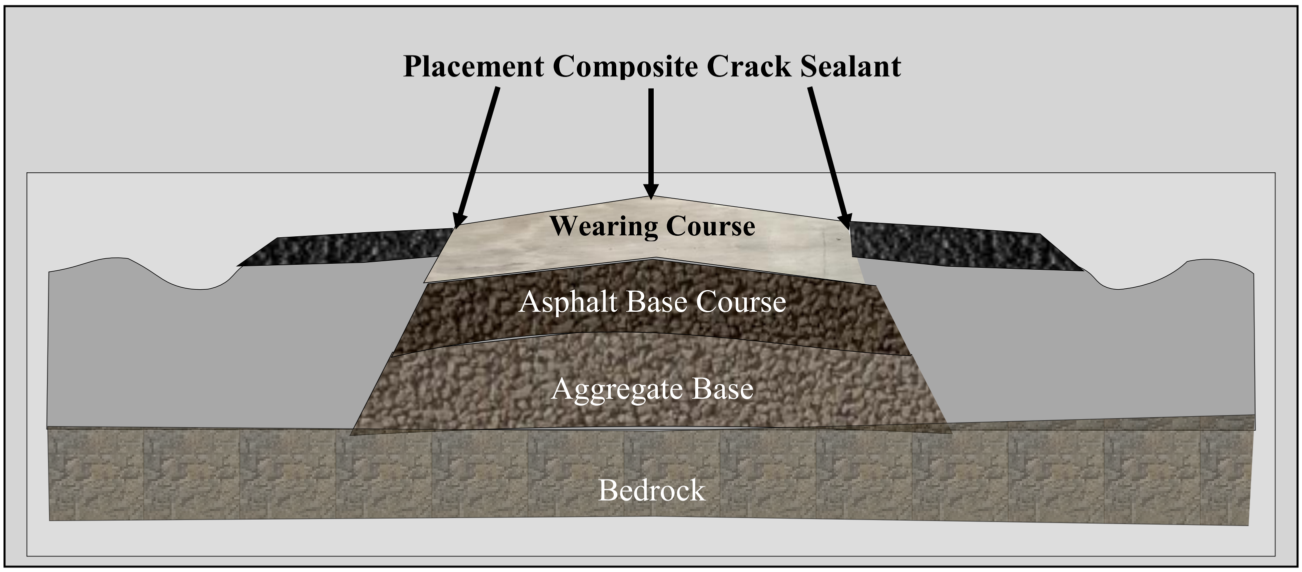
Bituminous Pavements: Composite Crack Sealant Specification

DATE	June 9, 2023
SCOPE OF SPECIFICATION	1. Application Use and Summary 2. Material Selection - Rheology Based Test Methods (Composite Crack Sealants) 3. Materials Selection - Notes for Guidance: Composite Crack Sealant Selection 4. Placement 5. Quality 6. Submittals
PAYMENT	1. Mobilization: One time event 2. Traffic Control: Additional for Collectors and Arterials (or where safety dictates additional requirements). 3. Rheology Based Materials: dollars per square yard ($\$/yd.^2$)
WARRANTY	1 Years

Section 1: Description Composite Crack Sealant Specification

Description: A Composite Crack Sealant (CCS) is a viscoelastic caulking material used to waterproof pavements to improve lifecycle performance of asphalt and concrete pavements. A CCS takes into consideration the climatic, pavement type, quality, and application requirements needed to provide a waterproofing sealant that adheres, flexes, and remains in joints and cracks to protect the pavements from debris, incompressible materials, de-icing chemicals, and water to flow into the base of the pavement thereby compromising the structural integrity of a roadway.

