SEAL COAT HANDBOOK

DHT-13

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16. Abstract

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Also contained in this handbook are experiences of individuals in different areas of the state. Rather than giving District by District information, Districts are combined into areas. Dividing the Districts into areas is justifiable because a survey of seal coat experience showed similar problems and results in Districts within certain parts of the state due to similar climatic and environmental conditions.

Lastly, selected asphalt additives are researched and discussed. Detailed explanations of advantages of polymers and latexes are given along with tables describing some manufactured additive products.

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SEAL COAT HANDBOOK

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and Public Transportation

Division 10 (Research)

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Introduction

This report is developed and reported in a handbook format in order to present seal coat information in an easy to follow and easy to understand sequence. Contained in this handbook are the various aspects of seal coats from asphalt to aggregate and surface preparation to final cleaning. A popular seal coat design method is also included for easy reference.

Also contained in this handbook are experiences of individuals in different areas of the state. Rather than giving District by District information, Districts are combined into areas as shown in the appendix. Dividing the Districts into areas is justifiable because a survey of seal coat experience showed similar problems and results in Districts within certain parts of the state due to similar climatic and environmental conditions.

Lastly, selected asphalt additives are researched and discussed. Detailed explanations of advantages of polymers and latexes are given along with tables describing some manufactured additive products.

Definition

A seal coat is a bituminous surface that results from one or more successive alternative applications of bituminous binder (asphalt) and cover aggregate in order to seal an existing paved surface. This is not a permanent maintenance process. The service life of seal coats on average is 5 to 7 years depending upon traffic volumes, weather, construction techniques, etc. Construction and subsequent satisfactory performance of seal coats depends on or is affected by several factors: quality of materials (asphalt and aggregate), adequate labor and equipment, careful design of material quantities and thorough exploitation of experience, strict control of application quantities and operational (construction) methods, sufficient traffic control to ensure minimum loss of aggregate, good pavement surface conditions (levelled or patched as needed), and suitable atmospheric conditions. Favorable weather conditions are important because inclement weather (cold, wet), particularly in combination with high-volume traffic, can be detrimental to seal coat construction and performance.

Uses of Seal Coats

Seal coats are capable of preventing and correcting a wide variety of maintenance problems. Seal coats can seal existing pavements against the penetration of air and/or water, thus reducing pavement oxidation, and can enrich a dry and/or ravelled surface. Seal coats can also provide or improve skid resistance qualities of a pavement surface as well as arrest fatigue block deterioration. Lastly, seal coats can increase visibility and demarcation of traffic lanes, improve the appearance of the highway by making it more uniform, improve nighttime visibility, and correct surface deficiencies such as small cracks, ravelling (or shelling), and flushing.

Seal coats *do not* strengthen the existing pavement, increase load-bearing capacity, smooth out rough pavement, bridge major cracks (nothing > 1/8"), or eliminate maintenance or reconstruction.

Asphalt for Seal Coats

Three common asphalt binder classifications are asphalt cement, cutback asphalt, and emulsified asphalt. Each one shall be discussed below.

Asphalt cement is a pure form of asphalt, i.e., no chemicals, and is commonly used in seal coat work. For example: AC-5 is preferred in areas of average temperatures. AC-10 is preferred in warmer areas. Asphalt cement requires a high application temperature (250 to 450 degrees F), which is difficult to maintain, and the cover stone must be applied rapidly.

Cutback asphalts are asphalts liquefied by blending with petroleum solvents called diluents or cutters. The solvents make the asphalt more workable and easier to spray and will evaporate leaving pure asphalt cement. Cutbacks are sprayable at lower application temperatures than pure asphalt (50 to 250 degrees F) and will remain fluid for a longer period after they have been applied to the road. However, they do not obtain their ultimate strength until a good part of the solvent has escaped (evaporated).

Emulsified asphalt is a combination of asphalt concrete, water, and an emulsifying agent. The emulsifying agent determines whether the mixture is anionic (negatively charged) or cationic (positively charged). The two should never be mixed. Emulsions are handled at lower temperatures (50 to 150 degrees F), can be mixed with damp and cool aggregates, and can be made with high viscosity to resist run-off on supers, crowns, and grades. Emulsions are not compatible with cutbacks or asphalt cements and if they are overheated (boiled) or frozen, they can break and become unusable.

Asphalt for Seal Coats (cont.)

Different types of emulsions include cationic rapid set (CRS), anionic, high float (HF), and polymer-modified emulsions (PMA). CRS-2 and CRS-2P may cure very slowly in hot, dry weather (CRS-2P more than CRS-2) causing rock to be whipped off or picked up by traffic. High float emulsions exhibit a longer life in some cases, have been used with good results in fairly arid climates and with high limestone (carbonate) content (70%) aggregate, perform satisfactorily with graded aggregate design, and normally can be opened to traffic in a shorter period of time. Polymer-modified emulsions have aggregate and asphalt application rates essentially the same as conventional emulsions. The stickiness of the PMA has caused some districts to increase the aggregate rate slightly (approximately 5%) to insure that the spreader and roller tires will not come in contact with the asphalt and cause picking up of the rock to occur.

A list of advantages and potential problems of asphalt cement, cutback asphalt, and emulsified asphalts is contained in Table 1. Tables and figures are especially helpful in the selection of asphalt binders. Asphalt selections based on climatic conditions is contained in Table 2 with an illustration of climatic zones in Figure 1, application, mixing, and storage temperatures for asphalt binders are listed in Table 3, and further discussion of polymers and other additives are in the supplemental section.

Table 1: Comparison of Asphalt Product Types Used for Surface Treatments and Seal Coats

Asphalt Type	Advantages	Potential Problem Areas
Asphalt Cement	1. Few cure time problems: road surface will usually accept traffic without shelling when rolling is completed.	1. High spraying temperature required: a. May reduce durability of asphalt if over-heated. b. Introduces operator safety and discomfort problems. c. Demands careful control to obtain uniform asphalt distribution. d. Is influenced by atmospheric and road surface temperatures. 2. Sensitivity to aggregate surface moisture. 3. Aggregate must be spread and rolled soon after asphalt is distributed.
Asphalt Emulsion (Anionic)	1. Can be applied at or above ambient temperature. 2. Water dilution can be used except for rapid setting emulsions.	1. Separation of asphalt and water on long storage or after freezing. 2. Asphalt stripping with high silica aggregates. 3. Emulsion may run off if road surface tempera-ture is too high. 4. Cure time problems: traffic control required until cure is completed. 5. Will seperate if mixed with cationic emulsions.
Asphalt Emulsion (Cationic)	1. Can be applied at or above ambient temperature. 2. Good adhesion with all aggregate types. 3. Good adhesion with moist aggregates. 4. Can be used in cool weather. 5. Resistant to wash-off if rain occurs soon.	1. Separation of asphalt and water on long storage or after freezing. 2. Emulsion may run off if road surface tempera-ture is too high. 3. Water dilution may cause premature break. 4. Cure time problems: traffic control required until cure is completed. 5. Will break if mixed with anionic emulsions.
Cut-Back Asphalt	1. Convienent to use: uniform distribution 2. Requires lower spraying temperature than asphalt cement. 3. Can be used in cool weather. 4. Residue will not be brittle in cold weather.	1. Cure time problems. 2. Cut-back solvent creates air quality problems. 3. Waste of energy in cut-back solvent. 4. Solvents have low flash and fire points thus a workman safety hazard. 5. Flushing problems.

(Ref. 9, 10)

Table 2: General Recommendations for Asphalt Selection Based on Climatic Conditions.

