THE USE OF ASPHALT RUBBER FOR CRACK SEALING
IN ASPHALT CONCRETE PAVEMENTS AND FOR JOINT SEALING IN
PORTLAND CEMENT CONCRETE PAVEMENTS

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INTRODUCTION

Asphalt concrete highways comprise approximately 1.9 million miles on 93% of the surfaced roadways in the United States with Portland cement concrete roadways comprising the remaining 7%. The asphalt concrete roadways range in type from low traffic volume seal coated roads and subdivision streets to high traffic volume full depth asphalt concrete interstate highways. The majority of asphalt concrete roadways are at least several years old and are exhibiting cracking of various types and extents.

The Portland cement concrete roadways are generally confined to your more urban, high density traffic areas. These types of pavements are experiencing various types of cracking, spalling etc. that now require rehabilitation.

Crack sealing in asphalt concrete pavements is thought by many to be an ineffective, low-priority pavement maintenance task which is performed only after other pavement maintenance activities, such as overlays, seal coats and fog seals are completed and only if time, budget and manpower are sufficient. Due to this belief, cracks in many miles of highways are not sealed each year resulting in accelerating pavement deterioration due to moisture and increased oxidation of the binder.

The "filling" of cracks in asphalt pavements and joints in concrete pavement has been a maintenance and construction function for many years. Until recent years, the "filling" approach was accepted as a medial maintenance task knowing the value was a short-term direction. Yet others, declaring no value in preserving their pavements with crack filling, deleted this task from their maintenance and construction programs altogether.

The questions that we must ask ourselves today is, "Do we want to "fill" the cracks/joints or do we want to "seal" the crack/joint?" From this point forward reference will be made to "sealing" our cracked pavements with a long-term direction.

Today's technology has greatly improved with a better performing type of sealant material and methods for sealing cracks/joints at the same time the demand for a cost-effective preventative maintenance technique is required to extend the life of our roadway system.

The current recognition that prompts corrective action to seal cracks/joints before they begin to contribute to accelerated pavement deterioration will pay great dividends. The investment that any city, county, state or property owner has in pavement-in-place is far too great to ever consider replacing at today's prices.

This paper is designed to give you a recommended procedure for evaluating cracks, proper sealing preparation and application, as well as, the use of asphalt rubber materials to properly seal your cracked pavements.
PROCEDURES

TYPE OF MATERIAL

What is your objective? We have already mentioned that in order to keep your pavements "sealed" versus "filled" we must obtain a quality asphalt rubber material that will function per particular geographical locations. Material characteristics and performance capability must be selected to meet the individual area needs.

Budgeting considerations are all important with a choice of function materials each possessing individual physical characteristics which offers the specifying engineer an option which he can exercise in material selection to his budget and his needs.

PREPARATION

Too often the proper preparation of the crack/joint is overlooked. The system fails and the first thought for rejection is the sealant failed when actually it may have been that the cleanliness or dryness that is required was not done properly. If you want an asphalt rubber sealant to perform as designed then you must have an equally prepared crack/joint.

APPLICATION MACHINERY

For maximum productivity in the melting/application operation, a very serious evaluation for type of machine is required. What are your production requirement? Will a fifty (50) gallon capacity machine fit your program or would a larger capacity unit be required?

Certainly knowledge of proper operation procedures is required to maintain economical operation, maximum hourly production, energy efficient heating system and heating and melting of asphalt rubber sealant as manufacturer recommends without damaging product performance.
I. ASPHALT CONCRETE PAVEMENTS (A.C.)

A. Asphalt concrete pavements by design are composed of a compacted subgrade, granular base course and asphalt concrete surface (figure 1). This design will vary by structural thickness pending, climate-condition, sub-base quality and traffic loading. A newer concept in today's industry is called "full-depth" asphalt (figure 2). This is a design of eliminating the granular base course and placing a thick asphalt structure on a compacted subgrade. Both installations are considered a flexible pavement system designed to deform without cracking under traffic loading, subgrade deflection or contraction and expansion due to thermal effects.

Regardless of location, design or thickness, our asphalt pavements begin to age at the day of placement. The plasticizer, asphalt cement, will harden through oxidation. The pavement becomes brittle and now unable to flex as originally designed under traffic loading or temperature changes, and a crack now develops (figure 3).

1. Temperature shrinkage cracks

Asphalt pavement is not subject to expansion and contraction cycles as in concrete pavements. The asphalt pavement only shrinks, it never expands. As stated, shrinkage is a result of reduction in volume by evaporation, condensation, polymerization, exudation of oil and oxidation (figure 4).

The horizontal stresses on our asphalt pavements as the ambient temperature decreases and the stiffness of the structure will develop both transverse and longitudinal cracks. Normally transverse cracks at wide spacing will develop first. The longitudinal crack, commonly called a joint crack, will develop when stresses in the transverse direction cannot be adequately distributed by the pavement. This will occur at the center of two lane pavements or at adjoining lanes of the asphalt mat to placement.

2. Fatigue or Alligator Cracking

Fatigue or alligator cracking is a crack developed due to material deformations caused by traffic loadings (vertical stressed) or base failure. Fatigue cracks generally develop in block-type patterns. They are usually associated with a granular untreated base that has failed or with a resilient subgrade.
Another type of fatigue cracking is edge cracks. Edge cracks are longitudinal cracks a foot or so from the edge of the pavement with or without transverse cracks branching toward the shoulder. Usually edge cracks are caused by lack of lateral or shoulder support for the asphalt pavement.