Diagram 1: Pavement Cross Section with Distresses & Application Guidance



Section 2: Rheology Based Composite Crack Sealant Specifications

Table 3: Rheological Performance Tests

<table>
<tr><th rowspan="2">Material Grade</th><th>High Temperature</th><th colspan="2">Intermediate Temperature</th><th colspan="2">Low Temperature</th><th>Aging</th></tr>
<tr><th>Jnr, 80°C, 1/KPa (maximum)</th><th>G*, MPa (minimum)</th><th>δ, degrees (minimum)</th><th>G*, MPa (maximum)</th><th>δ, degrees (minimum)</th><th>G-R ratio (maximum)</th></tr>
<tr><td>Standard</td><td rowspan="2">2.0, T_{HT} ≤58
1.0, T_{HT}≥64</td><td rowspan="2">0.10</td><td>42.0</td><td>100.0</td><td>30.0</td><td>5</td></tr>
<tr><td>Performance</td><td>75.0</td><td>75.0</td><td>35.0</td><td>2.5</td></tr>
</table>

Testing for G* and **δ** shall be conducted using ASTM D7175 at the appropriate temperatures.

$$G-R\ parameter = \frac{G^*(\cos\partial)^2}{\sin\partial}$$

Table 4: Rheological Performance Tests - Ductility		
Material Grade	**Original 4°C Ductility**	**PAV Aged 4°C Ductility**
	cm (minimum)	cm (minimum)
Standard	30	
Performance	35	25

Table 5: Adhesion Performance Requirements	
Adhesion in Peel to Mortar (ASTM C794)	**Max Adhesion Force lbs-force), minimum**
Standard	20
Performance	40

Table 6: Rotational Viscosity Requirements & Color		
Brookfield Viscosity (ASTM D4402/AASHTO T316)	**350°F Viscosity (cP), maximum**	**Recommended Application Temperature**
Standard	4000	355-375°F
Performance	6000	365-385°F
Color		

Never allow sealant temperature to exceed 400°F, even momentarily

Section 3: Notes for Guidance: Composite Crack Sealant Selection

Table 7: Location Based Performance Specification

Location	Low	Low + 30 rounded	Int. + 4	Int. (Rounded)	High	Sealant Grade[1]
Minneapolis	-27	2	14	15	53	58(15)-28
Kansas City	-21	8	22	22	61	64(22)-22
Dallas	-8	20	29-33	30	73	76(30)-10
Los Angeles[2]	-4 to -5	20	29-33	30	73	76(30)-10

1. *Sealant grade is using the basis as the PG grade system for binders. Use SG to reflect standard grade and PG to reflect Performance grade.*
2. *Locations close to LA in mountains have a considerably colder low temperature*