Type of Asphalt	Construction Season: Spring			Summer			Fall			Winter		
Climatic Region (See Figure 1)	I	II	III	I	II	III	I	II	III	I	II	III
Asphalt Cements ††												
AC - 5	*			*	*	*	*	*	*			
AC - 10				*	*		*					
Anionic Emulsions												
EA-HVRS	†	†		†	†	*	†	†	*	†	†	
EA-HVRS-90	†	†		†	†							
Cationic Emulsions												
EA-CRS-2	*	*		*	*	*	*	*	*	*	*	
EA-CRS-2h				*	*							
Cutbacks												
RC - 2								*	*		*	*
RC - 250								*	*		*	*
RC - 3								*	*		*	*
RC - 4		*	*					*	*	*	*	*
RC - 5		*	*					*	*	*	*	*
MC - 800								*	*		*	*
MC - 3000								*	*		*	*

Spring - March, April, May

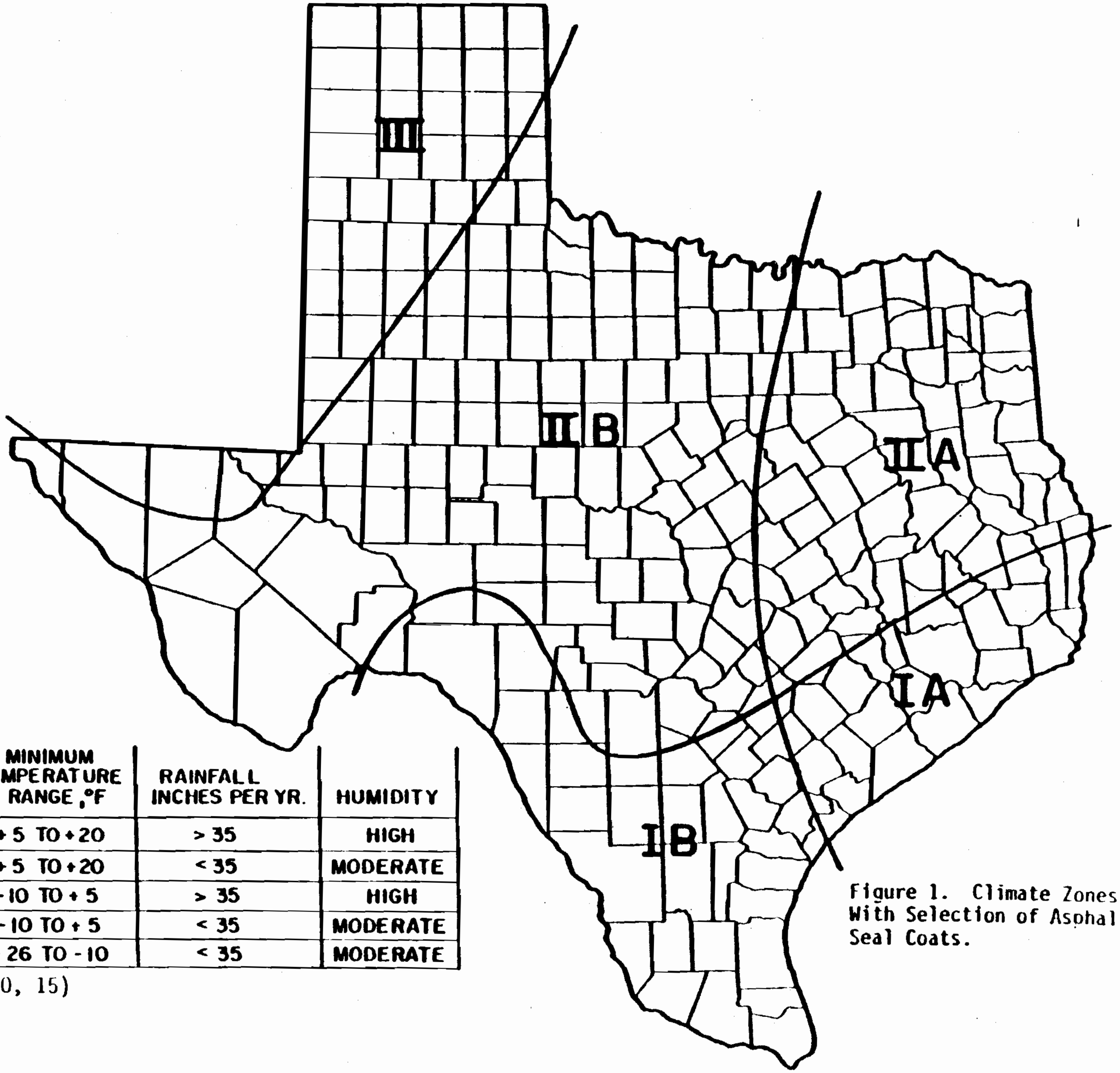
Summer - June, July, August

Fall - September, October

Winter - November, December, January, February

* - Indicates that this grade of asphalt can be used for defined applications.
† - Do not use in high humidity areas.
†† - Use caution when using dusty rock.

(Ref. 9, 10)



ZONE	MINIMUM TEMPERATURE RANGE, °F	RAINFALL INCHES PER YR.	HUMIDITY
IA	+5 TO +20	> 35	HIGH
IB	+5 TO +20	< 35	MODERATE
IIA	-10 TO +5	> 35	HIGH
IIB	-10 TO +5	< 35	MODERATE
III	-26 TO -10	< 35	MODERATE

(Ref. 9, 10, 15)

Figure 1. Climate Zones Associate With Selection of Asphalt Type for Seal Coats.

Table 3. Typical Temperatures for Applying, Mixing and Storing Asphalt Binders

Type of Asphalt		Application and Mixing: Recommended Range °F	Application and Mixing: Maximum Allowable, °F	Heating and Storage Maximum, °F
Asphalt Cement	AC-5	275-325	350	400
	AC-10	275-325	350	400
Anionic Emulsions	EA-HVRS	110-150	160	160
	EA-HVRS-90	110-150	160	160
Cationic Emulsion	EA-CRS-2	110-150	160	160
	EA-CRS-2h	110-150	160	160
Cutbacks	RC-2	125-180	200	200
	RC-250	150-200	210	210
	RC-3	160-210	230	230
	RC-4	180-240	270	270
	RC-5	215-270	285	285
	MC-800	175-260	275	275
	MC-3000	225-275	290	290

(Ref. 9)

Asphalt Application

Factors which influence the application rate of asphalt include:

1) Dryness of old pavement - dryer → more asphalt (correction factor called "hunger factor").
2) Gradation of aggregate - larger aggregate → more asphalt to embed properly.
3) Type of aggregate - porous aggregate → more (10%) asphalt than natural aggregate.
4) Type asphalt - influences application rate,
5) Traffic volume - higher traffic → lower amount of asphalt.
6) Transverse variation - adjust nozzle size to, for example, apply less asphalt in the wheel paths and a greater amount at the lane edges and between the wheel paths.
7) Climatic region in which the seal coat is to be constructed - minimum temperature, rainfall, and humidity.

Application should be limited to a time when the roadway surface is 60 degrees F or higher, humidity is 50% or lower, and under low wind conditions to avoid quick or over-drying and dust. Asphalt application will be discussed further in the design and construction portion of this manual.

Aggregates for Seal Coats

Selection of aggregate depends on whether skid resistance, cost, duration, or other factors are of most importance and/or concern. Aggregate selections include different grades, precoated or uncoated, normal or lightweight, and/or natural or synthetic.

Optimum gradation of aggregate is dependent upon the type of aggregate, volume of traffic, climatic region, etc. Grades 4 and 5 are the most common in seal coats. The grade 4 is usually used with higher traffic volumes and the grade 5 is usually used with lower traffic volumes. Larger aggregates require more asphalt and are thus more costly. Table 4 shows gradation specifications for Texas DHT grades of uncoated and precoated aggregates and Table 5 shows gradation for grades of lightweight aggregates.

Precoated aggregates have been utilized to reduce aggregate dust, to reduce automobile damage due to flying stones, and to promote bond with the asphalts. The types of uncoated and precoated aggregates referenced in Texas specifications are listed in Table 6.

Lightweight and/or normal weight aggregate selection depends on the aforementioned factors, traffic volumes, and availability. The potential benefits and problems associated with each type are discussed in Table 7.

