Arizona Chapter AGC Pavement Preservation Series

Chip Seal Guide for Application and Construction

Presented by the Pavement Preservation Committee through the Arizona Chapter Associated General Contractors

Developed by the

Pavement Preservation Committee
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Forward

This guide is a collection of chip seal best practices and recommendations for the State of Arizona. Chip seals are important Pavement Preservation applications, and when they are constructed properly will increase the life of a pavement. There will be instances where conditions or available materials dictate that the contractor, supplier or specifying agency need to deviate from these recommendations. It is very important that the contractors, suppliers and agencies work together and use common sense to modify procedures and practices contained in this document.

In 2003, the Arizona Chapter Associated General Contractors Pavement Preservation Committee developed this guideline to identify “best practices” to be used during the application of a chip seal. This revision was done by the current Pavement Preservation Committee, re-established in 2011.

The committee is comprised of contractors, material suppliers, aggregate producers and agency personnel. Special thanks to our partners in the Arizona Department of Transportation: Bill Hurguy, State Materials Engineer, and Janet Doersling – Manager Pavement Materials Testing for their contributions to this revision.

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1 - Introduction

1.1 This document is provided as a chip seal guide for Contractors, Suppliers, Agencies and Owners.

1.2 Chip seals have been used for over 100 years as a cost effective treatment to maintain all types of pavements and roadways. Chip seal applications are designed as a surface seal. Chip seals extend the life of the pavement by the prevention of moisture intrusion into base course and sub-grade. Additional benefits include increased skid resistance and improved aesthetics. When properly constructed, a chip seal application is a cost effective preservation tool that provides improved life cycle benefits.

Many variables affect the successful application of a chip seal, including:

- Existing Surface Condition
- Surface Preparation
- Materials
- Placement Practices
- Construction Procedures

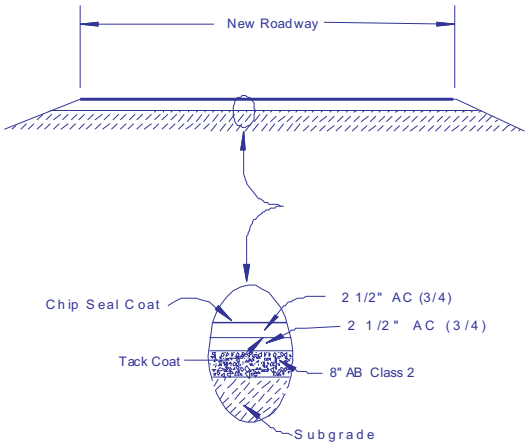
2 - Surface Preparation

2.1 Maintenance

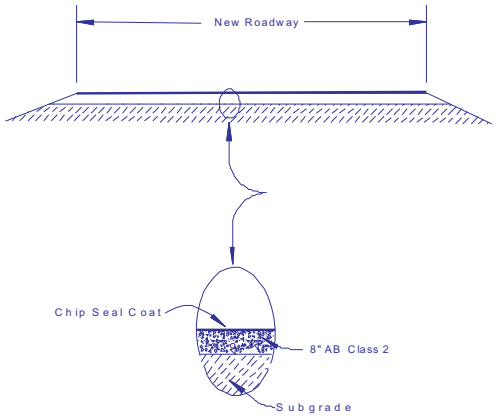
Significant deficiencies in the pavement surface must be repaired before applying a chip seal to the roadway. Potholes must be filled and ruts of significant depths must be leveled. Cracks ⅛ inch or wider must be filled. Crack filler overbands on the pavement surface should not exceed 4 inches wide and ⅛ of an inch thick. Pavement edge deterioration should also be repaired. The type of material used for the various repairs is important and can affect the quality and overall longevity of the finished chip seal surface. Cold mix patching materials and crack sealant need time to cure before placing a chip seal.

2.2 New Construction

2.2.1 When a chip seal is constructed directly on sub-grade, aggregate base course or RAP, the sub-grade should be graded smooth and thoroughly compacted. When needed, aggregate base course should be a minimum of two (2) inches thick, graded smooth, and thoroughly compacted. The chip seal should be applied within 24 hours of the surface preparation. Depending on the binder used it may be necessary to apply a prime coat to the prepared surface prior to chip sealing. It is recommended that prime coat be allowed to cure for 48 hours prior to the chip seal application.



Typical section of chip seal, asphaltic concrete, aggregate base course and subgrade.



Typical section of chip seal, aggregate base course and subgrade

3 - Materials

3.1 Chip Seal Aggregate

3.1.1 Proper stockpile management is a critical factor concerning the consistency of the aggregate quality. This can be the difference between a positive pay lot and a penalty or even reject.

3.1.2 With stockpiles being placed within close proximity to any plant, sufficient pad(s) shall be constructed to mitigate ground loss, and material contamination from the surrounding area. Stockpiles shall be constructed to account for moisture and ensure that proper drainage is considered. The pad(s) created for the stockpile(s) should extend beyond the edge of each stockpile one-bucket width of the largest equipment used on site. Stockpile(s) shall be constructed so as to minimize aggregate segregation.