3. **Reflective Cracking**

Reflective cracking in asphalt concrete overlays is caused by transference of horizontal or vertical movements in the underlying pavement into the new overlay. The asphalt concrete overlay will crack in direct ratio to the cracks and/or joints of the asphalt or concrete mass over which it is placed (figure 5).

Normally this crack reflection into the overlay would be an underlying thermal or shrinkage crack/joint. Proper construction practice is to replace fatigue or alligator sections prior to an overlay.

**B. Consequences of Inadequately Sealed Cracks**

The number one culprit to an unsealed or inadequately sealed asphalt pavement is water (figure 6). The moisture enters the unsealed area into the base and subgrade of the pavement. Saturation of the underlying base layers weakens the pavement strength, which increased deflections when loaded promoting more cracking and deterioration. If left unsealed, the worse scenario, pavement failure - pothole. A comparison to keep in mind with an unsealed crack with moisture intrusion is an iceberg. All you see if the surface deterioration 10% +/- while the major damage 90% +/- is occurring in the underlying base. You have seen it happen many times. One day you have an unsealed crack in the pavement; the next day you have a pothole.

Another factor resulting in unsealed cracks, is deterioration of the pavement immediately adjacent to the cracks. Due to exposure of the cracked pavement, oxidation and hardening occur more quickly versus if the crack were sealed.

Our asphalt pavements shrink, cracks widen in the winter and close in the summer. A wider unsealed crack is a candidate for entrance of noncompressibles which restricts crack closure during warm weather (figure 7). The noncompressibles may also cause compressive stresses at the crack forces resulting in spalling and loosening of the asphalt concrete. In addition, heaving of the pavement near the crack may result in bumps.
FIGURES 1 - 7

STANDARD ASPHALT CONCRETE DESIGN

FULL DEPTH ASPHALT CONCRETE DESIGN

CRACK DEVELOPS

PAVEMENT FAILURE

REFLECTIVE CRACK

NON COMPRESSIBLES
II. PORTLAND CEMENT CONCRETE PAVEMENT (P.C.C.P.)

A. Concrete pavements are composed of jointed slabs on a compacted subgrade and thin granular base. The pavement functions as a rigid interconnected mat. The pavement performance is closely related to joint effectiveness and maintenance (figure 8).

Concrete pavements possess the greatest internal strength and the longest life cycle of any paving system developed worldwide. There is a more expensive expenditure for initial concrete placement.

Concrete pavement, like asphalt pavement, is reactive to temperature and moisture changes. The function of the joints are to transfer loads from one slab to adjacent slabs.

1. Working Joint

A working joint is an expansion joint, a contraction joint or a crack in concrete all of which are moving as a direct result of expansion and contraction cycles. A working joint requires the joint sealant to be capable of accepting that moment to functionally perform (figures 9 & 10).

2. Shoulder Joint (Edge Joint)

A shoulder joint is a working joint but to a lesser extent (figure 11). A concrete to bituminous joint could be where concrete paving is widened, and the wider area is bituminous paving. The joint is sealed where the bituminous paving abuts the concrete paving. Two entirely dissimilar materials will work independently of each other; concrete expands and contracts, the bituminous area only incur shrinkage cracks. Frequently, the bituminous pavement (shoulder) will drop or settle below the concrete surface level, and the sealer is required to not only extend in a horizontal plane, but to also accept differential settlement.

B. Consequences of Improperly Sealed Joints

Moisture can enter into the underlying base soils and decrease their strength and the load carrying capacity of the pavements (figure 12). Water entry can actually result in removal of fine soils under the joint creating a void which further reduces pavement strength, which results in increased deflection when loaded and cracking near the joint.

Incompressible materials (gravel, soil or even nuts and bolts from vehicles) can enter into improperly sealed joints and restrict the amount of possible joint movement (figure 13). When the pavement expands as it warms, joints containing incompressibles are stressed resulting in spalled or cracked concrete near the joint faces. In severe cases, slabs may even have to compensate for expansion (figure 14).
FIGURES 8 - 14

TYPICAL CONCRETE PAVEMENT

FIGURE 8

FIGURE 9

FIGURE 10

FIGURE 11

FIGURE 12

FIGURE 13

FIGURE 14
SEALANT MATERIALS

SELECTION REQUIREMENTS

For a material to perform adequately as a crack/joint sealant, it must have sufficient flexibility throughout the range of temperature encountered in service to remain bonded to the crack/joint forces.

The specific characteristics that are required of a quality crack/joint sealant such as asphalt rubber are:

1. Ability to be easily and properly placed in a crack through application equipment.
2. Adequate adhesion to remain bonded to crack/joint forces.
3. Adequate resistance to softening and flow at high in-service pavement temperatures to remain in the crack/joint and prevent tracking.
4. Adequate flexibility and extensibility to remain bonded to crack/joint force when extended at low in-service temperatures.
5. Sufficient elasticity to restrict the entrance of noncompressible materials into the crack/joint.
6. Sufficient pot-life at application temperatures for application of the total amount of prepared asphalt rubber material.
7. Resistance to degradation from weathering to ensure long in-service life of the sealant. Asphalt rubber with a high percentage of carbon black additive resists the oxidation of the ultra-violet rays.
8. Compatibility with asphalt and concrete.
9. Low cure time to permit opening to traffic as soon as possible after application.

