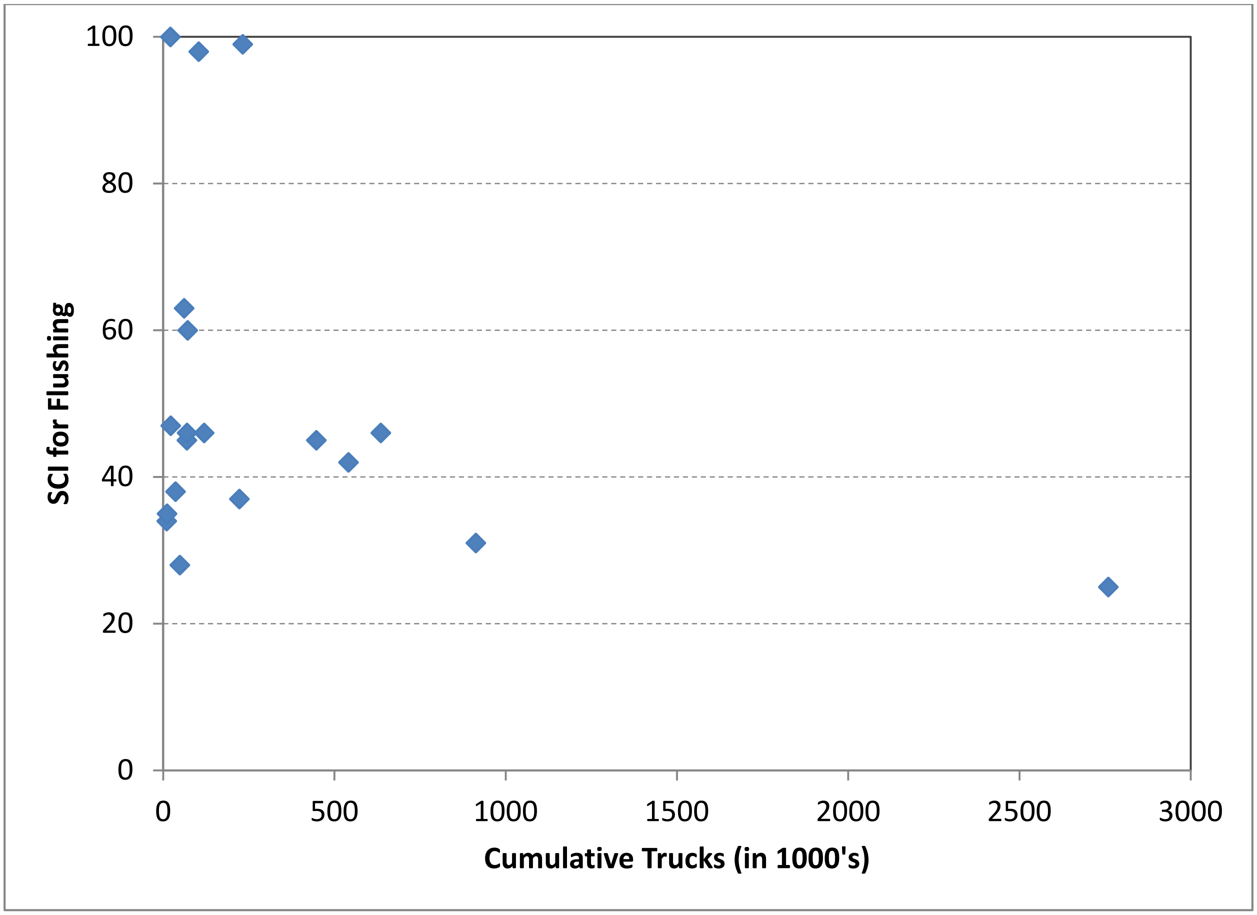

Figure 13. Surface Condition Index for Seal Coat Surfaces vs. Estimated Cumulative Heavy Trucks.

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