Table 4

Uncoated and Precoated	% by Weight
Grade 3:	
Retained on 3/4" sieve	0
Retained on 5/8" sieve	0 - 2
Retained on 1/2" sieve	20 - 35
Retained on 3/8" sieve	85 - 100
Retained on 1/4" sieve	99 - 100
Retained on No. 10 sieve	99 - 100
Grade 4:	
Retained on 5/8" sieve	0
Retained on 1/2" sieve	0 - 2
Retained on 3/8" sieve	20 - 35
Retained on No. 4 sieve	95 - 100
Retained on No. 10 sieve	99 - 100
Grade 5:	
Retained on 1/2" sieve	0
Retained on 3/8" sieve	0 - 5
Retained on No. 4 sieve	40 - 85
Retained on No. 10 sieve	98 - 100
Retained on No. 10 sieve	99 - 100

(Ref. 16)

Table 5

Lightweight	% by Weight
Grade 3:	
Retained on 3/4" sieve	0
Retained on 5/8" sieve	0 - 5
Retained on 1/2" sieve	30 - 50
Retained on 3/8" sieve	85 - 100
Retained on 1/4" sieve	95 - 100
Retained on No. 10 sieve	98 - 100
Grade 4:	
Retained on 5/8" sieve	0
Retained on 1/2" sieve	0 - 5
Retained on 3/8" sieve	20 - 40
Retained on No. 4 sieve	95 - 100
Retained on No. 10 sieve	98 - 100
Grade 5:	
Retained on 1/2" sieve	0
Retained on 3/8" sieve	0 - 2
Retained on No. 4 sieve	60 - 80
Retained on No. 10 sieve	98 - 100

(Ref. 16)

Table 6

Uncoated	Precoated	Description
A	PA	Gravel, crushed slag, crushed stone, or natural limestone rock asphalt.
B	PB	Crushed gravel, crushed slag, crushed stone, or natural limestone rock asphalt.
C	PC	Gravel crushed slag, or crushed stone.
D	PD	Crushed gravel, crushed slag, or crushed stone.
E	PE	Natural limestone rock asphalt.
E	PF	As shown on the plans.

(Ref. 16)

Table 7

Aggregate Type	Potential Benefits	Potential Problems
Lightweight	1. High skid resistance 2. Reduce windshield damage4. 3. Good color contrast 4. Reduce paint stripe maintenance	1. Aggregate degradation during handling 2. Abrasion resistance 3. Gradation control 4. High water absorption 5. Higher cost
Normal Weight	1. Availability and cost 2. Relatively low water absorption 3. High resistance to degradation and abrasion	1. Poor skid resistance if polish value is low 2. Windshield damage 3. Poor asphalt adhesion with high silica aggregates 4. Dust

(Ref. 9, 16)

Aggregates for Seal Coats (cont.)

Natural and/or synthetic aggregate selection depends on the type of roadway, volume of traffic, weather conditions, availability of the aggregate, and cost. Advantages favoring the use of synthetic aggregates include:

1) Traffic paint adheres to and provides a longer lasting traffic stripe on synthetic aggregate seal coats as opposed to natural aggregate seal coats.
2) Windshield damage and paint damage is significantly reduced or eliminated, and
3) Adequate surface friction is maintained longer.

Causes of poor synthetic aggregate seal coat performance and the solutions to the problems are listed in Table 8.

It must be remembered that, when using the different selections described above, embedment of aggregate in the asphalt is important and each selection will require a different shot rate. Too much asphalt may lead to bleeding or flushing while too little may lead to dislodging. Embedment also affects the mat thickness as illustrated in Figure 2.

Overall, aggregate is expected to resist the deteriorating effects of weathering and traffic, to have the ability to transmit traffic loads to the underlying surface, and to resist polishing.

Design and Construction

Design and construction procedures must work hand in hand in order to complete a successful seal coat project. If one of these procedures fails, it is almost assured the overall product will be deficient in one form or another. Key factors which may contribute to the construction of successful, high quality seal coats include:

1) Carefully planned sequence and timing of construction operations.
2) Proper preparation of the existing surface upon which the seal coat is to be placed, i.e., all repairs including patching, large crack sealing, cleaning, etc., of pavement must be done in advance of the seal coat.
3) Selection of equipment in good operating condition and proper handling of equipment during construction. For example, a conservative estimate for proper rolling would be 2000 sq. yds./hour.
4) Satisfactory environmental conditions. Examples include application of seal coats in humidity greater than about 50% is risky. Hot, dry weather with low winds and no forecast of rain is ideal.

Table 8

Causes of Poor Performance	Solutions
1. Wet aggregate → inadequate bond for bond for traffic conditions.	1. Allow sufficient time for proper bond to be established. Keep traffic low and slow.
2. Rainfall after construction → inadequate bond resulting in stripping or displacement of the asphalt from the aggregate surface by water.	2. Check weather forecasts.
3. Degradation of aggregate during transportation → dust and poor bond between asphalt and aggregate.	3. Alter manufacturing operations, i.e., precoating of the aggregate to minimize dust.
4. Degradation of aggregate during or immediately after construction → flushing.	4. Alter construction techniques. Steelwheel rollers should **never** be used in sealcoat construction and excessive use of pneumatic tired rollers is not recommended. Aggregate quantities should be limited to only the necessary amount.

(Ref. 7)

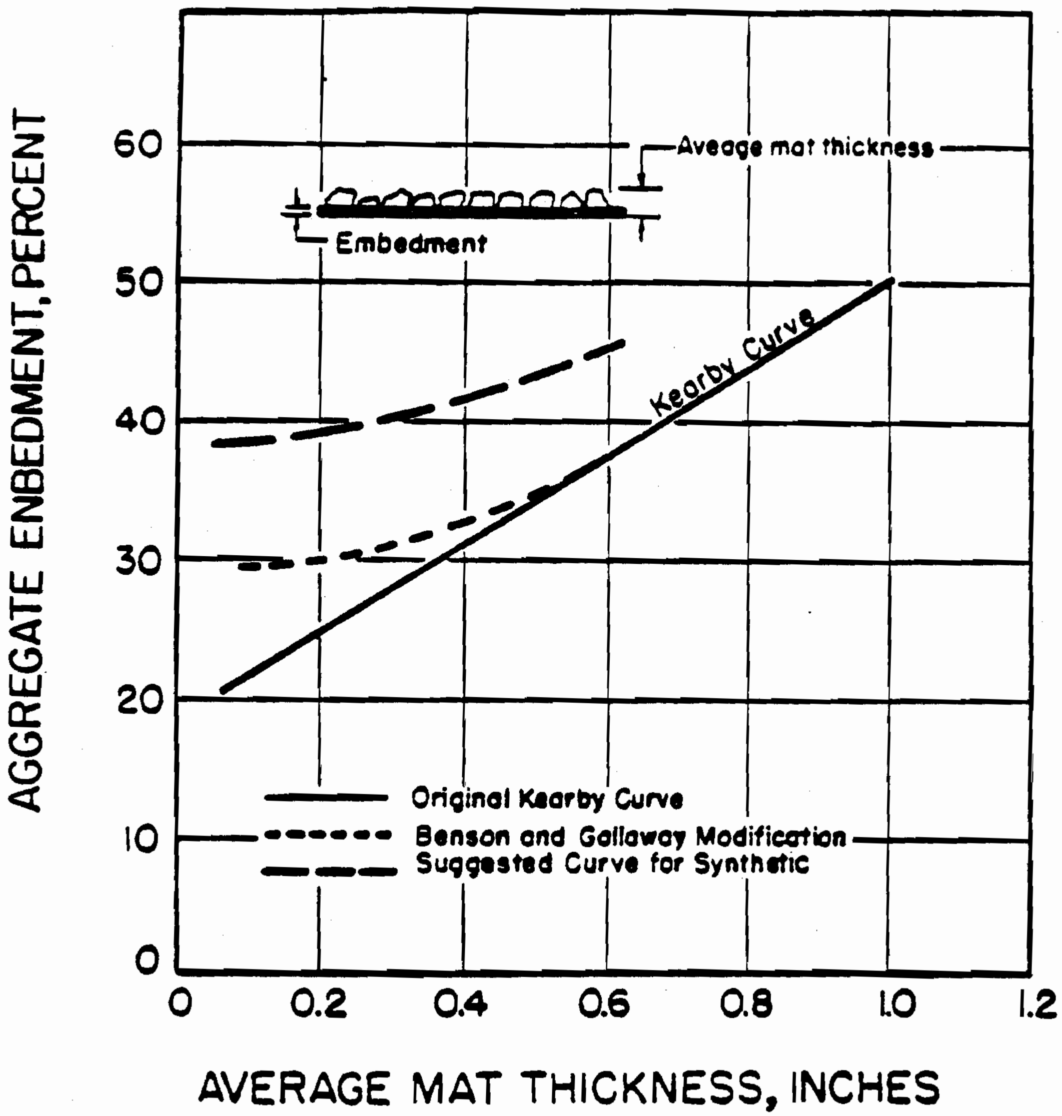


Figure 2. Relation of Percent Embedment to Mat Thickness for Determining Quantity of Asphalt.