3.1.3 Stockpile height shall be consistent and shall not exceed 45 forty-five feet (45') upon completion. Stockpile(s) shall also be built to ensure minimization of "coning" (if over a tunnel) – a stockpile should be built with ledges (or layers) in even sections of thickness to minimize aggregate segregation (see NAPA commentary – Stockpiling). If aggregate is loaded on top of a conical stockpile then larger aggregate sizes are more likely to roll to the outside and bottom). In all cases the loader operator shall try to prevent driving up onto a stockpile. As much care as possible in the handling of chip seal aggregate must be taken to reduce all variables for the aggregate to be segregated.

3.1.4 Aggregate material should also be blended appropriately and evenly across the face of the entire stockpile and not from side to side as this could cause additional segregation.

3.1.5 It is important to utilize an aggregate material that is composed of clean and durable crushed rock or crushed gravel. All binder types will have problems adhering to aggregate that has too high a percentage of fines or aggregate that is coated with fine dust. All aggregate should be processed to meet the gradation and physical property requirements. The following tests concerning the physical requirements of the aggregate have proven to contribute to superior chip seal performance (see Table 1).

Table 1. Aggregate Characteristics

Characteristic	Test Method	Requirement
Bulk Specific Gravity	Arizona Test Method 210	2.35 – 2.85
Water Absorption	Arizona Test Method 210	Maximum 3.0 %
Fractured Coarse Aggregate Particles (Minimum of 2 fractured faces – Plus #4 Material)	Arizona Test Method 212	Minimum 85 %
Fractured Coarse Aggregate Particles (Minimum of 2 fractured faces – Plus #4 Material)	Arizona Test Method 212	Minimum 85 %
Flakiness Index	Arizona Test Method 233	Maximum 20 %
Carbonates in Aggregate	Arizona Test Method 238	Maximum 20 %
Abrasion (Source Material)	AASHTO T96	100 Rev., Max. 9 % 500 Rev., Max. 40 %
Sodium Sulfate Soundness (Loss @ 5 cycles) (Source Material)	AASHTO T104	Maximum 10%

3.1.6 Gradation requirements for the above mentioned mineral aggregate materials utilized for "chip seal" applications should be as follows (this recommendation is made based on local materials, available from local aggregate producers) They are: MAG (Maricopa Association of Governments) Section 716.2.3, Table 1 or Table 2. ADOT Section 404-2.02 Cover Material as applicable for traffic load.

3.2 Chip Seal Binders

3.2.1 There are numerous types of binder materials utilized in chip seal applications. These various binder materials are an important part of successful chip seal construction as they will affect the speed of set time to return to traffic, performance characteristics with lower quality aggregate, rejuvenating properties, aggregate embedment, aggregate retention, resistance to traffic damage and resistance to temperature variation. Each binder type may require a different application rate to ensure the appropriate amount of residual binder on the pavement. In Arizona the following binder types are used. Recommended ADOT specifications are listed for each binder type:

- Conventional Emulsified Binder Materials (Section 1005, Table 1005-3)
- Modified Emulsified Binder Materials (Section 1005, Table 1005-3a & b)
- Polymer Modified Binder Materials (Section 1005, Table 1005-1a)
- Asphalt-Rubber Binder Materials (Section 1009, Table 1009-2)
- Cut-back Binder Materials (Section 1005, Table 1005-2)

3.2.2 In general, the base binder controls the temperature properties of the chip seal. Softer binders are generally more flexible and have better low temperature properties. Harder binders are tougher and generally have better high temperature properties. Polymer, tire rubber and other modifiers will influence these properties as well. It is generally accepted that the penetration of the residual binder indicates the acceptable temperature range of the binder (40 to 90 dmm) for hot climates and (100 dmm+) for colder climates.

3.2.3 Polymers, tire rubber and other modifiers also contribute to the high and low temperature properties of the binder and will improve aggregate retention of the chip seal. There are several test procedures that indicate the level of modification of the chip seal binder. These tests include: Softening Point, Ductility, Elastic Recovery, Resilience, Torsional Recovery, Force Ductility and Residue Performance Grading (PG).

3.2.4 In addition to the individual characteristics of each binder type, they each have unique handling requirements. Emulsified binder materials should be stored so that they do not freeze and all binder materials should not sit stagnant for extended periods of time. Also, for all binder types the contractor should follow the suppliers handling procedures and recommendations.

4 - Aggregate and Binder Application Rates

It is recommended that a chip seal design procedure be utilized to establish targets for binder and aggregate application rates. (See suggested example chip seal design in Appendix A.)

