## **Technical Bulletin**

## **Concrete Pavement Joint Sealing/Filling**



### INTRODUCTION

Joint sealant use dates back to the early 1900's. Through years of technical development and field application two basic approaches emerged, joint filling and joint sealing. An additional approach of leaving pavement joints open (unsealed) has also been applied. This bulletin discusses the proper consideration of joint sealants and fillers, and provides details on proper installation.

Sealing or filling transverse and longitudinal joints in concrete pavements is an important consideration for long-term pavement performance. For most pavement applications proactively sealing or filling joints provides a measure of added protection against potential problems, such as spalling, base/subgrade softening, dowel bar corrosion, pavement joint blow-ups, and even some materials-related distresses. However, to gain these benefits the installation and maintenance of the sealants/fillers must be performed with care.

Joint sealing involves a backer rod and more rigorous preparation of a sealant reservoir than joint filling, which often simply requires filling up a joint saw cut with sealant material after some prior preparation.

The purpose of joint sealing is to minimize infiltration of surface water, deicing chemicals and incompressible materials into joints. The purpose of joint filling is similar, but because the reservoir is often narrower, more difficult to clean and does not control shape factor, it may be more difficult to achieve and maintain full sealant adhesion. In this way, filling may be considered a strategy that emphasizes limiting incompressible material entry with slightly less regard for moisture entry into a joint. (Figure 1, next page, provides the basic options.)

Sealing Considerations — Water can contribute to subgrade or base layer softening, erosion and pumping of subgrade or base fines. Such a degradation of support to pavement slabs causes higher load stresses in the concrete, pavement settlements, corner cracks and/or faulted transverse or longitudinal joints (1).

Unfortunately, it is not practical to construct and continually maintain a completely watertight pavement because there are many sources of water to a roadbed. However, surface water is a significant source and the concrete pavement industry has developed joint sealing techniques to limit passage of surface water through joints. In this way, joint sealing or filling can aid the performance of concrete pavements, by eliminating or slowing waterrelated problems.

In addition to addressing water passage, sealing or filling joints also prevents incompressibles from entering joint reservoirs. Incompressibles (sand or other small, hard particles) are known to contribute to spalling and in extreme cases may cause slab migration that induces pavement "blow-ups" (2). In either case, excessive pressure along closing joint faces results when incompressibles obstruct slab expansion in hot weather (3).





Figure 1 — Different Types of Sealing Configurations.

Many factors play a role in joint sealant design, including (4):

- Environment,
- Drainage condition,
- Pavement use,
- Performance need,
- Life-cycle cost,
- Joint type/spacing,
- Concrete characteristics,
- Sealant type and material.

The required sealant characteristics will differ based on the movement expected for different joint types (Figure 2). For instance, a sealant for a typical roadway longitudinal joint may not need to be as extensible as one for a typical roadway trans-

verse joint when considering joint movement. This is because tied joints, like those separating roadway longitudinal lanes and shoulders, undergo virtually no opening/closing movements. In airfields or industrial site pavements, longitudinal joints often are not tied and similar movements to transverse joints are expected. Transverse joints are designed to freely open and close with temperature cycles. The longer the concrete slab length—distance between joints—the more each joint will open and close. For example, joints in 25-foot (7.6-meter) long panels will open or close farther than joints in 15-foot (4.5-meter) long panels after a temperature change.

Generally, opening movements at transverse joints can induce higher levels of stress and strain within a sealant material and at the concrete/sealant interface than is typically found in sealants in longitudinal joints. Also, vertical loading on sealants also may be higher at transverse joints due to joint deflections under vehicle loads. Sealant materials must be capable of handling these states in order to perform well over the full range of expected daily, monthly and seasonal joint opening and closing movements, as well as deflections.

Reservoir dimensioning has a significant impact on sealant design and performance. Reservoir dimensions (including consideration of bottom adhesion) are selected to help the sealant material withstand joint opening/closing movements while staying adhered to and/or in contact with the sidewalls. See section "Reservoir Design" for recommendations.







Figure 3 — Avenues for water infiltration into a pavement system (3).

Water in Pavements— Water contributes to several pavement distresses. Therefore to maximize the probability of good pavement performance a designer must consider multiple means to control water within the pavement layers. Limiting the amount of water that can get into the base and subgrade layers is one key element. Providing a means to efficiently remove water from within the pavement layers is another key. The pavement surface is just one of five potential points of water entry into a pavement and subgrade (Figure 3). Water present in the soil can migrate to critical pavement locations through capillary action and through water vapor from the water table. Water may also come from shoulder joints, from poorly designed or maintained ditches, and from high-ground runoff. Surface water, however, is usually the largest source with the greatest impact on a pavement.

Over the past 30 years, the industry has produced effective sealant materials and installation procedures to minimize entry of surface water. However, correct sealant installation steps and effective maintenance are necessary to gain this benefit (5).

How to Get Best Value From Sealing Joints — There is some question as to whether joint sealing is needed for all jointed concrete pavement applications. The basis for answering this question hinges on clearly defining the impact of joint sealing through pavement performance studies. Several state agencies have gained many years of experience with joint filling and with open (unsealed/unfilled) joints in concrete pavements. Wisconsin was the first highway department to stop sealing joints and specify open joints (18). With additional experience, Wisconsin now seals joints in roadways with lower speeds and with curb and gutter, but still uses open joints on high-speed highways. Caltrans uses both sealed and open joints depending on climatic zone (6). Other states, such as Minnesota and North Dakota, have tried open joints and have found better pavement performance with sealed joints, and no longer allow open joints as an option (7,8). Yet another state, New York, has reported good performance from a filled reservoir approach.

On a broader basis, numerous field studies have substantiated value from sealing joints over the years. Notable studies include referenced documents 9 to 15. Conversely, there have also been studies that have shown negligible impact from joint sealing (references 16 to 18). One way to make sense of these different conclusions is to recognize the complexity of the factors involved and the reality that certain combinations of environmental, design, construction and joint maintenance circumstances impact pavement performance differently than others.

Presently, the more widely held belief based on experience and past studies is that when installed and maintained properly, sealed joints prolong pavement life by providing important protections. Experience across the U.S. clearly indicates that the most critical aspects of getting the best value from joint sealing is through proper reservoir preparation and proper installation of the sealant material, including all related considerations. In this regard, investing in proper joint preparation and cleaning activities by the owner/agency and contractor is necessary to get the best value for almost all sealant types. There is little doubt that poorly designed or installed joint sealants will fall short of expectations and will contribute little to pavement performance.