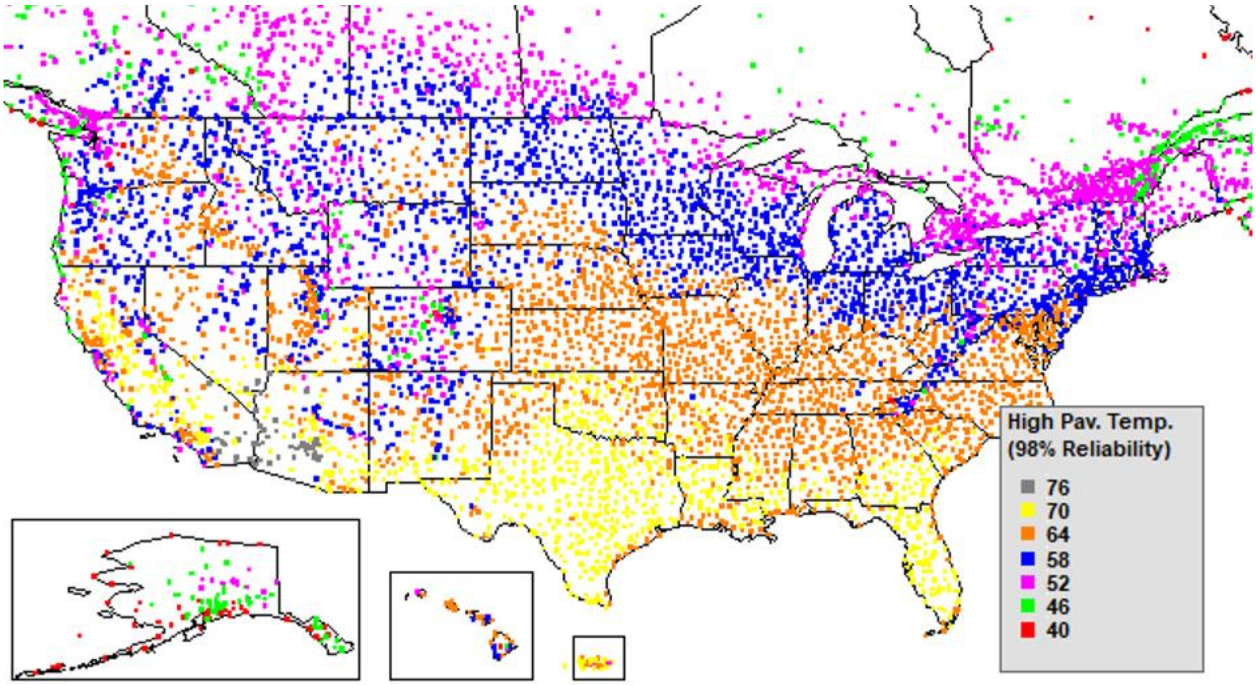
These notes have been prepared to enable Engineers and technicians to have an understanding why each parameter has been selected and included in this specification. The development of the specification followed principles and methods developed during research work such as the SHRP program, using rheological principles of time-temperature equivalency to arrive as suitable parameters that consider, high, intermediate and low temperature considerations. Parameters are considered with respect to how they change with aging, and furthermore they are related to the principal modes of failure that are seen with joint materials.

High Pavement Temperature (Reference AASHTO T350)

At high temperatures, the material should not flow and should not soften to an extent to cause tackiness with tires.

High temperature stiffness is assessed by Jnr tested at a stress level of 3200 Pa. This is a high stress test with Jnr requirements based on the climatic area. This ensures that material will not deform excessively at the higher temperatures for a climatic zone. The Jnr value quantifies the amount of deformation (strain) accumulated in the sealant over 10 cycles of loading and relaxation at constant stress of 3200 Pa; LOWER values indicate LESS accumulated deformation.

The climatic zone for a particular location in the USA is assessed by consideration of the PG (performance grade) 98% high criteria from the LTTP Bind database. We consider two performance areas for simplification – those with a PG64 and more mild climates where PG58. This effectively means that most of the southern part of the USA would have a requirement for the Jnr of less than 1.0 1/kPa, whereas the northern tier states would have a requirement of less than 2.0 1/kPa.



Map 1: High Pavement Temperature PG

<u>Intermediate Pavement Temperature (Reference AASHTO T315)</u>

The intermediate average annual pavement temperature requirement is an important consideration since most of the accumulated damage associated with joints opening and closing occur in this temperature range. At higher temperatures, materials are often soft enough that significant strains do not result in excessive stresses. However, if sufficient relaxation properties are not provided in this temperature range, stress and associated deformation will lead to cracking. The stiffness needs to be high enough to ensure that strains are limited, whereas the phase angle needs to be high to ensure that stresses developed are relaxed.

Recent work on asphalt paving materials, as part of NCHRP 9-59 studies have suggested that fatigue performance of asphalt binders can be related to the Mean Pavement Temperature (MPT). This temperature is adjusted in that work by adding 4-degrees Celsius. This approach for defining an Adjusted Mean Pavement Temperature (AMPT) is considered acceptable for the assessment of the average working average annual pavement temperature that a crack and/or a joint will experience. The 4°C adjustment considered how materials behave in fatigue and consequently we have also used this adjustment in our assessment of the climate. Thus, for a particular climatic zone we determine the adjusted mean pavement temperature, and round this to the nearest temperature of 15, 17, 19, 22, 25, 27 or 29°C. These temperatures have been adopted in NCHRP 9-59. An analysis of temperatures in the NOAA database has been conducted and the AMPT has been computed for sufficient locations around the USA. These have been used to determine the intermediate temperature for evaluation at a particular site or location in the USA.