Considerations for binder application rate(s) are as follows:

- Aggregate gradation and quality
- Type of binder
- Existing roadway conditions (deterioration and porosity of the roadway)
- Maintenance efforts and timing of those efforts prior to chip seal application
- Traffic conditions (present and future volume and percentage of traffic)
- Weather and environmental conditions

Typically the aggregate embedment should range from 50% to70% after rolling and the removal of the loose material. The finished product should result in an application of chip seal aggregate that is "one stone deep." The binder and aggregate application rates should be adjusted to account for the considerations listed above. When special conditions exist such as placement in intersections, on unpaved roadways and parking lots, etc. additional adjustments to methods and application rates may be required

5 - Construction Procedures

Prior to the application of the binder, the existing surface must be cleaned of all foreign materials. Mechanical sweepers or brooms and air blowing if necessary, will usually accomplish this cleaning. Once the surface is sufficiently clean and dry, the chip seal application can take place. The chip seal should normally be applied when the surface temperature is 85 F and the ambient temperature is 65 F and rising. (Surface temperature should be taken prior to start of operations).

5.1 - Application Temperature

Proceed with caution when ambient temperatures begin to fall below 70 F before the application has a chance to cure. No material should be applied when rain is imminent or when the wind is excessive. The information contained in Table 2 provides seasonal consideration guidelines for a chip seal application in Arizona. .

Table 2. Recommended Chip Seal Application

Area	Elevation	Recommended Dates
Mountain Areas	Above 5,000 Feet	June 1 – August 31
Foothill Areas	3,500 to 5,000 Feet	May 1 – September 30
Deserts	Below 3,500 Feet	March 15 – May 31 September 1 – October 31

Caution should be exercised when ambient temperatures exceed 110 F as additional cure time may be required.

5.2 - Binder Application

It is important that the distributor truck be in good working order. Distributor trucks should be “certified” as described in ADOT specification 404-3.02. The distributor must be capable of applying the binder uniformly in both transverse and longitudinal directions at the desired rate. The distributor must be in good mechanical condition, and must be equipped with a functioning computer rate control (CRC). The spreader bar must be properly adjusted for height, contain the correct size of spray nozzles for the type of binder being applied, and the nozzles must be set at the angle recommended by the manufacturer, for efficient coverage. The binder must be at the application temperature recommended by the supplier.

5.3 - Volume Measurement

The volume of material in the distributor truck must be determined in advance so that you can keep track of how much material is used. To determine the volume of material in the distributor truck;

- Make sure that the distributor is on level ground.
- Read the volume gauge
- Read the temperature gauge.
- Correct the volume reading for the temperature of the material us in Temperature - Volume Corrections for Emulsified Asphalts in Appendix B or the Temperature – Volume Corrections for Hot Asphaltic Materials shown in Appendix C.

5.4 - Aggregate Application

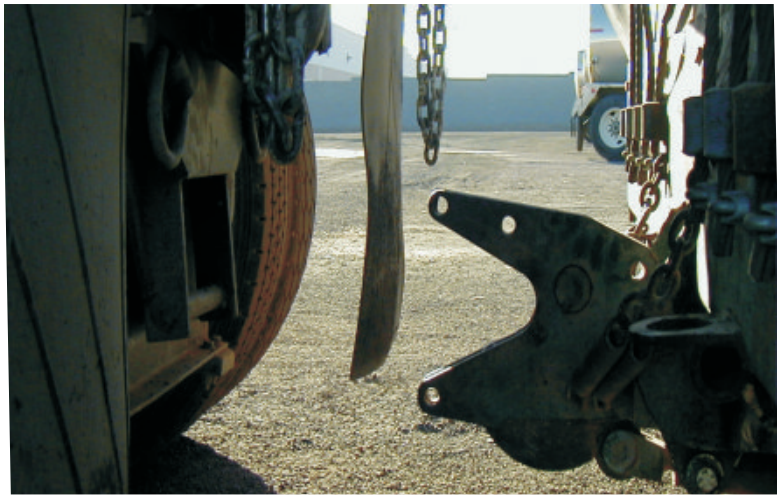
The application of the aggregate shall be accomplished by means of a calibrated chip spreader. The chip spreader should be calibrated prior to the start of each operation. The chip spreader must be a self-propelled, computerized rate controlled (CRC) unit capable of an application width of fourteen (14) feet or greater. The spreader must be in good mechanical condition and capable of applying the cover aggregate uniformly across the spread width.

5.5 - Rolling

A sufficient number of self-propelled pneumatic-tired rollers must be utilized to cover the full width of the application in one pass. The first pass must take place immediately behind the chip spreader. Rolling shall continue until three passes are complete.

5.5.1 The rollers must be staggered and the rolling speed should be determined by the production/speed of the chip box. It is recommended the rolling take place at a maximum speed of five (5) mph. As long as proper aggregate embedment is achieved, rolling speeds may be increased. This ensures adhesion of the aggregate to the binder.

5.5.2 The rollers should carry a minimum loading of 2,000 pounds on each wheel, with a minimum tire pressure of 90 psi or as recommended by the equipment manufacturer.



5.6 -Aggregate Hauling

The aggregate haul trucks must be tailgate discharge and must have a device to lock onto the hitch of the chip spreader. The trucks must be compatible with the chip spreader to eliminate aggregate spillage while dumping into the receiving hopper.