TESTING METHODS

Many testing methods which are applicable to asphalt rubber sealants for cracks/joints installation are contained in testing specifications for Portland cement concrete joint sealant materials.

Additionally, several other standard and non-standard tests can be used to determine asphalt rubber sealant properties. A listing of properties which should be utilized to test asphalt rubber sealants are shown in Figure #15.
FIGURE 15

TESTING METHODS TO DETERMINE SEALANT PROPERTIES

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>TESTING METHODS</th>
<th>ASTM SPECIFICATION NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application Characteristics</td>
<td>Brookfield Viscosity</td>
<td>D2994</td>
</tr>
<tr>
<td></td>
<td>at application temperature</td>
<td></td>
</tr>
<tr>
<td>Adhesion</td>
<td>Low Temperature Bond</td>
<td>D1191, D3407, D3408</td>
</tr>
<tr>
<td>High Temperature Softening</td>
<td>Flow</td>
<td>D1191, D3407, D36,</td>
</tr>
<tr>
<td>Resistance</td>
<td>Softening Point</td>
<td>D2398</td>
</tr>
<tr>
<td>Flexibility &amp; Extensibility at Low</td>
<td>Low Temperature Bond</td>
<td>D1191, D3407, D3408</td>
</tr>
<tr>
<td></td>
<td>Mandrel Bend</td>
<td>(Note 1)</td>
</tr>
<tr>
<td>Elasticity</td>
<td>Resilience</td>
<td>D3407, D3408</td>
</tr>
<tr>
<td>Pot Life</td>
<td>Extended Heating</td>
<td>D3407</td>
</tr>
<tr>
<td>Weathering Resistance</td>
<td>Weatherometer</td>
<td>G23, G53</td>
</tr>
<tr>
<td>Cure Time</td>
<td>(Note 2)</td>
<td>(Note 2)</td>
</tr>
<tr>
<td>Compatibility</td>
<td>Compatibility Test</td>
<td>D3407</td>
</tr>
</tbody>
</table>

Notes:
1. A non-standardized test used by several state agencies.
2. A general characteristic of the type of material being used. Hot-pour materials generally cure when cooled to ambient pavement temperature (one hour), while cold-pour solvent-based and emulsified materials take longer and may require several days to several weeks to cure to a non-tracking condition.
FLEXIBLE PAVEMENTS

A wide range of materials with varying properties are currently used to seal cracks in asphalt concrete pavements. The majority of these materials can be grouped into several basic classifications based on their physical characteristics and degree of temperature susceptibility modification:

A. Unmodified Asphalt
B. Asphalt Rubber

(Refer to Figure #16 - Typical Physical Properties of AC-10 Asphalt and Asphalt Rubber).

A. Unmodified Asphalt

This classification includes various grades of asphalt cements, emulsified asphalts, cut-back asphalts and asphalts that contain various types of mineral or fiber fillers.

As a class, unmodified asphalts have a high degree of temperature susceptibility. At low pavement service temperatures (approximately 0 degrees F.), unmodified asphalts are very stiff and brittle, whereas at high pavement service temperatures (approximately 140 – 160 degrees F.) they are soft and semifluid. In addition, unmodified asphalts have little or even negative resilience values as indicated in Figure #16. Generally the useful life as a sealant of an unmodified asphalt is less than one year.

B. Asphalt Rubber

Asphalt rubber is a mixture of paving grade asphalt cement and generally between 15 and 30 percent granulated reclaimed crumb rubber particles. When the asphalt and rubber are heated to approximately 375 degrees F., a reaction between the two occurs. The rubber particles absorb fractions of the asphalt which result in swelling and the rubber may partially dissolve in the asphalt. The degree of reaction is dependent on the physical and chemical characteristics of the asphalt and rubber as well as reaction time and temperature period. Reacted asphalt rubber has radically different properties than the base asphalt cement or un-reacted blends of asphalt and rubber. The reacted asphalt rubber has a much higher viscosity and greater elasticity than the un-reacted material and also has a lower degree of temperature susceptibility as evidenced by greater high temperature stiffness and lesser low temperature brittleness (refer to Figure #17). The asphalt rubber reaction has been studied extensively. In addition, much effort has been placed in studying properties in the laboratory of reacted asphalt rubber materials. Please refer to Figure #18. You will note the graphs of a sample paving grade asphalt and crumb rubber combined together at an established temperature of 375 degrees F. Note the reaction and the simulation "Hold down 8 to 24 hours" comparing to an overnight carry-over and resultant reaction.
Specifications currently in use for asphalt rubber sealants generally specify the grade(s) of asphalt cement that may be used, the percent and type of rubber and the gradation of rubber. Several agencies specify additional requirements at low and high in-service temperatures which requires an indication of the degree of temperature susceptibility modification achieved. These additional requirements may be a mandrel bend test at low temperature, ring and ball softening point and 39.2 degrees F. ductility.

Asphalt rubber sealants have greatly improved temperature susceptibility characteristics and higher elasticity than the unmodified asphalt sealants. Properly formulated asphalt rubber sealants can provide an effective and lasting seal for many types of cracks in flexible pavements except for possibly in the coldest of climates. Extreme working transverse thermal cracks in cold climates which when sealed with asphalt rubber may separate when the pavement contracts in the winter but an amazing characteristic of asphalt rubber sealant it will "re-heal" itself with warmer temperatures to maintain a lasting cycle seal.