(Ref. 8, 9, 15, 21)

Design and Construction (cont)

5) Implementation of an adequate field inspection and quality control plan including monitoring percent voids by observing the size of the spacing (or voids) between the aggregate particles (on average 20%) (see Figure 3) and percent full by observing how deeply the aggregate particles are set in the asphalt, i.e., what percentage of the aggregate particles are embedded into the asphalt (low volume roads → 40%, high volume roads → 30%) (see Figure 3).
6) Adequate traffic control during construction and in the first hours after completion of construction.

Care must also be taken in design procedures and specifications of asphalt and aggregate application rates. Traffic patterns as well as volumes must be considered. Starts and stops by many vehicles shorten seal coat life; therefore, check to see if the area is near an intersection, etc. If so, special procedures and/or materials may need to be used. Procedures and materials include reduction of traffic speeds and the use of polymers in order to resist aggregate 'rollover'.

Areas to be covered must be expressed in square yards because asphalt application rates are expressed in gallons per square yard. Also, aggregate rates are based upon cubic yards of aggregate per square yard of covered surface. Some reasonable estimates for asphalt and aggregate application rates are:

	Asphalt	*Aggregate*
Traffic Lanes	0.35 Gal/SY	1 CY/140 SY
Shoulders	0.32 Gal/SY	1 CY/165 SY

(*NOTE: These values should not be taken literally! These values are for comparison only and design procedures should still be followed.)

Example formulas for distributor speed, length of asphalt shot, and length of rock shot are given below:

Distributor speed for any rate of application

$$S(f) = \{9*G(t)\}/(W*R)$$

where:
S(f) = road speed, feet per minute
G(t) = spray-bar output, gal. per minute
W = spray width, feet
R = rate of binder application (corrected for temperature), gal. per square yard

Length of asphalt shot

$$L(s) = (9*T)/(W*R)$$

where:
L(a) = Length of asphalt shot, feet
T = total quantity of hot binder to be shot from the distributor, gal.
W & R = same as above

Length of rock shot

$$L(r) = (9*Q*S)/W$$

where:
L(r) = length of rock land or aggregate spread for a truck load of aggregate, feet
Q = quantity of aggregate in truck load, cubic yards
S = aggregate spread rate, square yards of roadway surface per cubic yard of aggregate
W = width of aggregate distribution, feet

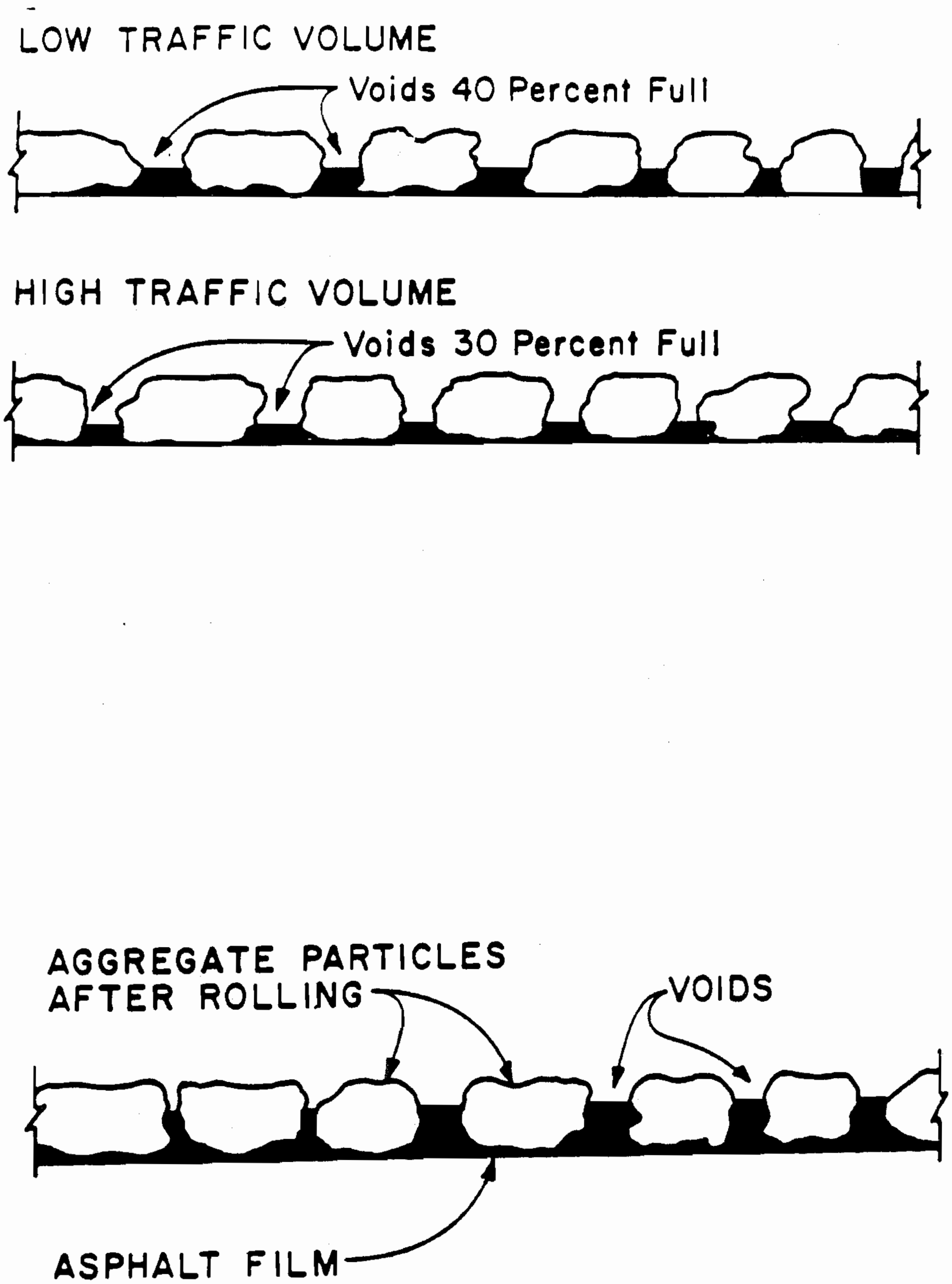


FIGURE 3: Percent Full and Percent Voids.

(Ref. 16)

Seal Coat Design Method

Laboratory Tests

Dry loose unit weight

The dry loose unit weight determination shall be made in accordance with Tex-404-A, except that the aggregate shall be tested in an oven-dry condition.

Bulk specific gravity

The bulk specific gravity shall be made in accordance with Tex-403-A for all natural aggregate and in accordance with test method Tex-433-A for synthetic aggregates.

Board test

Place a sufficient quantity of aggregate on a board of known area such that full coverage, one stone in depth, is obtained. A one-half square yard area is a convenient laboratory size. The weight of aggregates applied in this area is obtained and converted to units of pounds per square yard. Good lighting is recommended and care should be taken to place the aggregate only one stone deep.

Calculations

The quantity of aggregate expressed in terms of square yards of road surface to be covered with a cubic yard of aggregate and the quantity of asphalt in gallons per square yard can be found as described below:

Aggregate Quantity

$$S = (27*W)/Q$$

Asphalt Quantity

$$A = [5.61*E*[1-\{W/(62.4*G)\}]*T]+V$$

where:

S = aggregate spread rate, sq. yds. per cu. yd.
W = dry loose unit weight, lbs. per cu. ft.
Q = aggregate quantity determined from board test, lbs. per sq. yd.
A = asphalt quantity, gallons per sq. yd.
G = dry bulk specific gravity of aggregate
T = traffic correction factor obtained from Table 9
V = correction of surface condition obtained from Table 10, gal/sq. yd.
E = embedment depth obtained from Figure 2 as follows

$$E = e*d$$

where:

e = embedment depth, percent (Figure 2)
d = average mat depth, inches
= 1.33*Q/W

*Note: Asphalt quantities calculated by these methods are for asphalt cement. Appropriate corrections must be made where a cutback or an emulsion is used as illustrated in the example given below.