5.7 - Sweeping

Initial sweeping of the loose aggregate should take place after the binder has properly set. The timeframe for sweeping depends on cure time of the binder, ambient or surface temperature, and other variables. Subsequent sweeping may be required depending on embedment and retention of the aggregate.

5.8 - Traffic Control

All traffic, with the exception of necessary construction equipment, should be kept off the newly applied chip seal until it has had time to properly set. Traveling speed should not exceed 15 mph over a freshly sealed surface until the loose aggregate is removed. Special care should be taken at intersections to prevent dislodging of chip seal aggregate.

Turning should be limited until the initial sweeping is completed. Note: Barricades, signage and traffic control will follow current MUTCD (Manual on Uniform Traffic Control Devices) standards.

6 - Special Chip Sealing Procedures

There are special procedures and/or materials that can be utilized to improve the quality of the chip seal or to allow its use in unique conditions. The following is a list of these procedures:

6.1 - Fog Seal Application

Some chip seals are completed with the application of a fog seal after the final sweeping. Benefits include improved chip retention, prevention of raveling and improved aesthetics. The surface should be dry and must be free of loose aggregate and foreign materials. Emulsified asphalt materials must be diluted with water and applied by a distributor (as previously discussed) at an application rate of 0.08 to 0.12 gallons per square yard or adjusted as necessary in the field.

6.2 - Double Chip Seals

The first application of the double chip seal is the same as a single chip seal procedure. The second application may utilize a smaller aggregate gradation than the first application, which interlocks with the larger aggregate. This application is used to extend the life of a deteriorated pavement, or can be applied as a new surface on prepared native soil or aggregate base surfaces.

6.3 - Scrub Seals

This technique involves the use of a drag broom or squeegee that is positioned behind the distributor spray bar, followed if needed by a light application of sand or cinders. Scrub seals are often constructed to fill cracks using special binder materials designed for extending the life of a pavement.

6.4 - Cape Seals

This is a chip seal that is overlaid with a slurry seal or a micro-surfacing material. Some benefits of this procedure are the elimination of loose aggregate, less tire noise, a less course surface texture and can result in a longer service life of the pavement.

Chip Seal is Paced

Slurry Seal is Placed

Cape Seal Finished Surface

6.5 - Modified Binders

Modified binders are asphalt binders that have been modified with polymers, crumb rubber, or other additives. These materials are applied the same as conventional binders, but can be specified for varying road conditions. Using modified binder materials can result in better performance and increased service life of the road surface due to improved physical properties and heavier application rates.

7 - Summary

The following is a summary of the important requirements that MUST be used to obtain a quality chip seal product.

• Complete all needed repair work and allow adequate curing time prior to the placement of the chip seal.

• The chip seal shall be applied when the surface temperature is 85° F and the ambient temperature is 65°F and rising.

• Use the aggregate recommended in Table 1.

• Test materials for the project before and during construction to determine specification compliance.

• Thoroughly clean/flush distributor trucks and clean chip box prior to changing types of binder materials.

• Calibrate the chip spreader daily for uniform quantity and aggregate coverage.

• Adjust spray nozzles on the distributor spray bar for proper angle and set bar height for proper fan overlap.

• Start binder application only when the chip spreader and aggregate trucks are in line and the pneumatic tire rollers are ready to begin rolling.

• The distributor truck should stay within 200 feet of the chip seal box.

• The first pass should take place immediately behind the chip spreader with three passes completed within 1/2 hour (30 minutes) of the aggregate application.

• Initial sweeping of the loose aggregate should take place after the binder has properly set.

• Special care should be taken at intersections to prevent dislodging of chips by turning vehicles.

• Depending on embedment and retention of aggregate in the binder a second or final sweeping may be required.

Checklist Materials & Construction

Techniques/Application

	YES	NO
1. Does the aggregate meet the specified requirements?	☐	☐
2. Is aggregate stockpiled so that it will not become contaminated?	☐	☐
3. Is the moisture content of the aggregate appropriate?	☐	☐
4. Are proper storage / heating facilities available for the binder?	☐	☐
5. Has the binder been sampled for testing in accordance with established sampling methods ASTM D140 or AASHTO T40?	☐	☐
6. Is the binder at the correct temperature for application?	☐	☐
7. Has the binder application rate been determined and corrected for temperature?	☐	☐
8. Has the aggregate application rate been determined?	☐	☐