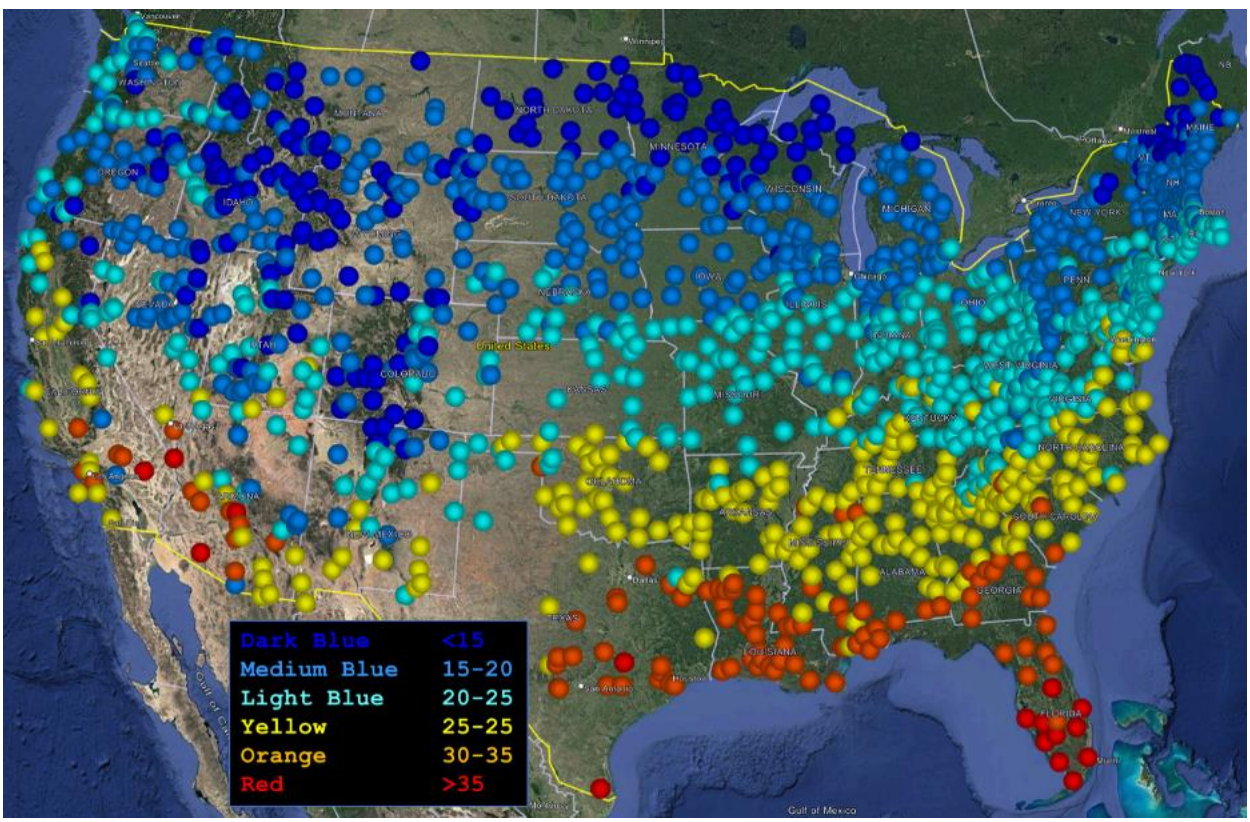
ADJUSTED AVERAGE ANNUAL PAVEMENT TEMPERATURE (AMPT)

The AMPT we have assessed the properties at 10 radians/second which is a speed of loading associated with typical traffic movements (Please reference Map 2 to gain a geographical orientation.).