It is also important to consider specific pavement design factors that may impact the value sealed joints can provide even with good installation quality, such as:

- <u>Design life</u> a temporary pavement (design life of five years or less) may not benefit from the inclusion of joint sealing/filling because the installation is not in need of long-term performance protective measures.
- 2. Lack of Drainage If improving roadbed or pavement structure drainage is not an investment an owner or agency is willing to make for a given pavement section, then a joint filling strategy focused on limiting incompressibles may be a reasonable compromise. Of course, this is not the ideal approach, but it may be necessitated under some circumstances. The best practice is to use doweled and sealed joints, and nonerodible or free-draining bases that allow free water to escape the pavement. These lessons have been learned by observing performance of "bathtub" sections were which particularly prone to moisture-related distresses (1,19). In these sections joint sealants became damaged prematurely by joint faulting, pumping and base cavitation (1). It has been determined that joint sealing is simply not a substitute for other aspects of good drainage design or maintenance.
- 3. <u>Slab Size</u> In some cases, shorter slab designs—6 ft (2 m) or less—may not benefit from sealed/filled joint reservoirs because the joints undergo very small opening and closing movements, reducing the probability of problems from intrusion of incompressibles. For instance, experience in dry-no freeze climates indicate pavements with short joint spacing and narrow-cut—0.125 in. (3mm)--unsealed joints may perform well. Conversely, MnRoad research data shows that in a wet-freeze environment there is benefit to sealing joints in bonded concrete on asphalt pavements to delay/prevent loss of bond with underlying asphalt (20).
- 4. <u>Expansion Joints</u> In the past, designers placed numerous transverse expansion joints to relieve compressive forces in the pavement. However, expansion joints placed at regular intervals allow too much opening of adjacent transverse contraction joints, which leads to loss of aggregate interlock as well as overstretching sealant material in nearby joints. Experience indicates contraction joints (including sealants) perform better when they remain tight and provide good load transfer.
- <u>De-Icer Applications</u> Studies of the effect of repeated application of harsher de-icing chemicals in the wet-freeze environmental zone indicate that effective sealant installation and maintenance, among other factors, are vital to protect the concrete (21). The issues are threefold. First, poorly maintained joints with small areas of compromise in



Freeze-Thaw Damage Below Joint

the sealant integrity may allow entry of the water and de-icer solution into the pavement. Second, lengths of intact sealant may act as a lid to reduce the evaporation of the solution and hold the moisture in the joint reservoir for longer periods. Third, the water/ deicer solution may get trapped in an un-cracked or non-draining joint prolonging the exposure time. These conditions may exacerbate deicer chemical intrusion into the concrete matrix near the bottom of the reservoir, accelerating deterioration. Sodium Chloride, Calcium Chloride, and Magnesium Chloride all are common salts linked to joint deterioration in the wet-freeze climatic zone.

Unless local experiences indicate that there is limited performance protection value, the industry-recommended practice is to seal and maintain joints, paying careful attention to reservoir design and sealant installation requirements. In all cases, joint sealing/filling is highly recommended and required for the following applications:

- Previously-Sealed Joints Experience indicates that it is likely to be detrimental to remove joint sealant materials from a jointed pavement that was originally designed with sealed/filled joints (22). A widened joint reservoir intended for a sealant will allow for more water and incompressible penetration if left completely open. Previously sealed/filled joints should be resealed/refilled as necessary during concrete pavement preservation activities.
- 2. Low-Speed Applications Pavements for low-speed traffic—45 mph (72 km/hr) or less—should be designed with sealed/filled joints. This includes applications such as urban arterials, collectors, residential streets and rural two-lane roadways, as well as any sections with curb and gutter. Curbs more readily trap incompressibles on the pavement surface and lower-speed traffic is not as capable of moving the incompressibles off the surface or out of joints from vehicle-induced air movement as may be experienced with vehicles at higher speeds.
- <u>Airfield Applications</u> Pavements servicing airplanes, particularly jet airplanes, require sealed joints to minimize the potential for joint spalling and foreign object debris (F.O.D.) issues. The Federal Aviation Administration and the military tri-service agencies require joints in airfields to be sealed, including general aviation facilities (23). Sealant materials in these applications must also be "jet fuel resistant".

Table 1. (next page) indicates potential joint performance with the different sealing options, considering pavement performance experience and studies to date. The information is a guide and not a definitive conclusion on cost-effectiveness of any option. The information in Table 1 is predicated on use of durable concrete and sealant installation and maintenance practices aimed to achieve long-term pavement performance. The table includes all pavement applications and considers base type (layer below slab), climatic zone and joint spacing.

### **Sealant Materials**

There are two joint sealant material categories, 1) formed-in-place sealants, and 2) preformed compression seals. For these categories there are excellent choices available from today's manufacturers.

Formed-in-place sealants are in a liquid state for installation. They are either hot- or cold-applied materials that are pumped into place and depend on adhesion to the joint face for successful performance. Preformed compression seals are manufactured, brought to the site on rolls and then inserted into place. Compression seals depend on lateral pressure against the joint sidewalls for long-term success. Basic sealant properties necessary for long-term performance depend on the specific application and the climatic environment of the installation. Properties to consider include:

- <u>Extensibility</u>: The ability of a sealant to stretch or deform (elastically) to accommodate joint movements.
- <u>Modulus</u>: The resistance (stiffness) of a sealant material when being stretched or compressed elastically, which may change depending on temperature. A lower modulus is desirable and is particularly important for sealant response in cold weather climates.
- <u>Adhesion</u>: The ability of a sealant to adhere to concrete or asphalt. Initial adhesion and long-term adhesion are equally important. (Not applicable to compression seals.)
- <u>Cohesion</u>: Ability of sealants to resist tearing under tension. (Not applicable to compression seals.)
- <u>Compatibility</u>: Reaction of the sealant in contact with other materials (backer rods, other sealants, asphalt or concrete). For instance, some sealants may not bond well with certain concretes due to the concrete aggregate properties, such as the case with silicones and concrete containing certain dolomitic limestones.

Table 1 — Potential Joint Performance Based on Sealing Options. The information in this table is predicated on use of durable concrete and construction and maintenance practices aimed to achieve long-term pavement performance.

### KEY:

NR=Not recommended

Should perform adequately based on engineering judgment and limited experience (if sealed/filled then also with correct installation/maintenance procedures)

Will perform adequately based on engineering judgment and limited experience (if sealed/filled then also with correct installation/maintenance procedures)

	STREETS / ROADS / HIGHWAYS							
	Any Posted Speed Limit (Unless Indicated by Note)							
Layer Below Slab	Dense	Dense-Graded Base or Subgrade Soil Non-Erodible (2) or Free-Draining Layer (3)						
Climatic Zone	Dry No-Freeze Other Dry No-Freeze Othe					her		
Joint Spacing	≤ 6 ft (2 m)	> 6 ft (2 m)	≤ 6 ft (2 m)	> 6 ft (2 m)	≤6 ft (2 m)	>6 ft (2 m)	≤6 ft (2 m)	>6 ft (2 m)
Open Reservoir Cut	NR	NR	NR	NR	NR	NR	NR	NR
Open Narrow Saw Cut				NR			(4,5)	(5)
Filled Saw Cut or Reservoir			(6)	(6)			(6)	(6)
Sealed Saw Cut or Reservoir								

AIRPORTS (1)						
Runway	Taxiway	Apron				
Any	Any	Any				
Any	Any	Any				
Any	Any	Any				
NR	NR	NR				
NR	NR	NR				
NR	NR	NR				

	INDUSTRIAL / COMMERCIAL							
	Heavy Load Site Pavement (7)		Mixed-Use Parking Area		Roller Compacted Concrete			
Layer Below Slab	Ai	лу	Any		Any			
Climatic Zone	Dry No-Freeze Other		Dry No-Freeze	Other	Freeze No Freeze		reeze	
Joint Spacing	Any	Any	Any	Any	≤ 15 ft (4.5 m)	> 15 ft (4.5 m)	≤ 15 ft (4.5 m)	> 15 ft (4.5 m)
Open Reservoir Cut	NR	NR	NR	NR	NR	NR	NR	NR
Open Narrow Saw Cut		NR		NR	NR	NR		
Filled Saw Cut or Reservoir	(6)	(6)	(6)	(6)	(6)	NR		(6)
Sealed Saw Cut or Reservoir								

Note 1) Includes commercial and military airfield airfields, including general aviation pavements.