Sample Calculations

Given:

W = Dry loose unit weight of aggregate = 52.4 lbs/cu. ft.
G = Dry bulk specific gravity of aggregate = 1.57
Q = Quantity of aggregate (board test) = 9.7 lbs/sq. yd.
Traffic = 700 vehicles per day per lane
Roadway surface condition = slightly pocketed, porous, oxidized

Seal Coat Design Method (cont)

Table 9: Asphalt Application Rate – Correction Due to Traffic					
	Traffic - Vehicles Per Day Per Lane				
	Over 1,000	500 to 1,000	250 to 500	100 to 250	Under 100
Traffic Factor (T)	1.00	1.05	1.10	1.15	1.20

(Ref. 9, 15, 21)

Table 10: Asphalt Application Rate Correction Due to Existing Pavement Surface Condition	
Description of Existing Surface	Asphalt Quantity Correction (V) gal/sq. yd.
Flush asphalt surface	-0.06
Smooth, nonporous surface	-0.03
Slightly porous, slightly oxidized surface	0.00
Slightly pocked, porous, oxidized surface	+0.03
Badly pocked, porous, oxidized surface	+0.06

(Ref. 9, 15, 21)

Sample Calculations (cont.)

Quantity of Aggregate

S = 27*W/Q = 27*(52.4)/9.7 = 146 sq. yds./cu. yd. (square yards of roadway surface per cubic yard of aggregate)

Quantity of Asphalt

A = [5.61*E*[1-{W/(62.4*G)}]*T] + V

d = 1.33*Q/W = 1.33*(9.7)/52.4 = 0.246 inches
e = 40% from Figure 2
E = e*d = 0.40*(0.246) = 0.0985 inches
T = 1.05 from Table 9
V = +0.03 from Table 10

A = [5.61*(0.0985)*[1-{52.4/(62.4*(1.57))}]*1.05] + 0.03

A = 0.30 gallons of asphalt per square yard of roadway surface.

If an emulsion with 30 percent water (→ 70% asphalt) was to be utilized, the quantity of emulsion would be:

0.30/0.70 = 0.43 gallons per square yard or *less* since emulsions will provide a greater "effective" embedment, initially.

Surface Preparation

The extent of the preparation of an existing pavement for a seal coat depends on the condition of the pavement. Pot-holes and broken edges, ravelling and streaking, cracks (longitudinal, transverse, and alligator), slippage, bleeding asphalt, rutting and corrugations, and pavement edge must be removed, replaced, and/or repaired. General cleaning should include removing and mud and debris, sweeping thoroughly with a power broom, and flushing with clean water and allowing to dry as necessary.

Material Sampling and Inspection

Sampling and inspecting on-site materials, i.e., aggregate and asphalt, is an important part of quality control on seal coat projects. As an example, if the aggregate is excessively dusty or wet, shelling may occur in the seal coat. Table 11 gives possible procedures for inspecting and sampling aggregate and asphalt to be used in a seal coat.

Table 11

Aggregate

1) Take a representative sample from each stockpile.
2) Quarter each stockpile sample. Test one quartered sample from each stockpile.
3) Label and retain unused samples.
4) Check test results against:
   a) Specifications
   b) Acceptance tests made prior to delivery
   c) Test data used for design
5) Take appropriate action if:
   a) Significant deviations in test data are noted
   b) There is significant pile-to-pile variation in test results
6) Inspect piles for drainage and cleanliness
7) Make visual check for excess moisture before aggregate is loaded into trucks.

Asphalt

1) If asphalt storage and distributor tanks are not clean and empty when placed on the project, take a representative sample of the material in each tank.
2) Have each sample tested to establish the type and grade of asphalt remaining in each tank.
3) If the type and grade of asphalt in a tank does not correspond to the type and grade specified for the project, the tank must be drained and cleaned before refilling. **
4) Carefully check the delivery document for each load of asphalt delivered to the site to ensure application of the proper type and grade.
5) Make a visual check for separation before loading asphalt emulsions into the distributor tank.
6) The inspector should take samples and have them tested if he has reason to believe that contamination of the asphalt has occurred.
7) Obtain D-9 test number for asphalt shipments and obtain viscosity-temperature data from D-9 in Austin.

** Care must be taken in use of cleaning solutions. Use proper precautions in order to prevent flash fires from solvent fumes, i.e., make sure all solvents and/or cleaning fluids are completely cleaned out before reusing the asphalt tank.

(Ref. 9)

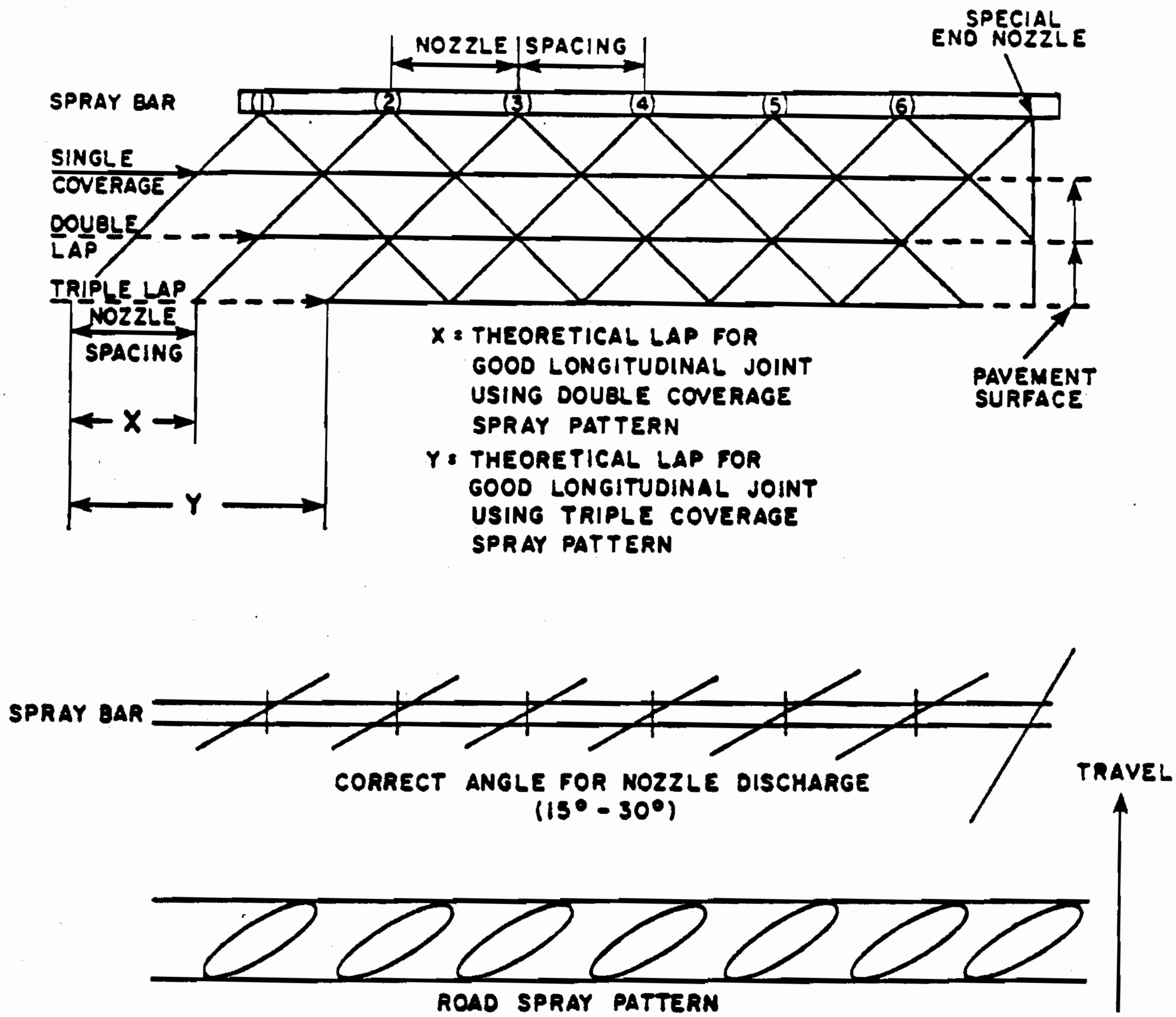


FIGURE 4. DESIRED SPRAY BAR HEIGHT AND NOZZLE ANGLES

(Ref. 9)

Spray-Bar Height and Nozzle Angles

A uniform asphalt layer is crucial to the production of a satisfactory seal coat. Spray-bar height and nozzle angles are the key factors involved in uniform distribution of the asphalt and both can be adjusted to obtain the desired spray pattern. One such adjustment involves placing less asphalt in the wheel paths and more outside and between the paths.