The National Cooperative Highway Research Program, sponsored by the American Association of State Highways and Transportation Officials and administered by the Transportation Research Board, has completed a survey of U.S. and Canadian Highway Department crack and joint sealing practices. Please refer to Figure #19 for the survey results of asphalt rubber sealants as compared to other types of sealant materials, the member of agencies using them and a composite of their experiences and comments.

C. Rigid Pavements

Joint sealing materials must have enough resiliency to move with the pavement and over the years many different types of sealants have been tested. Most of the materials that have been used or recommended for sealing joints in rigid pavements are less viscous such as polyvinyl chloride, polyurethane silicone and neoprene compression seals.

Pending the joint design criteria, asphalt rubber is limited for adequate penetration within the joint opening. Asphalt rubber has performed excellent in random cracks and very proficiently as an edge joint seal.

As stated previously, please refer to the Transportation Research Board Survey comparing asphalt rubber sealant for joint application as compared to other types of sealants (see Figure #20).
### TYPICAL PHYSICAL PROPERTIES OF AC-10 ASPHALT AND ASPHALT RUBBER SEALANT

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>TEST SPECIFICATIONS</th>
<th>AC-10 ASPHALT CEMENT</th>
<th>ASPHALT RUBBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cone Penetration</td>
<td>150 gm, 5 sec.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OF</td>
<td>77 F</td>
<td>ASTM D 1191</td>
<td>9</td>
</tr>
<tr>
<td>140 F</td>
<td></td>
<td></td>
<td>14</td>
</tr>
<tr>
<td>Resilience, 77F</td>
<td></td>
<td>130</td>
<td>60</td>
</tr>
<tr>
<td>Flow, 140 F, 5 hr.</td>
<td></td>
<td>&gt;300</td>
<td>220</td>
</tr>
<tr>
<td>Softening Point, F</td>
<td></td>
<td>-30%</td>
<td>40%</td>
</tr>
<tr>
<td>Bond, OF, 1&quot;, 50% ext.</td>
<td></td>
<td>115 F</td>
<td>170 F</td>
</tr>
</tbody>
</table>

FIGURE 16
*Upper Limit is Softening Point (ASTM D36)
Lower Limit is minimum Flexibility Temperature

EFFECTIVE TEMPERATURE RANGES FOR ASPHALT-BASE SEALANTS
FIGURE 18

Rotational Viscosity, 375 F, cP:

- Note: Holdover from 8 to 24 hours is at 325 F

Heating Period, 375 F, Hours

Minimum Plasticity Temperature, F:

- Note: Holdover from 8 to 24 hours is at 325 F

Heating Period, 375 F, Hours

Ring & Ball Softening Point, F (ASTM D30):

- Note: Holdover from 8 to 24 hours is at 325 F

Heating Period, 375 F, Hours

Resilience, R (ASTM D1407):

- Note: Holdover from 8 to 24 hours is at 325 F

Heating Period, 375 F, Hours

Durability, 77 F (ASTM D113), cm:

- Note: Holdover from 8 to 24 hours is at 325 F

Heating Period, 375 F, Hours

Cone Penetration, 1/10 in (ASTM D1407):

- Note: Holdover from 8 to 24 hours is at 325 F

Heating Period, 375 F, Hours

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### FIGURE 19

**MATERIALS USED TO SEAL AND RESEAL CRACKS IN FLEXIBLE PAVEMENTS**

<table>
<thead>
<tr>
<th>MATERIAL TYPE</th>
<th>NUMBER LISTINGS BY AGENCIES</th>
<th>EFFECTIVENESS RATING RANGE</th>
<th>AVERAGE EFFECTIVENESS RATING*</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt Cement</td>
<td>10</td>
<td>Fair-Very Good</td>
<td>3.50</td>
<td>Generally requires blotter, relatively short life.</td>
</tr>
<tr>
<td>Cutback Asphalt</td>
<td>20</td>
<td>Poor-Good</td>
<td>2.90</td>
<td>Relatively short life, tends to bleed.</td>
</tr>
<tr>
<td>Emulsions</td>
<td>20</td>
<td>Very Poor-Very Good</td>
<td>3.02</td>
<td></td>
</tr>
<tr>
<td>Asphalt General Class or Type Specified</td>
<td>5</td>
<td>Poor-Good</td>
<td>3.10</td>
<td></td>
</tr>
<tr>
<td>Rubberized Asphalt Hot Applied</td>
<td>31</td>
<td>Very Poor-Very Good</td>
<td>4.40</td>
<td>Relatively long life.</td>
</tr>
<tr>
<td>Asphalt Emulsion W/ Rubber</td>
<td>5</td>
<td>Poor-Very Good</td>
<td>3.40</td>
<td></td>
</tr>
<tr>
<td>Material Class Not Identified</td>
<td>11</td>
<td>Very Poor-Very Good</td>
<td>2.61</td>
<td></td>
</tr>
<tr>
<td>Mixtures</td>
<td>3</td>
<td>Good-Very Good</td>
<td>4.33</td>
<td>Mixtures of asphalt and sand or aggregate. Used in wide cracks.</td>
</tr>
<tr>
<td>Other, Vulken</td>
<td>4</td>
<td>Very Poor-Good</td>
<td>3.25</td>
<td>Vulken rates very poor.</td>
</tr>
<tr>
<td>Tar</td>
<td>3</td>
<td>Very Poor-Poor</td>
<td>1.33</td>
<td>Too rigid, short life.</td>
</tr>
<tr>
<td>Catalytically Blown Asphalt</td>
<td>1</td>
<td>Good</td>
<td>4.00</td>
<td>Texas</td>
</tr>
</tbody>
</table>