- Note 2) Non-erodible layers include stabilized bases and existing pavements for overlays.
- Note 3) Free-draining layers include permeable and open-graded base layers that permit water flow.
- Note 4) For bonded concrete overlays on asphalt pavement joint filling or sealing options recommended for wet or freezing climates.

Note 5) Not recommended for posted speed limits 45 mph (72 km/hr) or lower.

Note 6) Filling not recommended for joint less than 1/4 in. (6 mm) wide; adequate width is needed for effective cleaning and injection of material.

Note 7) Examples include pavements for heavy trucks, container handling straddle cranes, forklift operations, etc.

- **Durability:** Ability of a sealant to resist deterioration (e.g. hardening or oxidation) when exposed to the elements (primarily ultraviolet sun rays and ozone).
- Jet Fuel Resistance: Ability of a sealant to resist degradation in contact with jet fuel. Some material swelling may occur in contact with jet fuel. Upon evaporation of the fuel, the sealant must return to original shape and maintain adherence to the reservoir walls. Since there are few federal or ASTM-International specifications presently written for silicone sealant materials, manufacturers developed a test method to verify that silicone sealants can meet the jet fuel resistance requirements for airfield applications (24).

In addition to the sealants themselves, there are a variety of choices for backer rods and isolation/expansion joint fillers.

Table 2 gives descriptions of the available materials and their related specifications. Additional sections of this publication discuss the sealing materials and backer rods in more detail.

Sealant Type	Properties	Specification				
Hot-Applied, Formed-in-Place Materials						
Hot-Pour Asphalt Based	Self Leveling	ASTM D6690 Type I, II, III and IV, SS-S-1401c				
Cold-Applied (Single-Component), Formed-in-Place Materials						
	Non sag, toolable, low modulus	ASTM D 5893				
	Self Leveling (no tooling), low modulus	ASTM D 5893				
Silicone	Self Leveling (no tooling), ultra-low modulus	ASTM D 5893				
	Jet Fuel Resistant	Manufacturer's Test (See Ref 24 for Sample)				
Nitrile Rubber	Self Leveling (toolable), non sag	N.A.				
Polysulfide	Self Leveling( no tooling), low modulus	N.A.				
Polymeric Low Modulus	Self Leveling (no tooling), low modulus	N.A.				
Cold-Applied (Two-Component), Formed-in-Place Materials						
Elastomeric Polymer	Jet Fuel Resistant, Jet-Blast Resistant	SS-S-200E				
Preformed Polychloroprene Elastomeric Materials (Compression Joint Seals)						
Preformed Compression Seals	Jet Fuel Resistant	ASTM D 2628				
Lubricant Adhesive	Jet Fuel Resistant	ASTM D 2835				
Backer Rod Materials						
	Standard Delvathylana Faam	ASTM C 1330, Type C				
Closed Cell	Standard Polyetnylene Foam	ASTM D 5249				
	Cross-Linked Polyethylene Foam	ASTM D 5249				
Open Cell	Open Cell Polyurethane Foam					
Bicellular	Outer: Cross-Linked; Inner: Open Cell Foam	ASTM D 5249				
Preformed	d Isolation/Expansion Joint Filler Materials					
	Closed-Cell Polypropylene Foam	ASTM D1751				
	Asphalt Saturated Fiber Board (non-extruding)	ASTM D1751				
Preformed Filler Material	Asphalt	ASTM D994				
	Sponge Rubber	ASTM D1752, Type 1				
	Cork	ASTM D1752, Type 2				

Table 2 — Descriptions and Specifications for Common Joint Sealing Materials.



Hot-pour sealant being installed into a crack.

**Hot-Pour Sealants** — Hot-pour sealants were the first type of formed in place sealant. They have evolved over decades of research and development. Manufacturers have improved their adhesive qualities and provide low-modulus materials with excellent extensibility.

The materials require heating, usually to between 350 - 400°F (177 - 204°C), for proper installation. Manufacturers recommend melting the material in a double boiler. The inside melting vat is surrounded by a vat of oil. An agitator in the melting vat helps distribute the heat evenly. Accurate temperature control is important for desired sealant properties (3). Both contractor and agency personnel should ensure that the material is pre-

pared at recommended temperatures. Insulated hoses and applicator wands help make sure that the sealant does not lose temperature between the boiler and injection nozzle. **Silicone** — Silicone sealants are a field-poured liquid with a base ingredient of silicone polymer. Pavement specifications began allowing use of these materials in the 1970's (25). Installation procedures are similar to those for other formed-in-place sealants.

Silicone sealants may either be self-leveling (ultra low modulus) or non-sag (low modulus). Selfleveling silicones flow into shape once injected into the seal reservoir, while non-sag silicones require tooling.

The material comes prepackaged and ready for immediate application. It is important to store silicone

materials properly. Manufacturers recommend storing the containers out of direct sunlight, humid air and in temperatures between 35 and 90°F (2 and 32°C) until use.

The silicone material is a single component which requires no mixing or heating. The material cures when exposed to the atmosphere during and after application. Moisture in the air helps the sealant cure to attain its final properties. However, manufacturers caution not to apply the sealant during rain, frost, or temperatures below the dew point.

Non-sag silicones will be tack-free and may be opened to traffic in 25 to 90 minutes, and will fully cure in 14 days. Self-leveling silicones become tack-free and may be opened to traffic in about 3 hours and will fully cure in 21 days. Silicones also require about 30 minutes curing time before developing sufficient adhesion. However, the exact curing time may differ depending on the manufacturer and environmental conditions. It is always best to contact a manufacturer's representative for consultation on curing time needed for particular installation procedures and applications.

With regard to elastic properties, silicone sealants are suitable in climates with wide temperature ranges. Most silicones develop a low elastic modulus which allows good extension and compression recovery. Typical low modulus silicones can undergo at least 100 percent extension and 50 percent compression without detriment.



Non-Sag Silicone (Light Gray on Left) and Self-Leveling (Dark Gray on Right)



Preformed Compression Seal

**Compression Seals** — Manufacturers introduced preformed compression seals in the early 1960s. They differ from other sealants because they are manufactured ready for installation without field heating, mixing or curing.

Unlike all of the formed-in-place sealants, which experience both compression and tension, preformed compression seals are designed to only be in compression after installation. Therefore their success depends solely on the lateral pressure exerted by the seal during its lifetime.