The spray-bar height should be adjusted to produce the desired coverage over the entire width of a pavement and the nozzles should be adjusted to produce the desired coverage on the pavement width. The adjustment on the spray-bar can produce exact double-lap, or triple-lap patterns depending on the desired coverage (see Figure 4). The nozzle adjustments involve the angle between the long axis of the nozzle orifice and the spray-bar longitudinal axis (normally between 15 and 30 degrees). Adjust the end nozzles to a slightly greater angles or use a deflector nozzle (see Figure 4) and replace clogged or damaged nozzles.

Problems/Solutions

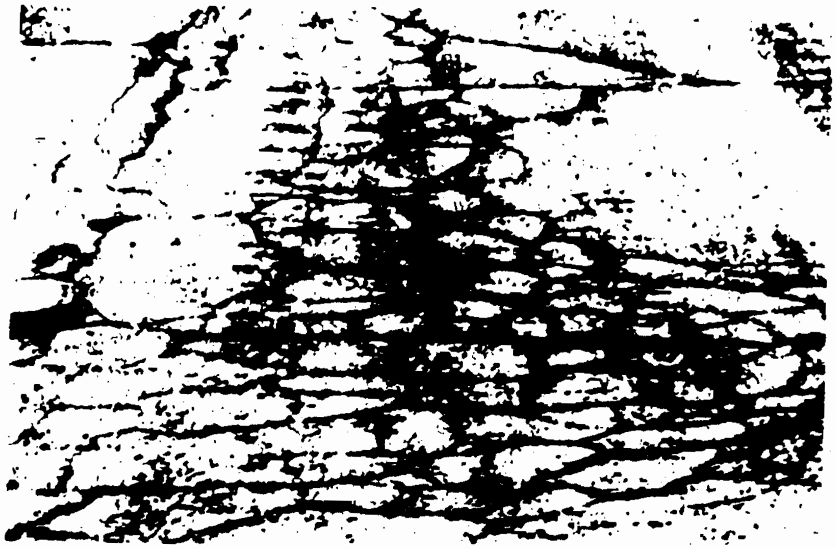
Unsatisfactory seal coats can often been traced directly to distress in the pavement, therefore, the following problem/solution discussion will deal with the pavement itself and how seal coats may or may not be used to remedy the problems.

Common problems with pavements (see Figure 5 for examples) and possible seal coat remedies are:

1) Traffic load cracking → seal coat for temporary solution, thick asphalt overlay (ACP) may be needed instead.
2) Rough riding surface → not improved by seal coat, level-up course topped with asphalt overlay better.
3) Non-traffic associated cracks → seal coat will seal out additional moisture and prolong pavement life if the cracks are < 1/8". (As an additional note: Latex mixed with asphalt (AC-10) has been used in numerous areas of the state for oxidized, cracked pavements).
4) Flushing or bleeding → difficult to repair with a seal coat, i.e., may migrate through unless the asphalt quantity applied to the roadway can be altered as these areas appear on the roadway. For example, place less asphalt binder in the wheel paths and a heavier amount between. Another solution may be to utilize a large maximum size aggregate.
5) Ruts and shoving → not remedied with seal coat. Use cold planer to remove high spots or asphalt overlay to level the surface.
6) Shelling → seal coats are effective in preventing ravelling (which is where the aggregate at the top of the pavement has become dislodged from the asphalt binder).

Typical defects in seal coats and their causes are:

1) Streaked appearance → clogged or partially clogged nozzles, misalignment of nozzles (including inconsistent angles), incorrect spray-bar height, high viscosity asphalt, wrong aggregate spread rate.
2) Bleeding and flushing → too high asphalt application rate, too soft asphalt grade for the level of traffic.
3) Loss of aggregate → insufficient asphalt application rate, insufficient compaction, excessive traffic and speed too soon, rain, brooming too quickly.
4) Surface breaks and poor adhesion to road surface → insufficiently swept surfaces (before seal), broom scars, aggregate deficiencies from blocked spreader openings.
5) Washboarding → too high asphalt emulsion application rate (asphalt "wave" is created as aggregate is applied).
6) Transverse and longitudinal joint defects → double asphalt and seal application, lack of compaction.

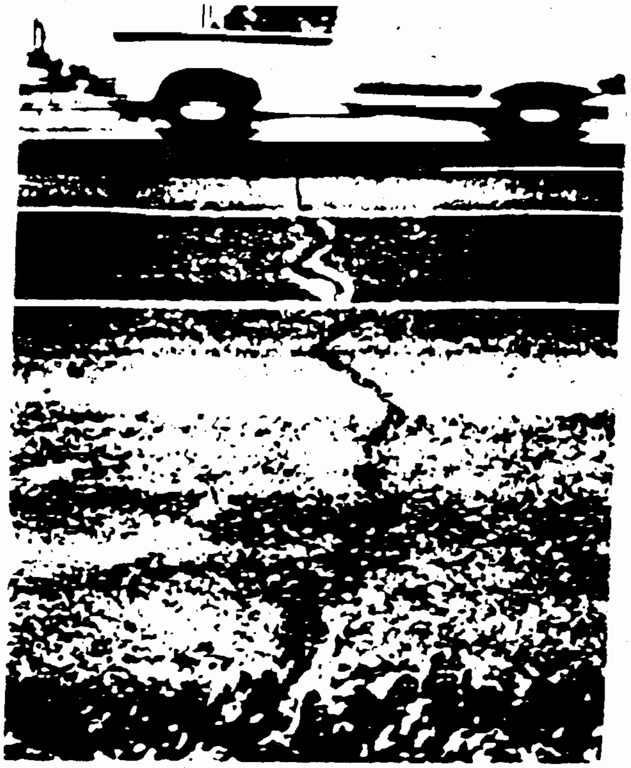


Alligator Cracking

Pothole

FIGURE 5: Pavement Distress Examples

(Ref. 16)



Transverse Cracking

Longitudinal Cracking

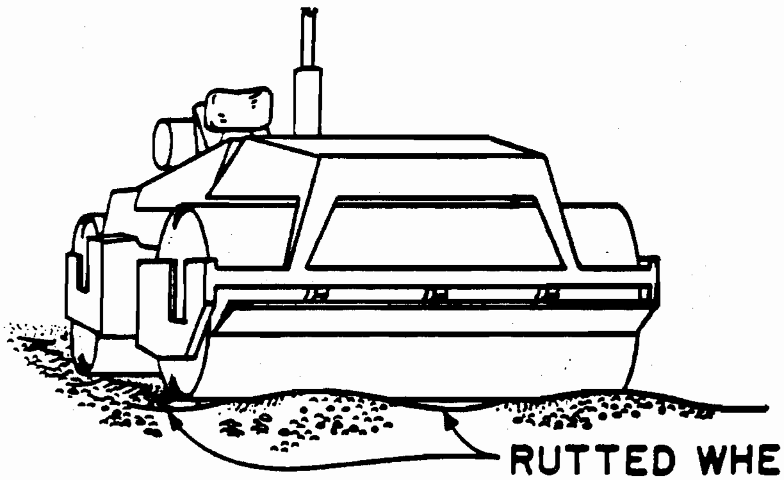


FIGURE 5 (cont.): Pavement Distress Examples

(Ref. 16)

Similar Treatments

Similar treatments include prime coats, emulsified asphalt treatments, multiple course surface treatments, and fog seals. Prime coats are intended to prepare the surface of a base course to receive a permanent surface. The main purpose is to promote a strong bond between the base course and the surface course.