For typical materials that are used for sealing of joints and cracks, the phase angle is typically over 40 degrees in the intermediate temperature zone. The phase angle defines the rate at which the sealant can relax stresses, with higher phase angles indicating higher relative rates of stress relaxation. This is associated with polymer modification and a tendency for this material to behave in a similar manner to a viscoelastic solid. For Standard sealants in our specification, the phase lag shall be greater than forty-two degrees. A phase angle of 75° for "Performance Grade" products ensures stresses are relaxed at a higher rate, sufficient to minimize the potential for loss of bonding and adhesion in the joint, and will also ensure that stresses do not build that lead to cracking.

In addition to the relaxation of stress as indicated by the phase lag, a minimum stiffness value is specified to ensure that the material will have an adequate stiffness at this temperature to resist loading from traffic and other applied forces. A value of greater than 100 kPa shall be required.

When the intermediate stiffness requirement is considered with the high temperature requirements, the resultant materials will tend to behave like viscoelastic solids over a fairly wide range of temperatures.

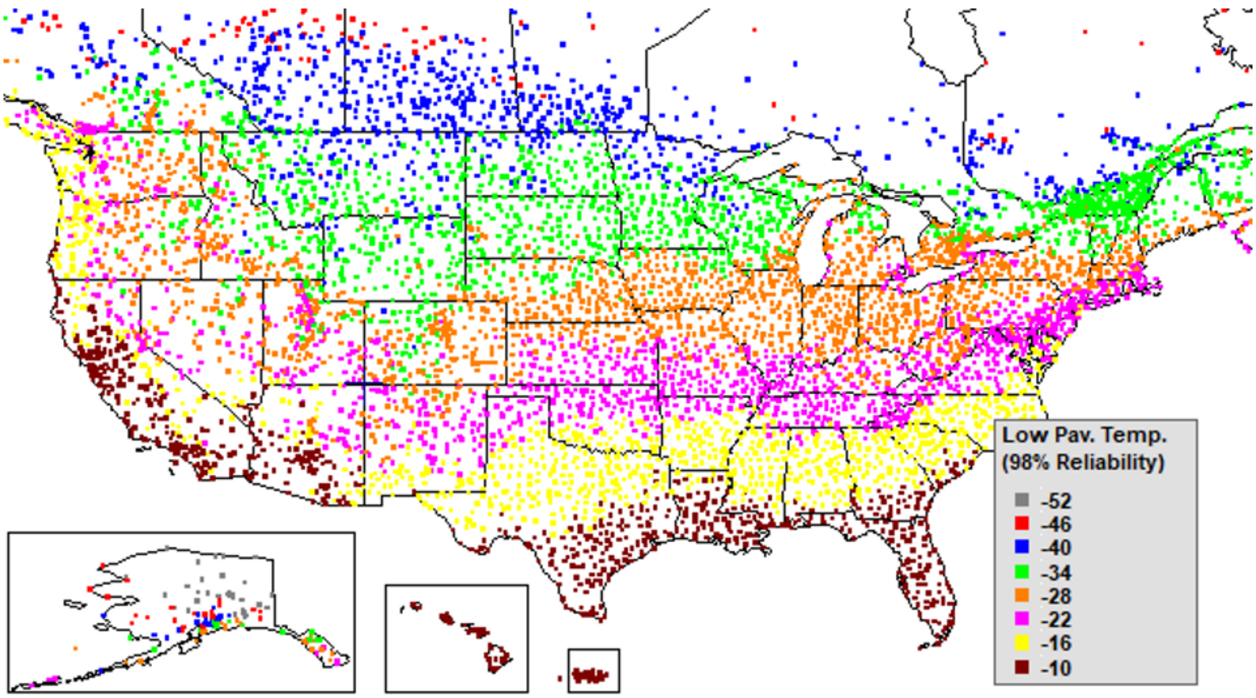


Map 2: Average Annual Pavement Temperature (AAPT)

Low Pavement Temperature (Reference AASHTO T315/ ASTM D7175)

At low pavement temperatures, materials tend to become stiff and lack the ability to relax stresses. For a joint and crack, the movement is higher than the surrounding pavement. Thus, a sealant material must cope with relatively large displacements, with the ability to relax stresses (Please refer to Map three for geographical orientation.).