The principal compound in compres-

sion seals is neoprene. Neoprene is a synthetic rubber providing excellent rebound pressure under compression. Seals typically consist of a series of five or six webs. The webs provide the outward force which presses the sealant against the reservoir walls.

Manufacturers provide seals of various nominal widths and depths to fit any design scenario. In all cases, the seal's width must be greater than the maximum (coldest weather) joint reservoir width. Generally, seals will be about twice the width of the reservoir, but seal and reservoir widths should be designed and selected carefully together. Also, the reservoir depth must exceed the depth of seal when compressed.

Good performance results when seals remain compressed at a level between 20 and 50 percent at all pavement temperatures. See details in "Reservoir Design" for recommendations of how to determine joint reservoir and seal widths to perform in this range.

If a compression seal is undersized, the seal may lose contact with the reservoir walls and loosen at cold temperatures. Also expansion/



**Backer Rods** 

isolation joints in the pavement may allow contraction joints within about 100 ft (30 m) to open wide, also causing the seals to loosen. Careful consideration of these factors is essential when sizing compression seals.

**Backer Rods** — Backer rods are an important component of a formed-in-place sealant installation (non-filling arrangement). They prevent sealant material from flowing out toward the bottom of a joint and adhering to the reservoir bottom. They help define the shape factor and optimize the quantity of sealant used. Options include (27):

- <u>Closed-cell</u>: Typically a polyethylene foam that does not absorb water and is moderately compressible. They are best suited for cold -applied sealants since they melt in contact with hotapplied materials.
- <u>Cross-linked/Closed-cell:</u> Typically a polyethylene foam that is compatible with hot-applied sealants. They will not absorb water and are easily compressible.
- Open-Cell: DO NOT USE open-cell backer rods in concrete pavement. Open cell rods are made from polyurethane foam that absorbs liquids. While these rods will not melt in contact with hot-applied sealants, their moisture retention may present a problem. When the rods hold water (and concentrated de-icing salt solutions in the wintertime). this can elevate the relative humidity in the sealant reservoir, and potentially contribute to oxychloride formation in the concrete. In the winter, salt concentration may also increase. Both conditions are known to contribute to concrete materials-related distresses. and therefore, it is best to avoid open-cell backer rods.

**Reservoir Design** Reservoir sizing is a critical consideration to facilitate proper installation and allow sealants to

function properly. The initial reservoir should be wide enough to allow for effective cleaning for formed-in-place sealants, and for preformed seals should be sized as needed for the seal width.

Bi-cellular: A rod com-

wrapper surrounding

for cold-poured sealants.

Backer rod size depends on the

joint reservoir width. In general,

backer rods should be com-

pressed about 25 to 50 percent

at the time of installation to en-

sure they stay at the desired

depth in the reservoir (28).

open-celled

prised of a closed cell outer

These rods are suitable only

inner

an

core.

Expecting the need to reseal joints in the future should not be overlooked during original sealant design decisions. Anticipating one or two resealing operations during the life of a pavement is a reasonable assumption. Therefore it is advantageous to keep the original reservoir width as narrow as practical to allow for future widening and resealing without introducing joint performance or wheel slap issues (38,39,40). Of course the starting reservoir width should not be so narrow that it is difficult to properly clean the reservoir for good sealant adherence or performance.

A good starting reservoir width is 1/4 to 3/8 in. (6 to 10 mm) for formed -in-place sealants if suitable for the climate, slab design and other local factors. The initial width for preformed compression seals also depends on design and climate factors. A good starting reservoir width is 1/4 to 1/2 in. (6 to 12 mm) for preformed seals—1/2 in. (12 mm) is typical for airfield pavements.

**Joint Type & Movement** — A sealant must be capable of accommodating the anticipated joint opening and closing due to temperature changes. Formed-in-place sealants are usually installed in reservoirs with standard dimensions, while compression seal manufacturers recommend calculating joint movements for proper dimensioning.

Joint movement estimates are made with the following equation:

$$\Delta L = C L (\alpha \Delta T + \varepsilon)$$

where:

- $\Delta L$  = Expected change in slab length; in. (mm).
- C = Base/slab frictional restraint factor (0.65 for stabilized material, 0.80 for granular material).
- L = Slab length; in. (mm).
- $\alpha$  = PCC Coefficient of Thermal Expansion (see Table 3); x10<sup>-6</sup>/°F (x10<sup>-6</sup>/°C).
- ΔT = Maximum temperature range; °F (°C). <u>Note</u>: this is generally the maximum concrete temperature at placement minus the minimum (coldest) ambient temperature in winter.
- ε = Shrinkage coefficient of the concrete (see Table 4); in./in. (mm/mm). <u>Note</u>: this factor should be eliminated on resealing projects, where shrinkage is no longer a factor.

### ACPA offers an online tool for estimating joint movement at: http://apps.acpa.org/applibrary/JointMovement/

# Table 3 — Typical Coefficient of Thermal Expansion ( $\alpha$ ) Values

Type of Coarse Aggregate	Concrete Coefficient of Thermal Expansion (x10 <sup>-6</sup> /degree)			
	° F	° C		
Quartz	6.6	11.9		
Sandstone	6.5	11.7		
Gravel	6.0	10.8		
Granite	5.3	9.5		
Basalt	4.8	8.6		
Limestone	3.8	6.8		

## Table 4 — Typical values for Coefficient of Shrinkage ( $\epsilon$ )

Indirect Tensile Strength	Concrete Coefficient of Shrinkage (strain)		
< 300 psi (2.07 MPa)	0.00080		
400 psi (2.76 MPa)	0.00060		
500 psi (3.45 MPa)	0.00045		
600 psi (4.14 MPa)	0.00030		
> 700 psi (4.83 MPa)	0.00020		

It is important to remember that there is almost no movement of tied longitudinal and shoulder joints. Tiebars which hold these joints tight will not allow the movement calculated from the formula. Therefore these joints may not require the same material as might be determined based on the calculated movement range. Opening ranges determined from the formula for doweled or undoweled transverse contraction joints will reflect actual field movements.

Even though only small joint opening movements are expected with tied centerline, highway shoulder or airfield longitudinal joints, it is still important to seal/fill them because these joints are typically perpendicular to the drainage slope. Therefore they can allow significant access for water. On highways the lane/shoulder joint is the most critical and can let in as much as 80 percent of the total water (29). Neglecting to seal and maintain the longitudinal joints will negate the benefit of even excellent transverse joint seals.

**Sealant Shape Factor** — The shape factor is the ratio of width to depth of a formed-in-place sealant. The saw cut width, depth and insertion depth of the backer

rod define the shape. The shape factor is considered critical to success of materials intended for use as sealants and not just as fillers.

The cross section of a joint sealant changes during the expansion and contraction of the concrete. Joint movements induce strain within the sealant and stress along the sealant/reservoir bond line. These material responses may become excessive if a shape factor is not appropriately selected/controlled. Although different formed-in-place sealant materials are able to withstand different levels of extension (and strain), all sealants are affected to some degree by joint movements.