*Rating Scale - Very Good - 5.00  Poor - 2.00  
  Good - 4.00  Very Poor - 1.00  
  Fair - 3.00
### FIGURE 20

**MATERIALS USED TO RESEAL CRACKS AND JOINTS IN RIGID PAVEMENTS**

<table>
<thead>
<tr>
<th>MATERIAL TYPE</th>
<th>NUMBER LISTINGS BY AGENCIES</th>
<th>EFFECTIVENESS RATING RANGE</th>
<th>AVERAGE EFFECTIVENESS RATING*</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt Cement</td>
<td>11</td>
<td>Poor-Good</td>
<td>3.15</td>
<td>Does not penetrate, must be resealed often.</td>
</tr>
<tr>
<td>Cutback Asphalt</td>
<td>17</td>
<td>Very Poor-Good</td>
<td>2.29</td>
<td>Generally requires blotter, relatively short life.</td>
</tr>
<tr>
<td>Emulsions</td>
<td>10</td>
<td>Very Poor-Very Good</td>
<td>3.22</td>
<td>Seasonal, generally must be resealed often.</td>
</tr>
<tr>
<td>Rubberized Asp. Cold Applied</td>
<td>1</td>
<td>Good</td>
<td>4.00</td>
<td>Labor intensive.</td>
</tr>
<tr>
<td>Rubberized Asphalt Hot Applied</td>
<td>36</td>
<td>Very Poor-Very Good</td>
<td>4.12</td>
<td>Relatively long life.</td>
</tr>
<tr>
<td>Preformed Fillers</td>
<td>2</td>
<td>Fair-Good</td>
<td>3.50</td>
<td>Relatively limited data but good performance to date.</td>
</tr>
<tr>
<td>Silicone</td>
<td>7</td>
<td>Good-Very Good</td>
<td>4.60</td>
<td>Relatively limited data but good performance to date.</td>
</tr>
<tr>
<td>Material Class</td>
<td>11</td>
<td>Very Poor-Very</td>
<td>2.61</td>
<td>Costly.</td>
</tr>
<tr>
<td>Preformed Joint Sealers</td>
<td>5</td>
<td>Poor-Very Good</td>
<td>3.60</td>
<td>Vulken rates very poor.</td>
</tr>
<tr>
<td>Other PVC, Polyurethane, Vulken</td>
<td>6</td>
<td>Very Poor-Good</td>
<td>3.25</td>
<td>Short life, too rigid.</td>
</tr>
<tr>
<td>Tar</td>
<td>2</td>
<td>Very Poor</td>
<td>1.00</td>
<td>Texas</td>
</tr>
</tbody>
</table>

*Rating Scale - Very Good - 5.00  
Good - 4.00  
Fair - 3.00  
Poor - 2.00  
Very Poor - 1.00

**SOURCE:** Transportation Research Board, "Synthesis #98: Resealing Joints and Cracks in Rigid and Flexible Pavements - Final Draft"
PAVEMENT PREPARATION

Asphalt Pavement Cracks and Use of Asphalt Rubber Sealants

In order for asphalt rubber sealant materials to adhere appropriately to the pavement and ensure maximum sealant life, the crack must be prepared in a manner which provides intact bonding surfaces which are free of moisture, dust, loose aggregate or other contaminants. Various methods and equipment types can be used to clean cracks.

With crack preparation there are additional factors to be considered for optimum asphalt rubber sealant performance and maximum life of the seal. This should include seal geometrics and expected crack movement (Figure #21).

The three application configurations are:

1) The Band-Aid
2) The Routed Reservoir
3) The Inverted Band-Aid

1. The Band-Aid

The band-aid application is quick and easy. The application should be limited to a minimal spread width, 2" to 4", and minimal surface thickness of 1/8". This entails a wiping or squeegee operation placing sealant over the crack and then leveling to a desired width and depth. A concern with this type of application is product performance. The smaller 1/8" to 1/4" wide cracks limit the penetration capabilities of your asphalt rubber sealant to seal within the crack. You virtually have sealant all on the surface of the pavement. In cold climate areas you’re limiting your asphalt rubber sealant’s cold weather performance for extension and in the summer you have a concern for tracking if you don’t use a high softening point material. Additionally, you have an unsightly appearance, and the sealant is subjected to vehicle wear-off and snow plow scuffing or complete removal.

2. The Routed Reservoir

The routed reservoir consists of a widen crack in a rectangular shape cut in the pavement surface. The pavement cutter (router) with forged heat treated steel cutters or forged carbide tip cutters will route a minimum of 1/2" x 1/2" to a maximum of 2" width x 1 3/8" depth.

The routed crack has several advantages as compared to the band-aid type of application. First, the asphalt rubber sealant is applied within the completed shaped area, and applied level to the surface. This can be accomplished by the squeegee method, forcing the material in the reservoir to assure adherence to the crack side walls.
Also, you have a neater appearing operation, and less subject to vehicle wear or snow plow abrasion.