Construction Techniques/Application

Techniques/Application

	YES	NO
1. Is traffic control in compliance with approved plan?	☐	☐
2. Have pavement markers been considered?	☐	☐
3. Is the ambient temperature at 65F and rising?	☐	☐
4. Is the pavement clean and dry?	☐	☐
5. Is there a chance of rain during the daily production?	☐	☐
6. Has the aggregate spreader been properly calibrated?	☐	☐
7. Is the proper equipment available for loading and transporting the aggregate to the chip spreader?	☐	☐
8. Is there adequate aggregate supply available on site to keep up with the distributor truck?	☐	☐
9. Are all the distributor trucks calibrated, and nozzles and bar height adjusted?	☐	☐
10. Is the aggregate spreader in position, with the dump truck, attached before starting the binder application?	☐	☐
11. Is the application of the aggregate being done in a timely manner directly behind the distributor.	☐	☐
12. Are adequate rollers available to keep up with the binder and aggregate application?	☐	☐
13. Are the rollers keeping pace with the aggregate spreader?	☐	☐
14. Has embedment been checked after rolling?	☐	☐
15. Has the excess aggregate been swept before opening to full speed traffic?	☐	☐

Appendix A

Chip Seal Design

There are several procedures for determining the appropriate quantity of asphalt binder and cover aggregate for chip seal applications. These methods usually involve utilizing laboratory tests to determine the average least dimension, voids, and bulk specific gravity of the cover aggregate. Using the results derived from these tests along with pavement and traffic conditions in various empirical mathematical equasions, allows for determination of the required quantities of asphalt binder and aggregate. Typical design procedures are available from ASTM, AASHTO, and many state DOT's, including the Arizona Department of Transportation (ADOT). The goal of any of these procedures is to have aggregate particles to be approximately 70% embedded in the asphalt binder. When a one-sized cover aggregate is applied by a calibrated spreader onto a properly applied asphalt binder, the particles will be randomly oriented. After rolling/compaction and application of traffic, the aggregate particles should realign with about 20 percent voids between the particles. A desirable design is usually based on 60 to 75 percent of the voids being filled with the asphalt binder. Adjustments must be made for the traffic volume, surface condition/porosity of the pavement or surface and the characteristics of the cover aggregate (size, shape, gradation and specific gravity).

Rather than utilizing one of these complex design procedures, a range of asphalt and aggregate application rates is provided in the following table to serve as a guide for estimating the proper quantity of materials for a given aggregate size. The indicated quantities of aggregate and asphalt binder cover the range of conditions that vary from primed granular bases to aged and oxidized pavement surfaces. The quantities and types of materials may require adjustment according to local conditions and experience.

Appendix B

Quantities of Asphalt and Aggregate for Single Surface Treatments[1,2,3,4,5]				
Nominal Size of Aggregate	**Size No.**	**Quantity of Aggregate** lb/yd² (kg/m²)	**Quantity of Asphalt** gal/yd² (l/m²)	**Type and Grade of Asphalt***
3/4 to 3/8 in. (19.0 to 9.5 mm)	6	40-50 (22-27)	0.40-0.50 (1.8-2.3)	RS-2, CRS-2
1/2 in. to No. 4 (12.5 to 4.75 mm)	7	25-30 (14-16)	0.30-0.45 (1.4-2.0)	RS-1, RS-2, CRS-1, CRS-2
3/8 in. to No. 8 (9.5 to 2.36 mm)	8	20-25 (11-14)	0.20-0.35 (0.9-1.6)	RS-1, RS-2, CRS-1, CRS-2
No. 4 to No. 16 (4.75 to 1.18 mm)	9	15-20 (8-11)	0.15-0.20 (0.7-0.9)	RS-1, MS-1, CRS-1, HFRS-2
Sand	AASHTO M-6	10-15 (5-8)	0.10-0.15 (0.5-0.7)	RS-1, MS-1, CRS-1, HFRS-2

*** Including polymer modified versions of these emulsions**

[1] These quantities of asphalt cover the average range of conditions that include primed granular bases to old pavement surfaces. The quantities and types of materials may be varied according to local conditions and experience.

[2] The weight of aggregate shown in the table is based on an aggregate specific gravity of 2.65. If the measured aggregate specific gravity differs from this value by 0.1 or greater, the amount of aggregate shown in the table above should be multiplied by the ratio of the actual specific gravity to 2.65.

[3] The lower application rates of asphalt shown in the above table should be used for aggregate having gradations on the fine side of the specified limits. The higher application rates should be used for aggregate having gradations on the coarse side of the specified limits.

[4] It is important to adjust the asphalt quantity for the surface condition of the road, increasing it if the road is absorbent, badly cracked, or coarse, and decreasing it if the road is flushed with asphalt. (See table below.)

[5] It is important to adjust the asphalt quantity for traffic count and conditions. An increase in traffic will mean a decrease in asphalt content.

Corrections for Surface Condition		
Pavement Texture	**Correction**** gal/yd²	(L/m²)
Black, flushed asphalt	-0.01 to -0.06	(-0.04 to -0.27)
Smooth, non-porous	0.00	(0.00)
Absorbent - slightly porous, oxidized	0.03	(0.14)
- slightly pocked, porous, oxidized	0.06	(0.27)
- badly pocked, porous, oxidized	0.09	(0.40)

****This correction must be made from observations at the job site.**

Note: The quantities of aggregate and asphalt determined in this design procedure are a result of the methodology used to account for the average range of conditions that include primed granular bases and old pavement surfaces. The quantities and types of materials may vary according to local conditions.