Strain induced on the extreme sealant fiber depends on the amount of sealant elongation (joint opening) and the shape factor (Figure 4). Silicones and some other low-modulus formed-in-place materials can withstand up to 200 percent strain, but manufacturers generally recommend limiting strain to less than 25 to 50 percent depending on the material. Sealant strain is controlled by effectively applying the shape factor, which thereby limits potential for adhesive or cohesive loss. Controlling the shape factor represents a fundamental engineering difference between using formed-in-place materials as joint sealants rather than joint fillers.

Figure 5 (next page) shows reservoir and sealant dimension recommendations for formed-in-place sealants for both sealing and filling. For silicone sealants shape factor design should include recessing the





sealant from 1/4 to 3/8 in. (6 to 10 mm) to prevent tire contact. For hot-pour materials filling the reservoir flush with the pavement surface is preferred because experience suggests traffic keeps the materials pliable and studies indicate it eliminates wheel slap (38,39,40).

### **Compression Seal Reservoir**—

To size a preformed compression seal properly requires consideration of pavement temperature at installation and joint movement range. The seal must remain within the desired compression range (typically 20 to 50 percent). If compressed too much for an extended period, the webs of a seal may either stick together or the rubber may permanently deform (called compression set). If not compressed enough a seal may be-



- B = Depth to Top of Backer Rod = Min. of 5/8 in. (16 mm)
- D = Nominal Sealant Thickness (Depth) = Min. 1/4 in. (6 mm)

W = Joint Reservoir and Sealant Width = Min. 1/4 in. (6 mm)

Shape Factor (W/D) = Min. 1/1 to Max. 2/1

### Joint and Sealant Dimensions – Hot Poured Materials

- R = 0.0 in. (0 mm) Flush Fill; No Recess
- B =Depth to Top of Backer Rod = Min. of 5/8 in. (16 mm)
- D = Nominal Sealant Thickness (Depth) = Min. 1/2 in. (12 mm)
- W = Joint Reservoir and Sealant Width = Min. 1/4 in. (6 mm)

**Dimensions for Filled Joints** 

R = 1/4 to 3/8 in. (6 to 10 mm) for Silicone and Other Cold-Poured

W = Joint Width  $\geq 1/4$  in. (6 mm) to Clean Walls

D = Initial Saw Cut Thickness (Depth) R = 0.0 in. for Hot-Poured Sealants (Flush Fill)

Shape Factor (W/D) = 1/1

Sealants



R = Recess 1,	R = Recess 1/8 to 1/4 in. (3 to 6 mm)						
Wi = Installed width depends on calculations							
Nominal Seal Width in. (mm)	l Seal Reservoir Width Reservoir Narrowest Widest th (Wi) Typ. Depth (D) Opening Opening im) in. (mm) in. (mm) in. (mm) in. (mm)						
7/16 (11)	1/4 (6)	1 (25)	0.219 (5.6)	0.372 (9.5)			
9/16 (14)	5/16 (8)	1-1/16 (27)	0.290 (7.4)	0.478 (12.1)			
11/16 (18)	3/8 (10)	1-3/16 (30)	0.325 (8.3)	0.584 (14.8)			
13/16 (21)	1/2 (13)	1-7/16 (37)	0.378 (9.6)	0.691 (17.5)			
1 (25)	9/16 (14)	1-5/8 (41)	0.400 (10.2)	0.850 (21.6)			



Figure 6. Typical reservoir dimensions for preformed compression seals (26).

come loose in colder temperatures. Either situation may lead to the sealant dislodging from the reservoir. Figure 6 shows the current best practice dimensioning for six-celled seals, which provide excellent rebound life (26).

The first step to sizing a seal is to calculate the total range of joint movement using the formula previously discussed or the ACPA Joint Movement web application. The second step is to select a compression seal with an allowable movement workable for the calculated movement range. If the anticipated joint movement exceeds that allowable to keep the seal in compression then a larger seal must be chosen. Consideration can also be given to decreasing the joint spacing on the project.

The final step is to select a reservoir (saw cut) width to meet seal size, movement range and installation temperature criteria (26). Only a rough estimate of the pavement temperature is necessary, but accounting for temperature at installation is important so the seal will operate in the 20 to 50 percent compression range. Warmer installation temperatures require more seal compression at installation than cooler installation temperatures. When cooler, the concrete slabs contract and the joints are at least partially open.

The following equation calculates saw cut width (26):

$$S_c = (1 - P_c) * w$$

where:

Sc = Joint saw cut width; in. (mm).

w = Width of the uncompressed seal; in. (mm).

Pc = Percent compression of seal at installation (expressed as a decimal).

 $Pc = C_{MIN} + (T_{INSTALL} - T_{MIN}) / (T_{MAX} - T_{MIN}) * (C_{MAX} - C_{MIN})$ 

C<sub>MIN</sub>= Minimum compression of seal expressed as a decimal (usually 0.2).

C<sub>MAX</sub>= Maximum compression of seal expressed as a decimal (usually 0.5).

### ACPA provides a web-based compression seal joint width calculator at: *http://apps.acpa.org/applibrary/CompressionSeal/.*

Of course, the actual installation temperature cannot be accurately known during the design process. Therefore, designers may calculate sizing for various potential installation scenarios (hot, moderate, cool). When working with compression seals it is a best practice to always have a manufacturer's technical representative on site for the

first two days during installation (26). The representative will help to determine if the designed and specified seal size is workable based on actual field conditions.

### Installation

Successful sealant performance requires attention to detail and consistency in following the proper installation steps. Of critical importance is cleaning prior to installing the sealant, which will be discussed in detail. Proper cleaning is not a costly endeavor to the contractor. Figure 7 shows that for any type of sealant, cleaning costs less than 10 percent of the installation expense (30). The installation process consists of five steps:

- 1. Sawing the reservoir.
- 2. Cleaning the reservoir.
- 3. Installing the backer rod (if required).
- 4. Cleanliness check.
- 5. Installing the sealant.

A very important component of sealing joints effectively is inspecting the reservoir prior to installing the sealant material. Experience shows that lack of emphasis on the importance of good reservoir cleaning is a major problem impacting sealant performance. With the proper emphasis, quality control and inspection can lead to vastly improved sealing techniques, maximizing the value from the sealant (31,32,33). The quality control process improves the knowledge of workers on proper techniques. This will heighten the level of competence and improve the consistency of results.



Figure 7 — Relative cost of joint sealant installation steps (30).



Sawing Reservoir for Shape



Water Flushing the Reservoir

**Step 1. Reservoir Cutting** — Sawing/widening shapes the reservoir for sealant installation. Saws equipped with wet diamond blades are preferred to minimize dust creation, although dry blades also work well. The reservoir saw cut will remove any raveling caused by the initial cut and provide the proper dimensions for the sealant.

If a sealant will be placed as a filler and the initial saw cut is wide enough to be cleaned —1/4 inch (6 mm) minimum—then no reservoir cut is needed. Some minor sliver spalling along the joint face will not inhibit performance of materials placed as fillers even where flush filling is employed.

As with all concrete sawing, follow manufacturer and industry recommended practices for selecting saw blades properly for the hardness of the concrete (aggregates). A minimum 65-horsepower saw is recommended whenever cutting hardened concrete.