One of the most important factors of this reservoir configuration is that the asphalt rubber sealant is allowed to perform as designed. With a reservoir routed to a desired 1:1 ratio, this allows the asphalt rubber to extend to it’s maximum capabilities, pending coldness of the geographical area related to the sealant on temperature qualities. This "tough" material is allowed to perform as designed with minimal extension strain.

This routing for a crack reservoir does add an extra operation to the crack sealant preparation, as compared to the simple band-aid approach. But on the other hand, you have an established reservoir for sealant, and the sealant has the ability to perform as designed. In addition, you do have an extra cost, 0.05/ft. to 0.10/ft., but compared to the total operation this is minimal, and you have material in the crack not on the pavement. The money you save through increased longevity will more than pay for the initial added cost for proper crack preparation.

Routing is strongly recommended in thermal and fatigue cracks in sound pavements in most areas where movements less than 1/2" are expected.

3. The Inverted Band-Aid

The inverted band-aid reservoir can be done with the pavement cutter (router) to a wider desired width, 1 1/2" to 2" x 1/4" x 1/2" depth. You have yet a superior shape factor that develops less asphalt rubber sealant strain for extension at cold climate temperatures. This type of routed reservoir is recommended for uses in transverse thermal cracks in sound pavements in cold climates where movements greater than 1/2" are expected.

Also, like the routed reservoir, the inverted band-aid does develop an extra cost as compared to the simple band-aid configuration.

As stated, this type of configuration is designed when extreme pavement thermal movement (usually wide spaced transverse cracks 50' to 100' apart).

Asphalt Crack Preparation Methods

Unfortunately, asphalt cracks are very irregular in alignment as well as surface width exposed. Cracks will vary from a hairline type to multiple inches wider. A given crack length will vary in thickness, too! What we have said here is that there is no consistency. That is the number one reason to create a consistent shape factor regardless what the crack width is to start with. By preference, budget and timing, engineers will vary with designation of which cracks to rout.
It is recommended that cracks less than 3/8 inch wide should be routed to 1/2 inch wide and 3/4 to 1 inch deep to provide an adequate sealant reservoir. Also, cracks wider than 1/2 inch wide should be considered for routing: (a) when the faces of the crack are deteriorated to the point that they must be cut back to provide intact asphalt concrete, (b) install vertical crack face, which the carbide cutter is designed for and (c) clean debris wedged within open crack area.

An experienced operator can rout, on the average, 1,000 linear feet per hour subject to pavement design and crack alignment.

Wire Brushing

Following the routing process, a brush/blower can be used in cleaning and resurfacing pavement cracks to improve the adhesion of the asphalt rubber sealant in the pavement. While the wire brushes clean, the air blower removes relatively loose deteriorated asphalt.

Air-Blowing Equipment

If by your selection you rout or do not rout, it is imperative to have a clean and dry crack for proper asphalt rubber sealant bond to the asphalt pavement. Several different types of air-blowing equipment are available.

(a) Low Pressure - High Volume Air

The back-pack blower is effective for removing loose debris, dust and slight amounts of moisture. They are not effective in removing caked dirt, debris wedges in the crack or laitance.

(b) Compressed Air

Compressed air at a minimum of 80 to 100 psi can be used to remove relatively loose debris, dust and slight amounts of moisture from cracks. The nozzle should be placed at the crack opening, directed to the crack face to remove the caked dirt to ensure cleanliness. You do not want the wand elevated or all your doing is cleaning the surface, not the side walls of the crack.

(c) Hot-Compressed Air

Another tool that can be considered for cleaning the crack is the hot compressed air lance. The lance deliveries are heated to 3,000 F. at a velocity of 3,000 feet per second. The unit requires a propane or butane source and compressed air. If properly used, the unit can remove loose debris and dust from cracks, as well as, dry out and remove excess moisture prior to sealing which can aide in extending the sealing season in cold or damp weather. An added benefit of the hot compressed air cleaning operation is warming the pavement, thus promoting an improved seal with hot-pour sealants.
There is no other word that can be said other than it is "IMPERATIVE" to have a properly prepared crack for asphalt rubber sealant application and maximum material performance. So often thorough inspection is overlooked within this phase of a crack sealing operation. It is to your advantage to do the preparation to the best of your ability the first time for extended pavement life.

Concrete Pavement Joints and Cracks Preparation Methods

A concrete pavement is considered a rigid pavement that, as stated previously, will expand and contract with weather. Therefore, to control this movement on new installations and rehabilitation projects, joints (longitudinal and transverse) are created at designed spacing to control the cracking. If left unsealed, open joints lead to spalling, break-outs, blow-ups, potholes and ultimately, destruction of the pavement to the point it has to be replaced.

Concrete pavements, like asphalt pavements, do not have a singular direction for pavement preparation. It will require one or more types of machinery to adequately prepare a joint for sealant application. Recommendations are as follows:

1. **Sawing**

Conventional diamond blade paving saws are used to create the joint in new installations and also can be used for removing the old joint filler and sealants. It is very important the saw maintains the proper alignment when sawing for proper crack control.

2. **Plowing**

Plowing is a means of removing old joint filler with steel and carbide bits. This is generally one of the first methods in a rehabilitation project for material removal. The plow will not remove all existing material, and other equipment is required.