For asphalt binders, the standard Superpave PG specification is associated with the ability of a material to build stresses and then relax those stresses. The ability to build stress is considered via a stiffness measured with a Bending Beam Rheometer (BBR), which must be maintained below 300 MPa to ensure stress build up is minimal. In addition, an m-value defines relaxation properties and shall be greater than 0.300. These values translate to properties measured in the Dynamic Shear Rheometer (DSR) of a complex modulus (G*) maximum of 111 MPa, and a phase angle minimum of 26.2 degrees.



Map 3: Low Pavement Temperature PG

In the development of the specifications, a critical loading time of 7200 seconds was considered to be related to cracking at low temperatures. However, this loading time was considered too long for a practical test and a time temperature superposition method was used to reduce the test time to 60 seconds with a 10-degree temperature adjustment to the test with the bending beam rheometer (BBR).

In the method considered for joint materials and incorporated herein, the use of a standard DSR with a 10 radians/second testing rate is considered preferable and the temperature shift associated with the 7200 seconds condition is found to be 30°C. Using this DSR testing rate of 10 radians/sec, and applying the 30°C temperature shift, we require the same maximum stiffness value of 100 MPa for the Standard grade products. This value of stiffness was not easily attainable with rheometers in the early 1990s as Superpave was implemented, but now this is easier to obtain with the more modern rheometers. For "Performance Grade" products, the stiffness requirement is reduced to a maximum of 75 MPa. In terms of the phase angle requirements, the phase angle defines the rate at which the sealant is able to relax stresses. A phase angle minimum of 30° for Standard grade products implies the material can relax stresses at a rate sufficient to avoid thermal cracks at the lowest expected air temperatures for the relevant climate region. For Performance Grade products, the minimum phase angle requirement is increased to 35°, ensuring that Performance Grade Products have an exceptional low temperature performance for sealing and resisting the propensity for low temperature cracking.

In the adopted procedure the low temperature for the region is assessed using the LTTP bind software or equivalent plus 30° to give an equivalent temperature for testing at 10 radians/second. This temperature is rounded to closest of -10, -4, 2, 8, 14, 20°C.

Tensile Strength at High Elongations (Reference AASHTO T51)

In addition to the rheology parameters, our specification requires that sealants display an ability to relax stress at relatively high strain levels. The best means for evaluating the tensile properties of a sealant at high strain levels, and that is also readily available in most construction material labs, is the asphalt ductilometer. To ensure that sealants display good tensile strength at high strain levels, we require a minimum ductility or elongation at failure for unaged sealants of 30 cm for Standard Grade products, and 35 cm for Performance Grade products when measured at a temperature of 4°C. The ductility is assessed at a temperature of 4°C because stress relaxation by deformation is more difficult for most asphalt and other resin-based materials at lower temperatures, so it is considered a more discriminating test. Furthermore, we require Performance Grade sealants to show a retained 4°C ductility minimum of 25 cm after PAV aging, to ensure these high tensile properties are maintained on the roadway after initial application

Aging of Materials

The aging of sealants has been investigated with a number of methods. To ensure good consistency of product the G-R ratio using 15°C and 10 radians / second is determined. This is calculated from tests on ORGINAL and PAV conditioned samples. The RTFO step as with paving grade binders is not performed for these sealant binders. The Glover-Rowe parameter is defined as follows:

The Aging Ration is Calculated as:

$$G-R\ parameter = \frac{G^{*}(\cos\partial)^{2}}{\sin\ \partial}$$

$$\text{Aging Ratio} = \text{G-R}_{\text{PAV}}/\text{G-R}_{\text{ORGINAL}}$$

<u>Test Methods</u>

1. Testing for G* and **δ** shall be conducted using ASTM D7175 (AASHTO T 315) at the appropriate temperatures
2. Jnr is measured using the Dynamic Shear Rheometer (DSR) according to AASHTO T 350
3. Ductility is tested at 4°C according to AASHTO T 51 (ASTM D113)