**Step 2. Cleaning** — Cleaning is the most important aspect of joint sealing. For all formed-in-place sealants, manufacturers suggest similar cleaning procedures. Likewise the performance claims of formed-in -place sealant products is predicated on preparation and cleaning procedures.

Reservoir faces require a thorough cleaning to ensure good sealant adhesion. No dust, dirt or visible traces of foreign material should remain on the joint faces after cleaning. The ability to attain this condition may depend on the reservoir width. Most contractors report that it is essential that joint reservoirs are at least 1/4 in (6 mm) wide or they will not be able to adequately clean the side walls. Attempting to clean narrow 1/8 in (3 mm) reservoirs is very difficult at best and likely futile.

Do not use chemical solvents to wash the joint reservoir. Solvents can carry contaminants into pores and surface voids on the reservoir faces (2). Contaminants may inhibit bonding of the sealant.

Proper cleaning requires mechanical action and pure water flushing to remove contaminants. Do not use wire brushes as the sole means to clean joint reservoirs for a sealant installation. While it can be helpful, brushing alone is not a thorough enough process to produce consistently good results. The following outlines the preferred procedures:

- A. Immediately after sawing, use a water wash to remove the slurry from the sawing operation. Perform this operation in one direction to help minimize contamination of surrounding areas and previously flushed joints.
- B. After the joint has sufficiently dried, use an abrasive blasting operation to remove any remaining residue. Do not direct the abrasive blasting nozzle straight into the joint. Hold the nozzle close to the surface at an angle to clean the top 1 in. (25 mm) of the joint face.

Repeat this for both joint faces. One pass along each reservoir face can provide excellent results. This not only cleans the joint faces, it provides texture to enhance sealant adhesion.

C. Use an air blowing operation to remove particles, dirt and dust from the joint and pavement surface. Conduct this operation just prior to installing the sealant to provide better assurance that the sealant material will enter an extremely clean reservoir.

When performing this operation occasionally check that the air compressor is properly filtering moisture and oil from the air by directing the air onto a clean surface for an extended time. Fix the equipment if needed. The compressor should deliver air at a minimum of about 120 cu.ft./min. (3.4 cu.m./min.) and develop at least 90 psi (0.63 MPa) nozzle pressure to be effective.

D. It is a best practice to also use a vacuum sweeper and hand brooms to keep the surrounding pavement clean. (Preformed compression seals do not require steps B or C.)

Workers are reminded to wear appropriate personal protective equipment (PPE) for blasting and cleaning operations, including face shields, masks and respirators as required by OSHA for the type of sawing/blasting/cleaning and length of work shift (exposure time).

**Step 3. Backer Rod Installation** — When required, install backer rod after cleaning and before formed-in-place sealant installation. Before starting, check that the backer rod is compatible with the sealant and sized about 25 to 50 percent greater than the reservoir width. Backer rods are inserted easily with a double-wheeled, steel roller that will force it uniformly to the proper depth (Figure 8). Always select and install a center insertion wheel that will provide desired installation



Figure 8 — Double-wheeled, backer rod roller.

depth. It is best to roll the insertion wheel over the rod twice being careful not to puncture or stretch the rod. Do not cut the backer rod at intersecting joints. Install the rod through the intersection in both directions, inserting transverse rod over the longitudinal rod.



Abrasive-Blasting Reservoir walls



Air Blasting to Remove Dust



**Installing Backer Rod** 



Step 4: Check for Dirt/Dust on Walls



Step 4: Conduct Wipe Test



Step 4: Wipe Test with Moderate Contamination



Step 4: Wipe Test with Minimal Contamination

**Step 4. Cleanliness Check** — The crew foreman should not allow the installation crew to begin installing sealants until the reservoir is demonstrated to be clean. There are a variety of ways that the joint reservoir can be evaluated objectively for this purpose.

With a finger, a foreman or inspector can simply wipe the reservoir sidewalls to check for dirt and dust. The foreman should require further cleaning with any traces of contamination. However, this method is only workable for wider joint reservoirs.

A simple and quick test for checking any reservoir for cleanliness is the "wipe test" developed for industry by Wiss, Janney, Elstner Associates and adopted by ACPA as a standard quality control (QC) test (34).

### ACPA provides the QC procedure at: http://wikipave.org/index.php?title=Wipe\_Test.

The wipe test captures the relative amount of concrete dust, slurry, and contaminants in the joint prior to sealing. The procedure requires that a clean, black cloth is used to wipe the surface of the joint to determine the presence of contaminants.

The foreman or QC inspector inserts the cloth using a tongue depressor and firmly rubs the entire width of the cloth against each side and the bottom of the joint reservoir. After rubbing, the foreman or QC inspector withdraws the cloth and compares the visible level of contamination on the test cloth with benchmark photos in the test procedure. The comparison provides a visual delineation of clean and unclean joints.

It is important that the foreman or QC inspector handle the cloth carefully to avoid contaminating it with debris from the surface (34). The cloth may pick up contaminants through inadvertent contact with the top surface of the slab or contaminants picked up during the test might be inadvertently removed by rough handling of the cloth.

Full details of the test method are available in reference 34 or online.

**Step 5. Sealant Installation** — The installation requirements vary slightly for each sealant type. Manufacturers recommend some curing or cooling time for formed-in-place sealant materials and provide suggested limits on the outside air and pavement temperatures for installation. Compression seal manufacturers include recommendations for lubrication and desirable limits on sealant stretch during installation.

Table 5 (next page) provides current recommendations on placement conditions for different sealants. General QC tests for joint reservoir moisture condition are currently in development and may be added in the future. Regardless of sealant type, it is always advisable to consult the sealant manufacturer for their updated recommendations.

## Table 5 — Typical manufacturer's recommendations for air and concrete temperature, concrete curing time, and time required before opening sealed joints to traffic.

Sealant Type	Temperature Limits for Placing Sealant <sup>(1)</sup>	Concrete Curing Time Sug- gested for Best Adhesion	Time Required Before Opening Sealed Joints to Traffic
Hot-Pour (Asphalt Based)	40°F (4°C); Frost-free	7-days <sup>(2)</sup>	Upon Sealant Cooling
Silicone	40°F (4°C); Frost-free and below dew point <sup>(3)</sup>	7-days <sup>(2,4)</sup>	When Sealant is Tack Free <sup>(5)</sup>
Preformed Compression	30°F (-1°C)	None	May be Opened Immediately

(1) Temperature limits apply to air and/or concrete surface temperatures.

(2) Seven days must be considered good drying weather (free of major precipitation). An additional day of good drying weather is recommended for each day of poor drying weather encountered.

(3) Do not install sealant if temperature is at or below the dew point (temperature at which air is saturated with moisture vapor and liquid water—dew—begins to form on surfaces, especially the concrete).

(4) For best results a primer application on the concrete may also be recommended prior to the installing the sealant. (This recommendation may apply in certain situations or with certain materials, such as with concrete containing dolomitic limestone aggregate.)