Emulsified asphalt treatments are mixtures of emulsified asphalt mixed with water to reduce the viscosity to a very "thin" mixture. They are used as base treatments, earthwork seals, or as dust preventatives. This type of treatment is frequently used on base courses, subgrades, shoulders, or detours in a construction area.

Multiple course surface treatments refer to two- and three- course surface treatments. These are basically the same as single seal coats but are usually applied directly upon a primed base course. Multiple course treatments can be expected to last 6 to 8 years or more.

A fog seal is a very light application of diluted emulsion sprayed on the surface course of a pavement to seal out surface water and hold the aggregate. The fog seal is frequently applied over a new hot-mix overlay or a fresh seal coat, particularly if a highly porous aggregate is used. Its main purpose is to prevent surface water from being absorbed into the asphaltic concrete or cover aggregate, which may cause ravelling or shelling, respectively. The fog seal will also increase the effective embedment of the aggregate and provide better holding power.

Other types of treatments include construction seals, sand seals, and slurry seals. A construction seal is an application of dilute emulsion to enrich or tighten a new asphalt concrete surface (overlay or seal coat) to provide resistance to the entrance of moisture and/or to prevent ravelling under traffic. This is similar to a fog seal.

A sand seal is an application of an asphalt followed by a sand cover aggregate to tighten the pavement texture and reduce ravelling, i.e., pavements that have lost some of their matrix leading to a loss of aggregate.

A slurry seal is a mixture of specially graded aggregate and an asphalt or coal tar emulsion. It is used primarily to seal an existing pavement and produce some minor levelling without the inconvenience of loose cover stone for mass crack filling, to improve skid resistance, to enhance appearance, and to reduce studded tire wear.

Appendix

3 4 5 6 11 13 17 20 21

Area Information (refer to map)

West Texas Experience

Latex-modified asphalts in seal coats are used primarily where a high volume of traffic is anticipated, because it holds the aggregate quicker and longer. In addition to better and longer aggregate retention, the latex-modification will reduce bleeding and shelling, especially in the winter. The designs are usually done by rule of thumb, i.e., higher shots on low volume roads and lower shots on high volume roads, and/or based on experience. For designing with the addition of polymers and/or latex, do not cut back binder quantity.

Latex-modified asphalts in seal coats are used on up to 75% of the projects and are applied within the general season of May 15 to September 1. There have been mixed results on the use of latex over the years, especially during the rainy season. Rain after application tends to cause the aggregate to shell off. In order to increase retention, precoated aggregate is often used. There have also been some random problems with segregation and with limestone rock asphalt and its rideability.

Asphalt application rates using Chevron AC-10, Fina MC-1200, and Fina MC-800 are in the range of 0.45 to 0.48 gallons/sq. yd. for grade 3 aggregate. These shot rates tend to bleed less and provide a good seal. MC-1200 with latex (3%) works well in the winter months and for covering heavily with aggregate.

Seal coats have been used between AC layers instead of tack coats. Also, fog seals have been used in the past and are working well. Fog seals are sometimes applied after the seal coat to provide extra protection but are only used on an "as needed basis".

Latex-modified asphalts are more costly than regular asphalts, approximately $0.10 more per gallon, and the modification may cause the nozzles to clog more. The added cost and trouble are justified by the resulting tougher surface it produces.

Northwest Texas Experience

Latex-modified asphalt seal coats have been used as underseals on ramps, tapers, and shoulders. They have reduced windshield damage, provided very good adhesion, and the use of MC-1200 with latex has given a tough and durable seal, when applied during the winter months, that is not available through other asphalts.

Disadvantages of the latex modification include shelling (a large loss of aggregate) when applied just before or near the time of rainfall and added costs due to the latex additive. The increased cost is not justifiable during the summer months; however, the use of MC-1200 shows good promise for use in situations where the seal coat needs to be applied during winter months.

Central Texas Experience

Emulsified asphalts with polymer additives have been used experimentally for some seal coat projects. Latex-modified asphalts in seal coats have been found to perform satisfactorily and are used routinely. Polymer-modified emulsions require less setting time and, in many instances, exhibit less aggregate loss during the winter months. The polymer modification results in an overall increase in the cost of seal coat projects by about 10% but its advantages seem to justify the increase. Flushing, however, has occurred in some emulsions with polymers due to excessive prime coats.

Tack coats are used before a seal coat in many instances to decrease dust. Also, fog seals are often used with seal coats for added pavement protection. An asphalt application rate of 0.2 to 0.3 gal/sq. yd. is used with a grade 4 aggregate. The Kearby design method is usually used.

Area Information (cont.)

South Texas Experience

Latex-modified asphalts in seal coats are used primarily on high volume roads (1500 ADT or greater) and on some lower traffic volumes where there will be a large number of turning movements (urban areas). In some areas, the shoulders will be sealed with latex when the adjacent traffic lanes are sealed with latex. The use of latex modification has led to better retention of the aggregate, less tendency to flush in wheel paths, and, as already stated, better performance in urban areas where traffic turning movements and starting/stopping at traffic signals tend to roll the embedded aggregate. The design method is the modified Kearby and experience. Grade 4 aggregate and an asphalt application rate of 0.25 to 0.3 gal/sq. yd. (increase rate 12-15% for emulsions) is most often used. Use of latex includes a cost increase of 20-30% but it is well worth it.

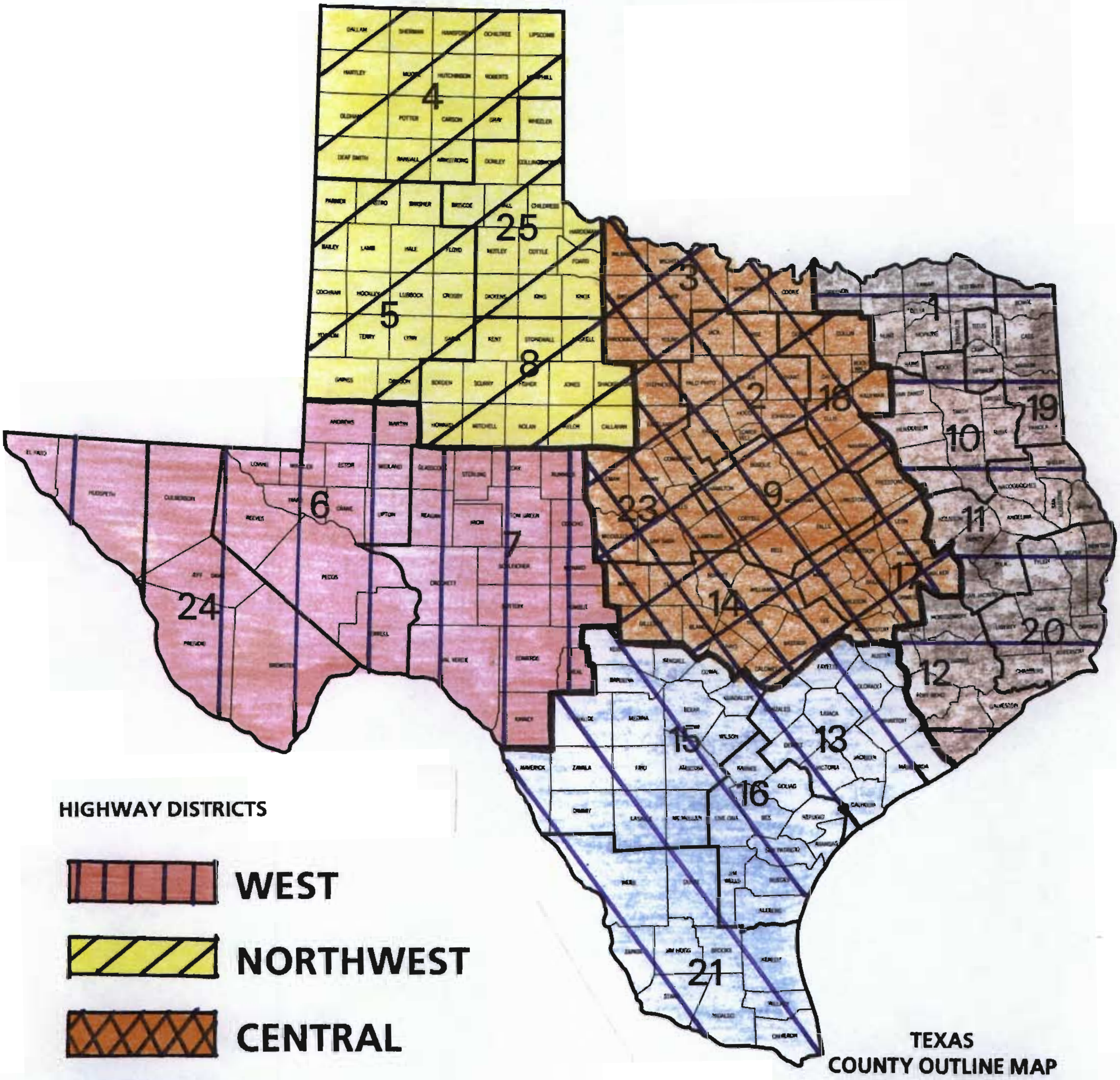
The asphalt season ranges from June to the end of September. The different asphalts used in the southern region include AC-5, AC-10, MS-1, HF-P, and MFRS-P. According to the opinions of the South Texas experiences, AC is better than emulsions which are more flexible with temperature changes. The best AC results have come with overnight cooling especially with low traffic conditions. This technique is used mainly in the hot months of July, August, and September.