Section 4: Composite Crack Sealant Placement

I. Equipment Requirements:

A. Air Compressor

i. Minimum of 100 CFM (Cubic feet per minute) flow

ii. Minimum of 100 PSI (Pound per square inch) pressure

iii. Air lance attachment with diameter no larger than 1 inch to allow for precision blow out

iv. Heat lance attachment that can be used to dry and heat areas of moisture while blowing out cracks simultaneously

B. Kettle

v. Application and storage tank capacities of 180 gallons or more to ensure uniform heating and appropriate viscosity profile

vi. Ability to agitate application tank to minimize colds pockets and coking inside the kettle

vii. Application wand with an ergonomic design to minimize repetitive movement injuries

viii. Temperature control equipment and application wand that ensures placement temperatures (at the point of crack and joint sealing) over 300 degrees F with appropriate material viscosity to ensure strong sidewall adhesion

ix. Kettle and application equipment mounted on a chassis of a truck to improve efficiency and safety

C. Support Equipment

i. Power Rotary Wire Wheels for proper clean out of dirt and vegetation

ii. Dust Suppression Sprayers for Lasso use ahead of application trucks in areas with a high concentration of dirt or gravel

iii. Kinder Torches that can be used to dry and heat areas of moisture while blowing out cracks and joints simultaneously

iv. Grass/Vegetation picks for areas of vegetation that must be manually removed

II. Traffic Control

A. Plans

x. An outline will be created with maps being reviewed and communications being made to the
xi. inspector prior to daily start.
xii. Plans will be in accordance with the Manual of Uniform Traffic Control Devices (MUTCD)

B. Training
xiii. All employees take requires Safety and Traffic Control Training (OSHA 10.)
xiv. Flagger Certification.

C. Equipment
xv. Orange Cones in good condition
xvi. Traffic signage (Road Work Ahead, One Lane Road Ahead and Stop/Slow Paddles)
xvii. Strobe and Work Lights on all application vehicles
xviii. Arrow boards for use on Thoroughfares or roads with speed limits over 55 MPH

D. Safety
xix. High Visibility Safety Vests
xx. Designated storage for all PPE
xxi. ANSI Approved First Aid Kit
xxii. Hearing Protection
xxiii. Face Shields
xxiv. Eye Protection
xxv. Leather Gloves
xxvi. Composite or Steel Toe Boots

III. Crack Preparation Steps

A. Cracks will be thoroughly blown out using air compressor and air lance with minimum of 100 PSI
B. If necessary, Kinder Torches will be used to remove moisture from cracks and joints
C. Cracks and joints to be clean and free of debris to a minimum of 0.5 inches and no deeper than 1.5 inches
D. Cracks and joints will have no free or standing water after preparation steps are completed

IV. Start-up

A. Appropriate safety inspection of equipment will be performed by the crew leader before the commencement of start up procedures
B. Face shields, gloves and appropriate burn protection will be used while material is being charged into the application tank
C. Sealant will be brought up to specified temperature to ensure effective viscosity for placement

V. Sealant Application

A. Check to ensure all safety requirements are being met including:

ii. Final check that areas are blocked off to protect the general public

iii. Final safety check of equipment operability

iv. Final temperature check to ensure appropriate viscosity

v. Engage application wand and begin work

B. Oversized Crack Segment - Where pavement distress extends into the pavement base:

iii. Determine best remediation

iv. If backer rod method is being used, select a melt resistant material

v. If choosing to build an in-situ macadam, complete the following steps:

1. Apply crack sealant into the distress to serve as an aggregate lock
2. Place an open graded aggregate into the pavement with a 1 inch reservoir at the surface
3. Apply crack sealant

iv. Crack sealant should be filled in a uniform manner that is visually appealing with a consistent over banding, ideally no greater than 0.5 inches

v. Highly fatigued cracking areas on asphalt pavements should not be crack sealed. Alternative strategies such as surface patches should be considered for these areas