(5) Time varies by temperature and humidity. At 75°F (24°C) and 50% relative humidity silicone will cure to a tack free condition in 30 minutes. At 40°F (4°C) it takes from 2 to 4 hours.

**Formed-in-Place Sealants:** Formed-in-place sealants function best when installed in a consistent and uniform manner. Filling the reservoir from the bottom upward and pulling the nozzle toward the operator will avoid trapping air pockets.

For hot-poured materials special attention to the heating temperature is vital (28). Sealants should not be installed before reaching proper installation temperature and likewise overheated hot-poured sealants will not have the desired properties and should be discarded. Always consult the manufacturer for recommendations on pot life and number of times the material may be reheated before losing its effectiveness.

The major pieces of power equipment required to install hotpour sealants include a melter/double-boiler tank and a pump [typically 100 cfm (47.2 l/s)] connected to a heated applicator hose, wand and nozzle. A heating element, which runs the length of the installation hose heats the material within the hose. The hose is covered with a durable insulating material. The wand has a disposable valve on the end, which shuts off the flow of material when the pump is turned off and prevents excessive dripping of material.

The major pieces of power equipment required to install silicone pavement sealants include an extrusion pump to transfer the material from a drum or other container and an air compressor capable of delivering air at 60 cfm (28.3 l/s) and 100 psi (690 kPa).

Because silicone sealants cure on exposure to atmospheric moisture, it is important for hoses and fittings to prevent or



Typical Melter-Applicator Equipment for Hot-Pour Sealants



Schematic of Extrusion Pump, Hose and Sealant Wand Installation Equipment for Silicone Sealants



Installing Sealant (Hot-Pour) Drawing Nozzle toward Operator



Installing Non-Sag Silicone with Proper Nozzle Size



Tooling a Non-Sag Silicone Sealant



Hot-Pour Sealant at Transverse-Longitudinal Joint Intersection

minimize moisture permeation in addition to withstanding the pumping pressure. Manufacturers recommend hoses lined with Teflon<sup>™</sup> to minimize air and moisture permeability. Nylon-lined hoses are not recommended.

It is important to pump the formed-in-place sealants through a nozzle sized for the width of the joint reservoir. A nozzle that fits into the reservoir allows dispensing material from the bottom up and/or along the top of the backer rod. Operators should draw the nozzle toward them, as pushing the nozzle usually results in a nonuniform bead (4).

Low-modulus silicone sealants which are not self-leveling require tooling to provide desired results. After sealant pumping, a laborer draws a tool or backer rod strip over the fresh silicone. This forces the sealant into contact with the sidewalls and produces the desired shape factor (35). Tooling is necessary within about 10 minutes of installation before the sealant begins curing and forms a "skin".

It is extremely important that the reservoir walls are dry before installing a formed-in-place sealant (26,31,35). Moisture will boil in contact with hot-pour materials, forming steam that can bubble the sealant. Moisture also will inhibit silicone sealant adherence. Most silicone manufacturers recommend a drying time or condition before installation. This includes drying after wetting due to water flushing and even rainfall. Refer to Table 5 and follow the manufacturer's guidelines to achieve optimum sealant adherence.

Installing different sealants in transverse and longitudinal joints requires some forethought in sequencing the installation to get the best results at the joint intersections. For instance, the installation sequence is important where transverse joints are sealed with a silicone and longitudinal joints with hot-poured material. In this case, it is better to install the silicone in the transverse joints first. Non-sag silicone is somewhat more viscous than hot-poured sealant while in a liquid state during installation, and experience has found the extent of silicone migration into the longitudinal joints is tolerable.

**Preformed Compression Seals:** A preformed compression seal is mechanically compressed and inserted into the reservoir using a special machine designed specifically for that purpose. The equipment is usually self-propelled or semi-self-propelled with a guide that keeps it on course over a joint. The equipment also applies a lubricant/ adhesive to the sealant edges and/or reservoir sidewalls as part of the process. The lubricant/adhesive material eases sealant insertion, and forms a bond to help hold the seal in place.

The joints must be clean and relatively dry at the time of seal installation. Abrasive blasting of the joint reservoir is not necessary, but may be required in the specifications. Before installing the sealant, it is important to inspect the reservoir for proper width and depth, and to ensure that the faces of the reservoir are at 90 degrees to the surface of the pavement. The inspection process should also identify any suspect areas, such as raveling or spalling. Such irregularities can reduce the seal's lateral pressure and allow the seal to extrude or pop out of the joint. (Small spalls about 5/8-in. (15 mm) wide or narrower and less than 3 in. (75 mm) long, can be filled with a silicone sealant after inserting the preformed compression seal. Larger spalls require a more extensive partial-depth repair of the concrete.)

Stretching preformed compression seals during installation is the major cause of premature failure. Sealant stretch of three percent or less is desirable and stretching over four percent is considered unacceptable and detrimental to performance of the seal (26). Some neoprene seals can stretch by as much as 50 percent without breaking, but any significant stretching reduces the cross-section and compression recovery of the sealant (36). If stretched excessively during installation, the integrity and performance of the joint seal will be compromised.

Focused attention on the installation process should help operators avoid twisting, nicking or stretching the seal. The installation machines control most of the stretching and twisting problems that are common with hand installation (3). Hand installation is not recommended except in unavoidable circumstances.

Checking for seal stretch is an important step to ensure the installation methods are proper, and this should be done as a QC check very early in the sealing process (26). The QC check involves loosely laying a piece of the preformed compression joint seal on the pavement surface and cutting it to the exact width of the pavement. The seal is then installed into the joint. Any excess amount of seal remaining at the end of the joint is due to stretch. A measurement of this protruding seal provides an accurate number for calculating stretch percentage. If seal stretch is determined to be over four percent, the machine and method should be adjusted to work within the desirable range.

Avoid splicing preformed compression seals if possible (37). Splices may allow water to enter the pavement so it is always best to use only one length of compression seal, especially in transverse joints. However, this may not be practical for pavements 25 ft (7.6 m) wide or more. For wide sections it is acceptable to position a single splice at the location of an intersecting longitudinal joint (and ideally at the location of the pavement crown).

When using preformed compression seals in both longitudinal and transverse joints, the best installation sequence is to install the longitudinal seals first, extending the seals for as long a length as practical. After allowing the lubricant-adhesive to dry (approximately 20



Hand Pushed Insertion Machine for Smaller Seals



Self-Propelled Insertion Machine for Compression Seals



Monitoring the Preformed Compression Seal on the Machine



Preformed Compression Seal Intersection Showing Transverse Over Longitudinal

minutes), each longitudinal seal can be severed with a sharp instrument or saw blade at the middle of the intersection of the transverse joints. The seals should retract slightly in both directions at the intersections, leaving enough room for transverse seals to cross. Transverse joint seals are then installed in one continuous piece through the cuts in the longitudinal seal, forming tightly sealed intersections.

The lubricant-adhesive may thicken at temperatures of  $40^{\circ}$ F (4.4°C) or lower. If seal installation operations are pursued when the air temperature falls below  $40^{\circ}$ F (4.4°C), special precautions are needed. Always follow the manufacturer's recommendations on weather and temperature limitations.