3. **Waterblasting**

The use of high pressure water to the joints aid in removing material left after plowing and/or sawing.

4. **Power Brush/Blower**

The Power Brush/Blower also can be used after material removal has been done. The wire bristle brush will clean the side-walls and blow the loose debris out of the joint.

5. **Sand-Cleaning**

After sawing, joints can be sand-cleaned to remove any residue remaining on the joint face. Sand-cleaning is a lighter application of sand than sandblasting.
6. Sandblasting

After sawing or resawing for rehabilitative joints, plowing and/or waterblasting; sandblasting is the more common means to finish the joint preparation.

As noted before, there are different types of equipment available to clean the interface of the joint. To properly sandblast the joint face, it is necessary for the operator to hold the sandblast nozzle very close to the pavement. This is a very unpleasant chore, but necessary. To assure proper cleaning, some agencies specify two passes by the sandblaster be done at a slight angle to one side of the vertical face and then make a similar type pass on the adjacent vertical face.

Every bit as critical in concrete preparation, like asphalt pavement preparation, is the proper inspection. How does the inspector assure himself the joint is clean? Several thoughts and recommendations in this direction; 1) the use of an inspection mirror (something along the line of a dental mirror), 2) the use of a cloth rubbed adjacent to the joint or 3) the use of a device (example is clipboard) to cast a shadow on the pavement surface near the joint reservoir to deflect the white surface to enable visual inspection.

7. Backer Rod

The shape factor (width to depth ratio) of formed in placed sealants has a decided effect on the amount of tensile stress induced into the sealant during periods of extension. The design should be kept at 1:1 or 2:1 to minimize the strain concentration.

In order to do this a dormable bond-breaker should be inserted in the joint reservoir; thus creating a formed joint geometry which will keep stress concentrations within the performance limits of the sealant.

However, if there is not sufficient compression exerted on the deformable bond-breaker, the sealant will make its way around it, resulting in a width to depth ratio outside the limits of design. It is advised that the diameter of the bond-breaker should be approximately 25% greater than the width of the joint (see Figure #22).

The backer rod serves as a bond-breaker to prevent three-sided adhesion of the sealant to the joint substance.

The shoulder joint (concrete to asphalt longitudinal joints) will normally have a varying depth and pending pavement deterioration may also have a varying width. With this type of mode asphalt rubber sealants are very effective.
**APPLICATION CONFIGURATIONS**

**Advantages**
1. Quick and Easy

**Disadvantages**
1. Unsightly
2. Vehicle and Plow Abrasion
3. Localized Extensions
4. Tracking

**Recommended Uses**
1. Badly fatigued and distressed pavement areas.

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**Advantages**
1. Neater than band-aid
2. Not subject to abrasion and plow damage
3. Cleaned bonding faces
4. Lesser extensions

**Disadvantages**
1. Extra operation
2. Cost $0.05/ft to $0.10/ft.

**Recommended Uses**
1. Thermal and fatigue cracks in sound pavements in most areas where movements less than ½" are expected.
2. Overfilled and flush squeegee recommended

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**Advantages**
1. No. 1, 2 and 3 of routed reservoir
2. Much less extension than in band-aid or routed reservoirs

**Disadvantages**
1. Same as routed reservoir

**Recommended Uses**
1. Transverse thermal cracks in sound pavements in cold climates where movements greater than ½" are expected.
2. Overfill and flush squeegee recommended.
FIGURE 22

JOINT UNDER EXTENSION

SHAPE FACTOR OF 2
$S_{\text{max}} = 94\%$

SHAPE FACTOR OF 1
$S_{\text{max}} = 62\%$

SHAPE FACTOR OF 0.5
$S_{\text{max}} = 32\%$
Asphalt rubber sealants are manufactured, pre-blended for consistency, placed in a removal container and then the semi-solid cube is placed in a melter unit for proper melting and application.

The asphalt rubber sealant must be heated to approximately 350 to 380 degrees F. prior to being applied to ensure development of maximum adhesion and to provide appropriate sealant consistency for penetration into crack/joints. Asphalt rubber may degrade if overheated (pot life approximately 12 hours), therefore, the sealant should not be heated in excess of the manufacturer's recommended safe heating temperature. Several different types of equipment can be used to melt and apply hot-pour asphalt rubber sealant.

"Safety" cannot be overly stressed for a proficient crack sealing operation. Always maintain respect for your equipment and keep in mind the temperature that you are exposed to. Always wear long sleeve shirts and gloves. When working around preparation equipment, safety glasses should be worn. A fire extinguisher and a first-aid kit should always be readily available.

Melter Units

For proper application of asphalt rubber sealant, two important criteria must be required with a melter unit. The first requirement is a unit designed to create an agitation movement (horizontal and/or vertical paddle) to properly mix and maintain consistency of the asphalt rubber. The second requirement is an in-direct heat transfer to maintain an even heat distribution to the melting sealant.

Melter applicator units generally are constructed in a "tank within a tank" type configuration in which the asphalt rubber sealant is melted in the inner tank and the space between the tank shells is filled with a heated heat transfer media which provides in-direct heating. This prevents against localized overheating and possible sealant degradation. Asphalt rubber sealant, at the proper application temperature, is generally applied to the crack/joint through a pump-fed applicator wand and nozzle.