Appendix C

TEMPERATURE-VOLUME CORRECTIONS FOR EMULSIFIED ASPHALTS

LEGEND: t = observed temperature in degrees Fahrenheit
M = multiplier for correcting volumes to the basis of 60 degrees Fahrenheit

t	M	t	M	t	M
50	1.00250	92	0.99200	134	0.98150
51	1.00225	93	0.99175	135	0.98125
52	1.00200	94	0.99150	136	0.98100
53	1.00175	95	0.99125	137	0.98075
54	1.00150	96	0.99100	138	0.98050
55	1.00125	97	0.99075	139	0.98025
56	1.00100	98	0.99050	140	0.98000
57	1.00075	99	0.99025	141	0.97975
58	1.00050	100	0.99000	142	0.97950
59	1.00025	101	0.98975	143	0.97925
60	1.00000	102	0.98950	144	0.97900
61	0.99975	103	0.98925	145	0.97875
62	0.99950	104	0.98900	146	0.97850
63	0.99925	105	0.98875	147	0.97825
64	0.99900	106	0.98850	148	0.97800
65	0.99875	107	0.98825	149	0.97775
66	0.99850	108	0.98800	150	0.97750
67	0.99825	109	0.98775	151	0.97725
68	0.99800	110	0.98750	152	0.97700
69	0.99775	111	0.98725	153	0.97675
70	0.99750	112	0.98700	154	0.97650
71	0.99725	113	0.98675	155	0.97625
72	0.99700	114	0.98650	156	0.97600
73	0.99675	115	0.98625	157	0.97575
74	0.99650	116	0.98600	158	0.97550
75	0.99625	117	0.98575	159	0.97525
76	0.99600	118	0.98550	160	0.97500
77	0.99575	119	0.98525	161	0.97475
78	0.99550	120	0.98500	162	0.97450
79	0.99525	121	0.98475	163	0.97425
80	0.99500	122	0.98450	164	0.97400
81	0.99475	123	0.98425	165	0.97375
82	0.99450	124	0.98400	166	0.97350
83	0.99425	125	0.98375	167	0.97325
84	0.99400	126	0.98350	168	0.97300
85	0.99375	127	0.98325	169	0.97275
86	0.99350	128	0.98300	170	0.97250
87	0.99325	129	0.98275	171	0.97225
88	0.99300	130	0.98250	172	0.97200
89	0.99275	131	0.98225	173	0.97175
90	0.99250	132	0.98200	174	0.97150
91	0.99225	133	0.98175	175	0.97125

Appendix D

TEMPERATURE-VOLUME CORRECTIONS FOR HOT ASPHALTIC MATERIALS
GROUP 0 – SPECIFIC GRAVITY AT 60 °F ABOVE 0.966

LEGEND: t = observed temperature in degrees Fahrenheit
M = multiplier for correcting volumes to the basis of 60 degrees Fahrenheit