### Step 6. Checking the Installa-

tion — It is advisable to check the installation at several times. A field adhesion test performed on a test section prior to full production will confirm the methods. Field adhesion tests should also be performed as the project proceeds and then after installation to confirm the materials quality and adhesion after they are fully cured.

Knife Test: A knife test is a simple screening procedure that detects application problems, such as improper cleaning. The knife test is useful for hotpoured sealants to indicate how well the sealant adhered to the sidewalls (Figure 9). The QC



Figure 9 — Simple Knife Test to Spot Check Sealant Adherence.

inspector simply inserts the knife blade along the walls and uses feel to gage adherence.

**Sample Stretch Test:** This test is useful for silicone sealants after they have cured fully over 14 to 21 days. To perform the test, the QC inspector removes a small 2-in (50-mm) sample of sealant. Stretching the segment about 50 percent [by 1 in (25 mm)] for about 10 seconds before releasing gives a quick check of its elastic property. A fairly fast and uniform relaxation of the sample indicates adequate curing. Slow rebound and curling of the sample indicates differential curing. The curl results from the upper (cured) seal retracting faster than the lower (less cured) portion, and could indicate a material problem.

It is important to repair the gap in the sealant where the sample was taken. It is advisable to use the same silicone sealant for the repair to take advantage of the good adherence that silicone has to itself.

**<u>Hand-Pull Test</u>**: The hand-pull test is useful to check silicone sealant adherence to the reservoir sidewalls. To perform the test:

- 1. Make a knife cut perpendicular to the joint from one side of the joint to the other.
- 2. Make two parallel cuts approximately 2 in. (25 mm) long, along each side of the joint.
- Place a 1-in. (25-mm) mark on the sealant tab as shown in Figure 10. Grasp the 2-in. (50-mm) cut segment of sealant firmly just beyond the 1-in. (25-mm) mark and pull at a 90° angle. Hold a ruler alongside the sealant.
- 4. If the 1-in. (25-mm) mark on the sealant can be pulled to the 5.5in. (140-mm) mark on the ruler (a total pull of 4.5 in. (110 mm) or 450% elongation) and held with no failure of sealant, the sealant should perform in a joint designed for +100/-50% movement.





### **Special Considerations**

**Nonuniform Joint Cracking** — In plain jointed pavements initial cracking from shrinkage occurs at intervals from about 40 to 150 ft (12 to 46 m). The exact spacing varies depending on concrete properties, thickness, subbase friction and climatic conditions during and after placement.

Contractors report closer and more uniform working joint intervals when using early-entry saws than when using conventional saws, which is attributed to the earlier sawing time. With conventional saws the joints within multiple slab lengths sometimes do not crack (work) for several weeks to months after construction even though saw cut spacing is much closer. As a result, the initial shrinkage and thermal movement occurs at the initially working (cracked) joints. These joints (sometimes called "dominate" joints) often become much wider than those in intermediate locations. To account for this variability, contrac-

tors are encouraged to have several sizes of backer rod or compression seals available.

**Expansion/Isolation Joints** — The steps for sealing isolation/expansion joints are similar to those for other pavement joints. However, sealing isolation/expansion joints requires installing the sealant above a preformed isolation/expansion joint filler. An isolation/ expansion joint filler is typically placed over the entire face of a joint prior to placing the concrete. Therefore, when a sealant is required, a portion of the filler will need to be sawed out to form the reservoir for the sealant. Isolation or expansion fillers must be taken down to a depth to place a closed cell backer rod at the correct location to create a sealant with a proper shape factor and to eliminate the possibility of 3 point adhesion (Figure 11). If a preformed compression seal is used, then the isolation/expansion must be removed to accommodate the seal when compressed and recessed.

Lane/Shoulder Joints — Sealing and maintaining the longitudinal joint between a concrete lane and concrete shoulder requires no further effort than is required for other longitudinal joints, such as at the centerline or other locations. However, joints between concrete lanes and asphalt shoulders pose a more difficult sealing challenge.

Over time, asphalt shoulders tend to settle due to water accumulation, traffic encroachment, and lower soil or asphalt compaction at the pavement edge. Vertical settlement at the lane/shoulder joints is common and the sealant reservoir needs to be wider to ac-







Closeup View of Prepared Concrete/Asphalt Shoulder Sealant



Installing Hot-Poured Sealant Along Concrete/Asphalt Joint

count for this potential. Experience has found that a 1-in. (25mm) minimum width and depth of sealant is adequate to accommodate the lateral and vertical shoulder movements. This provides a reservoir shape factor of one and should be effective for most formed-in-place sealants capable of accommodating a 25 percent strain.

Formed-in-place sealants for shoulder joint sealing should be capable of adhering well to both concrete and asphalt materials; hot-poured sealants are the most commonly applied for concrete/asphalt joints. Specially formulated silicone sealants (usually self-leveling in this application) are also used and provide good adhesion to both concrete and asphalt (35).

As with all sealing, preparation of the lane/shoulder joint reservoir is important. Sawing the joint reservoir delivers the most consistent width and depth dimensions. The saw should cut vertically and remove any asphalt material from the edge of the concrete slab. Immediately after sawing a water flush will remove sawing slurry. Both sides of the reservoir require abrasive blasting. A lighter blasting operation along the asphalt face is acceptable. Air blowing just before sealant installation dries the reservoir and removes dust and dirt.

**DO NOT** use a propane torch for joint drying and cleaning. Torching has led to concrete spalling and raveling.

**DO NOT** seal newly placed asphalt until it cools to at least ambient temperatures. At higher temperatures asphalt can ravel, erode and deteriorate under saw action (29). A cleaner reservoir face results if sawing is delayed until after cooling.

### Summary

Experience with different joint sealing options shows that properly installed joint sealants can provide important protections that improve joint and pavement performance. This bulletin presents a table showing the potential joint performance based on sealing options and rationalizes the related factors, providing a new guide for consideration. In general, unless local experiences indicate that sealing or filling provide limited performance protection value, the recommended practice is to seal and maintain joints paying careful attention to reservoir design, sealant installation and maintenance requirements.

Regardless of method (joint filling or sealing) it is important not to expect joint sealants to provide more benefit than is reasonable from an engineering standpoint. Joint sealants are not a panacea for concrete pavements with poor drainage design, non-durable concrete or weak foundations. The performance protections realized from sealed or filled joints is predicated on use of durable concrete.

Similarly, the effectiveness of joint sealing or filling is inextricably linked to proper design, preparation and installation of the sealing or filling material. The latest recommendations on reservoir dimensioning is covered in this bulletin, including recommendations for adequate reservoir width to facilitate effective cleaning of the reservoir walls.

As important, successful performance of joint sealants requires attention to detail and consistency when following the required installation and maintenance steps. A renewed emphasis on proper reservoir cleaning and sealant installation techniques is a significant subject within this bulletin. A new quality control test that provides an effective means for contractors to assess the effectiveness of reservoir cleaning prior to installing the joint sealant or filler is also available.

Contractors and engineers that specify and work with concrete pavements are encouraged to review the recommendations in this bulletin as a starting point to reassess their joint sealing/filling practices.

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