Asphalt rubber may also be applied through hand operated gravity fed pour-pots. The asphalt rubber is first melted in the melter and then the pour-pot is filled. The pour-pot is then used to apply the sealant.
Asphalt rubber crack sealing is a timing function, not the absolute cure all! If performed adequately and soon after the crack develops, crack sealing can be economical and an effective preventative maintenance technique. Additionally, crack sealing can be performed along with other types of pavement maintenance and rehabilitation functions.

Thermal cracks/joints should receive the highest priority when crack sealing because they occur before the pavement has significantly deteriorated. Sealing thermal cracks/joints will aid in limiting crack/joint growth and minimize moisture related deterioration while extending the life of the pavement.

Sealing fatigue cracks in asphalt or concrete will not increase pavement life as compared to sealing transverse cracks/joints will. However, sealing fatigue cracks will aid in retarding further deterioration by minimizing moisture intrusion, and can therefore, increase the useful life of deteriorated pavement areas by extending the time of reconstruction.

Reflective cracking in asphalt overlays appear within a year after construction of the overlay. Sealing of reflective cracks will aid in ensuring that the overlay does not prematurely deteriorate, and provides useful service throughout it's design life. Sealing cracks or joints in the existing surface, prior to the overlay, will also aid in minimizing deterioration by preventing moisture from penetrating the base and subgrade.
CONCLUSION

At the beginning of this paper it was stated, "Do you want to "fill" or "seal" your pavement cracks/joints". With the ease of asphalt rubber crack sealing materials, you now have the long term direction. The synopsis of this paper can be described as:

1) Cracks developing in asphalt and concrete pavements are a normal occurrence due to aging characteristics and loading of the pavement.

2) If cracks and joints are not effectively sealed, pavement deterioration is hastened due to detrimental effects of moisture intrusion into the pavement structural system.

3) Cracks and joints in the pavements experience significant movement from summer/winter. Therefore, it is essential that the sealant material be capable of extending and flexing at low ambient temperatures so that it can maintain the seal as the pavement moves.

4) Considerations for climate conditions, economics, short term/long term and performance are some of the factors that require reviewing for use of asphalt rubber sealant.

5) There are several basic types of sealant geometrics (band-aid, routed reservoir and inverted reservoir) currently in use, each with advantages and disadvantages in specific situations. Concrete joint configurations is very important for the sealant to perform as designed.

6) Equipment specifically designed for use with asphalt rubber is available and in turn maintain high production requirements.

7) With asphalt rubber sealants, equipment and today's technology, crack sealing in asphalt concrete pavements and joints in Portland cement concrete pavements is a lasting and cost effective preventative maintenance function which can greatly extend the useful life of our total pavement system.
ACKNOWLEDGEMENTS


3. R.F. Butler, President of the National Purchasing Institute.

4. K.W. Henderson, Jr., Director of Cooperative Research Program, Transportation Research Board.

5. J. Chehovits and M. Manning, "Materials and Methods for Sealing Cracks in Asphalt Concrete Pavements".


"Asphalt Concrete Pavement Crack Sealing and PCCP Pavement Joint Sealing", by Vern Thompson, Crafco Inc., Chandler, AZ

Question/Dean Maurer:

The inverted bandaid method, do you literally mill out that area, or is that just routing that is performed?

Vern Thompson:

There has been various approaches on that. Some folks use a router or a pavement cutter and widen the cracked area to a shape from 4" wide x 1/2" depth. That is one approach. Some agencies have literally came in on the wide thermal cracks and have actually milled as much as a foot.

Don White, University of Arizona:

This is my first visit to such a meeting and I’m still on a learning curve, hopefully a fast track learning curve with respect to rubberized asphalt. We have talked a lot about reactive asphalt with rubber, but I have not heard anyone say what those reactions are, maybe that is all history and it is in the literature, but I have not read it yet. I know that polymers such as polyethylene are reactive at these high temperatures by oxidation combined with cross linking. I know much about asphalt, and know it has aromatics in it. I am knowledgeable about rubber, in that it cannot dissolve in asphalt; it can swell and some of the asphalt permeates into it because the cross-links will hold it there. What is the primary reaction that is going on in rubberized asphalt and maybe one or two of the secondary reactions. This is important as I am trying to predict the life and performance of new formulations.

Vern Thompson:

That is a very good question. Very simply put Don, its very similar to your polymers. You are working with the various types of rubber, your SBS type rubber and so on. You take a liquid asphalt, add the following: a crumb rubber, and I hope maybe I’ll get some thought across, maybe with a different types of climatic conditions, you work with different types of rubber and so on. OK But, when you induce the crumb rubber at the ambient temperature into a hot liquid asphalt, this reaction starts, and the crumb rubber literally starts to swell. You start getting this chain link affair that I call a lattice, and
interlocking affect if I can say that. The rubber starts flowing and it starts absorbing the asphalt. Again this takes time, this doesn’t occur like that. One comment I may make about the graphs there, is that it is revolved around time/temperature relationships which you can go beyond that point to where the rubber actually breaking down and this lattice or this chain linking starts falling apart.

Russ Schnormeier:

There has been some research done by the Australian people on the swelling of Asphalt-Rubber, by John Oliver. Also, there has been some work done by Tolonen & Green at the Arizona Department of Transportation. The work was done in the early 70’s and somehow was presented at the last Asphalt-Rubber Seminar in San Antonio.