C. Typical Crack Segment:

i. Determine best remediation

ii. If backer rod method is being used, select a melt resistant material

iii. Crack sealant should be filled in a uniform manner that is visually appealing with a consistent over banding, ideally no greater than 0.5 inches

1. Apply crack sealant into the distress to serve as an aggregate lock
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3. Apply crack sealant

iv. Crack sealant should be filled in a uniform manner that is visually appealing with a consistent over banding, ideally no greater than 0.5 inches

v. Highly fatigued cracking areas on asphalt pavements should not be crack sealed. Alternative strategies such as surface patches should be considered for these areas

D. Kettle Temperatures:

i. Overheating Parameters

1. Max Material Temperature Set Limit of 380 degrees F
2. Alerts when material temperatures exceed 400 degrees F inside kettle
3. If material exceeds 420 degrees F inside kettle operations will be halted to allow kettle to return to specified temperature range

ii. Under-Heating Parameters

1. Minimum Material Temperature Set Limit of 340 degrees F

2. Alerts when material temperature drops below 340 degrees F inside kettle
3. If material drops below 340 degrees F inside the kettle operations will be halted to allow kettle to return to specified temperature ranges

E. Environmental Conditions

i. Air temperatures not to be below 34°F (1°C) to ensure proper sidewall adhesion. Goal is to have pavement temperatures no lower than 23°F (-5°C), or rising.

ii. Pavement Temperatures not to exceed 104°F(40°C) to ensure acceptable set time and non-tracking of material. Goal is to have pavement temperatures no higher than 140°F (60°C), or lower - alternatively anti-tracking strategies as cooling water misting can be applied.

iii. In the event of rain or wet weather, operations will be stopped until weather has stopped and streets have had sufficient time to dry

E. Traditional Crack Sealant Application

i. Revert to legacy overbanding of crack sealant to maximize application

ii. Consider using a squeegee to assist in strike off of excess material

iii. Refer to application requirements as stipulated by the crack sealant supplier

Section 5: Quality

A. Inspection

i. Crack Preparation - Crew leads will inspect 250 feet of crack preparation twice a day. If crew leads observe poor quality on any of these stretches the crew will return to that particular street to re prep the road.

1. Reservoir depth will be measured with appropriate tool
2. Moisture in the cracks will be measured using blotting paper or moisture test strips
3. Cleanliness of cracks will be checked visually and clean rags may be used to check that cracks are free of debris

ii. Application - Crew leads will inspect 250 feet of crack preparation twice a day. If crew leads observe poor quality on any of these stretches the crew will return to that particular street to re prep the road

1. Aesthetically pleasing placement will be undertaken
2. Crack reservoir will be filled and the sealant will have a uniform strike off
3. Active cracks will be sealed
4. Attention to transverse and longitudinal cracks to ensure waterproofing of the pavement
5. Failed pavements that are defined as a series of fatigue cracks will not be sealed. This will include “bird bath areas.” A simple field evaluation criteria is the ability to touch three or more cracks when placing the inspectors hand on the pavement.

B. Sampling and Testing (Quality Control)

i. A sample of the crack sealant will be taken at the application wand a minimum of once every 10,000 lb. of material being placed.
   1. Composite Crack Sealant - Samples will have specified DSR tests run that are consistent with the testing protocol stipulated in table 3 of this specification
   2. Traditional Crack Sealants - Samples will have the specified empirical tests that are listed in Table 2 of the specification.

B. Quality Assurance

i. Every twentieth quality control sample will have a third party laboratory test the material to ensure conformance to meeting specifications.

Section 6: Submittals

A. Scope of work and plan of construction

B. Weekly event log that includes:

i. Quantities consumed and pavements that have been sealed

ii. Exception report that reports problems or quality issues

iii. Forecast of anticipated next phase work

C. Quality Reports

i. Quality Control Summary Reports

ii. Third party Quality assurance tests.