t	M	t	M	t	M	t	M	t	M	t	M	t	M	t	M
100	0.9861	150	0.9689	200	0.9520	250	0.9352	300	0.9187	350	0.9024	400	0.8864	450	0.8705
101	0.9857	151	0.9686	201	0.9516	251	0.9349	301	0.9184	351	0.9021	401	0.8861	451	0.8702
102	0.9854	152	0.9682	202	0.9513	252	0.9346	302	0.9181	352	0.9018	402	0.8857	452	0.8699
103	0.9851	153	0.9679	203	0.9509	253	0.9342	303	0.9177	353	0.9015	403	0.8854	453	0.8696
104	0.9847	154	0.9675	204	0.9506	254	0.9339	304	0.9174	354	0.9011	404	0.8851	454	0.8693
105	0.9844	155	0.9672	205	0.9503	255	0.9336	305	0.9171	355	0.9008	405	0.8848	455	0.8690
106	0.9840	156	0.9669	206	0.9499	256	0.9332	306	0.9167	356	0.9005	406	0.8845	456	0.8687
107	0.9837	157	0.9665	207	0.9496	257	0.9329	307	0.9164	357	0.9002	407	0.8841	457	0.8683
108	0.9833	158	0.9662	208	0.9493	258	0.9326	308	0.9161	358	0.8998	408	0.8838	458	0.8680
109	0.9830	159	0.9658	209	0.9489	259	0.9322	309	0.9158	359	0.8995	409	0.8835	459	0.8677
110	0.9826	160	0.9655	210	0.9486	260	0.9319	310	0.9154	360	0.8992	410	0.8832	460	0.8674
111	0.9823	161	0.9652	211	0.9483	261	0.9316	311	0.9151	361	0.8989	411	0.8829	461	0.8671
112	0.9819	162	0.9648	212	0.9479	262	0.9312	312	0.9148	362	0.8986	412	0.8826	462	0.8668
113	0.9816	163	0.9645	213	0.9476	263	0.9309	313	0.9145	363	0.8962	413	0.8822	463	0.8665
114	0.9813	164	0.9641	214	0.9472	264	0.9306	314	0.9141	364	0.8979	414	0.8819	464	0.8661
115	0.9809	165	0.9638	215	0.9469	265	0.9302	315	0.9138	365	0.8976	415	0.8816	465	0.8658
116	0.9806	166	0.9635	216	0.9466	266	0.9299	316	0.9135	366	0.8973	416	0.8813	466	0.8655
117	0.9802	167	0.9631	217	0.9462	267	0.9296	317	0.9132	367	0.8969	417	0.8810	467	0.8652
118	0.9799	168	0.9628	218	0.9459	268	0.9293	318	0.9128	368	0.8966	418	0.8806	468	0.8649
119	0.9795	169	0.9624	219	0.9456	269	0.9289	319	0.9125	369	0.8963	419	0.8803	469	0.8646
120	0.9792	170	0.9621	220	0.9452	270	0.9286	320	0.9122	370	0.8960	420	0.8800	470	0.8643
121	0.9788	171	0.9618	221	0.9449	271	0.9283	321	0.9118	371	0.8957	421	0.8797	471	0.8640
122	0.9785	172	0.9614	222	0.9446	272	0.9279	322	0.9115	372	0.8953	422	0.8794	472	0.8636
123	0.9782	173	0.9611	223	0.9442	273	0.9276	323	0.9112	373	0.8950	423	0.8791	473	0.8633
124	0.9778	174	0.9607	224	0.9439	274	0.9273	324	0.9109	374	0.8947	424	0.8787	474	0.8630
125	0.9775	175	0.9604	225	0.9436	275	0.9269	325	0.9105	375	0.8944	425	0.8784	475	0.8627
126	0.9771	176	0.9601	226	0.9432	276	0.9266	326	0.9102	376	0.8941	426	0.8781	476	0.8624
127	0.9768	177	0.9597	227	0.9429	277	0.9263	327	0.9099	377	0.8937	427	0.8778	477	0.8621
128	0.9764	178	0.9594	228	0.9426	278	0.9259	328	0.9096	378	0.8934	428	0.8775	478	0.8618
129	0.9761	179	0.9590	229	0.9422	279	0.9256	329	0.9092	379	0.8931	429	0.8772	479	0.8615
130	0.9758	180	0.9587	230	0.9419	280	0.9253	330	0.9089	380	0.8928	430	0.8768	480	0.8611
131	0.9754	181	0.9584	231	0.9416	281	0.9250	331	0.9086	381	0.8924	431	0.8765	481	0.8608
132	0.9751	182	0.9580	232	0.9412	282	0.9246	332	0.9083	382	0.8921	432	0.8762	482	0.8605
133	0.9747	183	0.9577	233	0.9409	283	0.9243	333	0.9079	383	0.8918	433	0.8759	483	0.8602
134	0.9744	184	0.9574	234	0.9405	284	0.9240	334	0.9076	384	0.8915	434	0.8756	484	0.8599
135	0.9740	185	0.9570	235	0.9402	285	0.9236	335	0.9073	385	0.8912	435	0.8753	485	0.8596
136	0.9737	186	0.9567	236	0.9399	286	0.9233	336	0.9070	386	0.8908	436	0.8749	486	0.8593
137	0.9734	187	0.9563	237	0.9395	287	0.9230	337	0.9066	387	0.8905	437	0.8746	487	0.8590
138	0.9730	188	0.9560	238	0.9392	288	0.9227	338	0.9063	388	0.8902	438	0.8743	488	0.8587
139	0.9727	189	0.9557	239	0.9389	289	0.9223	339	0.9060	389	0.8899	439	0.8740	489	0.8583
140	0.9723	190	0.9553	240	0.9385	290	0.9220	340	0.9057	390	0.8896	440	0.8737	490	0.8580
141	0.9720	191	0.9550	241	0.9382	291	0.9217	341	0.9053	391	0.8892	441	0.8734	491	0.8577
142	0.9716	192	0.9547	242	0.9379	292	0.9213	342	0.9050	392	0.8889	442	0.8731	492	0.8574
143	0.9713	193	0.9543	243	0.9375	293	0.9210	343	0.9047	393	0.8886	443	0.8727	493	0.8571
144	0.9710	194	0.9540	244	0.9372	294	0.9207	344	0.9044	394	0.8883	444	0.8724	494	0.8568
145	0.9706	195	0.9536	245	0.9369	295	0.9204	345	0.9040	395	0.8880	445	0.8721	495	0.8565
146	0.9703	196	0.9533	246	0.9365	296	0.9200	346	0.9037	396	0.8876	446	0.8718	496	0.8562
147	0.9699	197	0.9530	247	0.9362	297	0.9197	347	0.9034	397	0.8873	447	0.8715	497	0.8559
148	0.9696	198	0.9526	248	0.9359	298	0.9194	348	0.9031	398	0.8870	448	0.8712	498	0.8556
149	0.9693	199	0.9523	249	0.9356	299	0.9190	349	0.9028	399	0.8867	449	0.8709	499	0.8552