East Texas Experience

Latex-modified asphalt is used in seal coats for better aggregate retention and because less asphalt is required to retain the aggregate. Some areas are trying winter seals with MC-1200 and latex but are using emulsions and latex or polymers for summer seal coats. The disadvantages associated with the use of latex include the need for more controlled application rates, higher temperatures and higher costs. The increase in cost is about 20-25% but is justified in the quality achieved.

There has been some trouble with seal coats flushing in some areas. Precoated aggregate is used with AC seals and uncoated aggregate with emulsions.

HIGHWAY DISTRICTS



WEST

NORTHWEST

CENTRAL

SOUTH

EAST

TEXAS
COUNTY OUTLINE MAP
STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION
TRANSPORTATION PLANNING DIVISION

SUPPLEMENT
(Asphalt Additives)

Asphalt/Asphalt Emulsion Additives

Introduction

Asphalts modified with additives, when mixed and used correctly, offer many advantages over unmodified asphalts. Physical characteristics including strength, temperature susceptibility, and fatigue resistance are improved. Extended pavement life along with reduced maintenance may yield a cost-effective product. The most common forms of additives are polymers and/or copolymers and latexes. Polymers, or plastics, may improve an asphalt's flexibility and strength. Latexes, or rubbers suspended in an emulsified mix, reportedly improve the elasticity much like natural or reclaimed rubbers. Latexes have received wide usage in surface seals to promote a tighter, stronger layer.

Polymers in Asphalt

Polymer-treated asphalts have proven themselves more flexible when cold and tougher when hot. Polymers increase adhesion and cohesion, reduce temperature susceptibility, improve modulus, increase resistance to fatigue cracking, increase resistance to rutting of underlying pavement, and may increase durability. Polymers also seem to be adding years to the usable life of roads which receive extra stresses. The polymer's potential comes from the lengths and strengths of their molecules and their tendency to bond chemically with asphalt.

When used in emulsions, polymers exhibit the following advantages:

1) More resistance to flushing or bleeding than ordinary emulsions. Good material to correct rich surfaces because you can get good initial stick of the rock with a lighter shot.
2) More resistance to rock loss in cold weather due to brittle fracture of the asphalt film.
3) More resistance to whip-off of rock under initial traffic.

A few polymers with their respective characteristics are listed in Table S1. For a more comprehensive listing, see the May 1988 issue of *Roads and Bridges* listed in the references.

Latex in Asphalt

Latex-modified asphalts (note that latex in an asphalt is a polymer) exhibit many improved characteristics as compared to standard asphalts. Addition of latex to asphalt makes a binder that is less temperature susceptible. A less temperature susceptible binder will perform better in cold weather (lower brittleness and higher ductility) and better in warm weather (higher viscosity) for a given asphalt grade. The addition of latex also improves toughness, softening point, bleeding resistance, tack and adhesion, recovery (elasticity), cold flow, and impact resistance at low temperatures. But, care should be taken when heating asphalt latex blends because they are more sensitive to loss of properties due to prolonged heating.

An example of a latex with its respective characteristics is listed in Table S2. For a more comprehensive listing, see the May 1988 issue of *Roads and Bridges* listed in the references.

Cost

Additives add cost to any asphalt project in which they are used. The question often arises, "Is it worth it?" The answer is dependent on the additive, the area (climate, asphalt source, etc.), traffic volume, etc. Polymer or latex modification can increase cost by anywhere from 10% to 40%. If this cost increase is compared to increased pavement life and performance, justification may be realized.

As an example, let us consider a project let in the Spring of 1985 in Fort Worth, District 2, on SH121 ("Airport Freeway"), downtown Ft. Worth northeast to IH820. At $63.40/cubic yard of hot mix, latex modification increased the cost about 10%. The 10% increase is quite small considering that a 5-year overlay would only have to last six (6) additional months to pay for itself. As of this report date, the HMAC with latex has held up well with a minimum of rutting. Although our example uses a HMAC project for comparison, it is presented to show a positive aspect of an additive.

Table S1

Modifier Type	Trade Name	Dosage Tot. Mix	Mix Temp. F.	Attributes
Ethylene Vinyl Acetate (EVA)	Elvax	2 - 4%	275 - 300	Increases durability, toughness, tenacity, resistance to cracking
Styrene-Butadiene (Vulcanized) Binder	Styrelf	Replaces Asphalt	NA	Arrives at jobsite ready to use; needs no incorporation equipment
Styrene Butadiene Reclaimed Rubber	Overflex	18 - 24% reclaimed rubber	300 - 360	Improves durability, decreases fatigue; protects asphalt from ultraviolet light
Polyethylene	Novophalt	4 - 6%	300 - 330	Made avail. on site, ready to use; prolongs pavement life
Thermoplastic Polymers	Rosphalt 50	45 lbs/ton	425	Densifier mix, extends high and low temperature ranges, adds skid resistance
Styrenic Block Co-Polymer	Kraton D Kraton G	6 - 9%	320 - 380 320 - 495	Reduces permanent deformation and thermal and fatigue cracking
Polychloroprene	Neoprene	1 1/2-3%	200 - 300	Increases elasticity, toughness, & tenacity
Styrene Butadiene Rubber	Latex	approx. 3%		Increases elasticity, toughness, tenacity, and adhesion

(Ref. 19)

Table S2

Modifier Type	Trade Name	Dosage Tot. Mix	Mix Temp. F.	Attributes
Styrene Butadiene Rubber Latex	Ultrapave 70	2 - 5%	Varies	Makes asphalt less susceptible to temp. changes and cracking
	Latex 275	1 1/2 - 3%	325	Improves resistance to cracking
	R-504 R-550	3 - 5%	Above 295	

(Ref. 19)

Glossary of Terms

Alligator Cracks: extensive cracking which takes the shape of a series of small squares or a pattern similar to an alligator's skin.

Bleeding: the upward movement of asphalt in an asphalt pavement, resulting in a smooth film of asphalt forming on the pavement surface.

Latex: a water emulsion of synthetic rubber or plastic obtained by a chemical reaction in which two or more small molecules combine to form larger molecules that contain repeating structural units of the original molecules.

Percent Full: how much the asphalt fills the aggregate voids.

Percent Voids: how much space between aggregate particles is left after rolling.

Polymer: a chemical compound or mixture of compounds formed in a chemical reaction in which two or more small molecules combine to form larger molecules that contain repeating structural units of the original molecules.

Ravelling (or Raveling): the progressive separation of aggregate particles in a pavement. It begins at the top and works downward, or at the edges and works inward, until the aggregate has been totally dislodged.

Shelling: when the seal coat aggregate is torn loose from the asphalt binder (same as ravelling).

Stripping: when seal coat aggregate is lost due to a lack of bond between the asphalt and the aggregate.

Viscosity: the resistance of a material to flowing. High viscosity means "thick" or resistant to flowing and low viscosity means having a consistency near that of water or easy flowing.

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