Appendix E

Gallons of Emulsified Asphalt Required per 100 Linear Feet For Various Widths and Applications Rates

Rate (Gals. Per Sq Yd.)	**Width** (feet)														
	1	2	6	7	8	9	10	11	12	14	16	18	20	22	24
0.10	1.1	2.2	6.7	7.8	8.9	10.0	11.1	12.2	13.3	15.6	17.8	20.0	22.2	24.4	26.7
0.15	1.7	3.3	10.0	11.7	13.3	15.0	16.7	18.3	20.0	23.3	26.7	30.0	33.3	36.7	40.0
0.20	2.2	4.4	13.3	15.6	17.8	20.0	22.2	24.4	26.7	31.1	35.6	40.0	44.4	48.9	53.3
0.25	2.8	5.6	16.7	19.4	22.2	25.0	27.8	30.6	33.3	38.9	44.4	50.0	55.6	61.1	66.7
0.30	3.3	6.7	20.0	23.3	26.7	30.0	33.3	36.7	40.00	46.7	53.3	60.0	66.7	73.3	80.0
0.35	3.9	7.8	23.3	27.2	31.1	35.0	38.9	42.8	46.7	54.4	62.2	70.0	77.8	85.5	93.3
0.40	4.4	8.9	26.7	31.1	35.6	40.0	44.4	48.9	53.3	62.2	71.1	80.0	88.9	97.8	107.
0.45	5.0	10.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	70.0	80.0	90.0	100.	110.	120.
0.50	5.6	11.1	33.3	38.9	44.4	50.0	55.5	61.1	66.7	77.8	88.9	100.	111.	122.	133.
0.55	6.1	12.2	36.7	42.8	48.9	55.0	61.1	67.2	73.3	85.5	97.8	110.	122.	134.	147.
0.60	6.7	13.3	40.0	46.7	53.3	60.0	66.7	73.3	80.0	93.3	107.	120.	133.	147.	160.
0.65	7.2	14.4	43.3	50.6	57.8	65.0	72.2	79.4	86.7	101.	115.	130.	144.	159.	173.
0.70	7.8	15.6	46.7	54.4	62.2	70.0	77.8	85.5	93.3	109.	124.	140.	156.	171.	187.
0.75	8.3	16.7	50.0	58.3	66.7	75.0	83.3	91.7	100.	117.	133.	150.	167.	183.	200.
0.80	8.9	17.8	53.3	62.2	71.1	80.0	88.9	97.8	107.	124.	142.	160.	178.	196.	213.
0.85	9.4	18.9	56.7	66.1	75.5	85.0	94.4	104.	113.	132.	151.	170.	189.	208.	227.
0.90	10.0	20.0	60.0	70.0	80.0	90.0	100.	110.	120.	140.	160.	180.	200.	220.	240.
0.95	10.6	21.1	63.3	73.9	84.4	95.0	106.	116.	127.	148.	169.	190.	211.	232.	253.
1.00	11.1	22.2	66.7	77.8	88.9	100.	111.	122.	133.	156.	178.	200.	222.	244.	267.
1.10	12.2	24.4	73.3	85.5	97.8	110.	122.	134.	147.	171.	196.	220.	244.	269.	293.
1.20	13.3	26.7	80.8	93.3	107.	120.	133.	147.	160.	187.	213.	240.	267.	293.	320.
1.25	13.9	27.8	83.3	97.2	111.	125.	139.	153.	167.	194.	222.	250.	278.	306.	333.
1.30	14.4	28.9	86.7	101.	116.	130.	144.	159.	173.	202.	230.	260.	288.	318.	347.
1.40	15.6	31.1	93.3	109.	124.	140.	156.	171.	187.	218.	249.	280.	311.	342.	373.
1.50	16.7	33.3	100.	117.	133.	150.	167.	183.	200.	233.	267.	300.	333.	367.	400.
1.75	19.4	38.9	117.	136.	156.	175.	194.	214.	233.	272.	311.	350.	389.	427.	467.
2.00	22.2	44.4	133.	156.	178.	200.	222.	244.	267.	311.	356.	400.	444.	489.	533.
2.25	25.0	50.0	150.	175.	200.	225.	250.	275.	300.	350.	400.	450.	500.	550.	600.
2.50	27.8	55.6	167.	194.	222.	250.	278.	306.	333.	389.	444.	500.	556.	311.	667.
2.75	30.6	60.1	183.	214.	244.	275.	306.	336.	367.	428.	489.	550.	611.	672.	733.
3.00	33.3	66.7	200.	233.	267.	300.	333.	367.	400.	467.	533.	600.	667.	733.	800.

Note: Formula used for calculation: Q = 100 x W x R

Q = Quantity of asphalt required in gallons per 100 ft
R = Rate of application in gallons per sq. yd.
W= Width of application in feet

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