

UNIFIED FACILITIES CRITERIA (UFC)

STANDARD PRACTICE FOR SEALING JOINTS AND CRACKS IN RIGID AND FLEXIBLE PAVEMENTS



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U.S. ARMY CORPS OF ENGINEERS (Preparing Activity)

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

Record of Changes (changes are indicated by \1\ ... /1/)

Change No.	Date	Location

This UFC supersedes TM 5-822-11, dated 11 June 1993. The format of this UFC does not conform to UFC 1-300-01; however, the format will be adjusted to conform at the next revision. The body of this UFC is the previous TM 5-822-11, dated 11 June 1993.

FOREWORD

\1\

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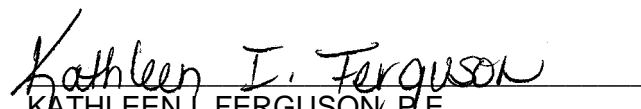

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TECHNICAL MANUAL

**STANDARD PRACTICE FOR
SEALING JOINTS AND CRACKS
IN RIGID AND FLEXIBLE PAVEMENTS**

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STANDARD PRACTICE FOR SEALING JOINTS AND CRACKS IN RIGID AND FLEXIBLE PAVEMENTS

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CHAPTER 1

GENERAL

1-1. Purpose. This manual contains guidance for ensuring the quality of joint and crack sealing or resealing of bituminous and portland cement concrete pavement.

1-2. Scope. Current state-of-the-art techniques and materials are presented in this manual to aid in achieving reduced life-cycle costs by providing information concerning the specification, use, and quality control of sealants for pavements. Sealants covered by Federal Specifications (FS) SS-S-1401C, SS-S-1614A, SS-S-200E, and American Society for Testing and Materials (ASTM) D 2628 are discussed in the following paragraphs. The newer types of sealants which are not covered by the above specifications are not discussed in detail in this manual and must be considered on an individual basis. This manual does not address all of the safety problems associated with the procedures and materials described herein. It is the responsibility of the user of this manual to obtain the appropriate material safety data sheets (MSDS) and to establish appropriate safety and health practices to determine the

applicability of regulatory limitations prior to use.

1-3. References. Appendix A contains a list of references used in this manual.

1-4. Background. Sealing joints and cracks in bituminous and portland cement concrete pavement is an effective method of extending pavement life and reducing the need for extensive repair work. When sealing is performed at the proper time, using the appropriate materials and procedures, life-cycle costs of the pavement structure can be reduced. One of the major factors in achieving optimum pavement performance is to properly seal and maintain joints and cracks. When incorrect procedures or poor quality materials are employed, major costs may result. Improper procedures can in fact accelerate other forms of pavement deterioration. This manual provides guidance on the evaluation of existing sealant condition, criteria for replacing sealants, data on selecting sealant materials, sealant installation procedures, and guidelines for inspection during and after the sealing operation.

CHAPTER 2

SEALANT MATERIALS

2-1. General. This chapter provides guidance for the selection of sealants, the functions of each sealant, and the background needed to understand sealant performance and quality control required to produce a sealing project with satisfactory performance. Appendix B provides comparisons between American Society for Testing and Materials (ASTM) and Federal Specifications (FS).

2-2. Sealant Functions.

a. There are two primary functions of joint and crack sealants. The first is to prevent surface water from seeping through the pavement structure into underlying water susceptible soils or base courses, and the second is to prevent the retention of incompressibles in the joint or crack. Both of these functions are extremely important in preventing premature pavement failure by maintaining pavement durability and structural integrity. A discussion of each function is given on the following pages.

(1) Water seepage must be prevented from entering into water susceptible soils such as those with a high fines content or a high plasticity index (PI). If water is allowed to penetrate into the water susceptible soil foundation of a pavement, the increased moisture content leads to a decrease in soil strength. For portland cement concrete (PCC) pavement, the water seepage reduces the subgrade support which may lead to pumping, corner breaks, shattered slabs, and other load associated distresses. For bituminous pavement, a reduction in foundation strength produces the appearance of alligator or fatigue cracking.

(2) Water infiltration into PCC can also lead to the loss of durability. The progressive loss of durability, commonly called "D-cracking," is a moisture-freeze-thaw aggregate interaction that destroys the structure of the concrete. This type of deterioration is often found where low-quality carbonate rocks are used as concrete aggregate and is common where moisture and temperature conditions produce the moisture-freeze-thaw cycles necessary for deterioration. The weakening of the concrete around joints and cracks leads to potential spalling of the concrete, increased roughness, and increased foreign object damage (FOD).

(3) The seepage water may also contain deicing salts or chemicals that cause load transferring steel dowels to corrode. The corroded dowels lock up and prevent the slabs from moving in response to temperature changes which in turn

cause the affected slabs to crack.

(4) In bituminous pavement, the heaving of the pavement at the cracks due to frozen moisture results in increased surface roughness. The saturated base or subbase material allows high deflections under wheel loading which causes additional cracking of the pavement.

b. The second function of the sealant is to prevent the retention of incompressibles in the joint or crack. There are several pavement distresses associated with the retention of incompressibles in joints and cracks. When the pavement contracts during low temperatures, the joints and cracks open, allowing incompressible materials to fill the available space. As the temperature increases, the pavement expands. However, the expansion is restricted by the incompressibles that have filled the joint and crack openings. In concrete pavement, the restricted movement causes spalling, and, in severe cases, blowups. In bituminous pavement, it causes upward tenting at the cracks. On airfield pavement, the retention of debris and incompressibles in joints create a potential for FOD to aircraft.

2-3. Sealant Types.

a. *The three types of sealant materials used when sealing or resealing joints* are field-poured (field molded) hot-applied, field-poured (field molded) cold-applied, and preformed elastomeric seals. The type of sealant that should be used for a project is determined from several considerations including the type of pavement, joint design, joint or crack condition, environment, cost, and the use of the pavement section in question. A typical joint which indicates the appropriate terminology used in discussing a joint is shown in figure 2-1.

b. *Field-poured sealant materials* are liquid at the time of application and solidify by either cooling or by a physical or chemical reaction. The hot-applied sealants which solidify by cooling are referred to as thermoplastic type materials. Hot-applied sealants that react when heated to solidify are referred to as thermosetting materials. The cold-applied sealants solidify by a chemical reaction between two components or a physical reaction, such as solvent evaporation. Sealants may be further classified as either jet-fuel resistant (JFR) or non-JFR. JFR sealants are normally a tar based material while non-JFR sealants are normally asphalt based materials. The base material for the

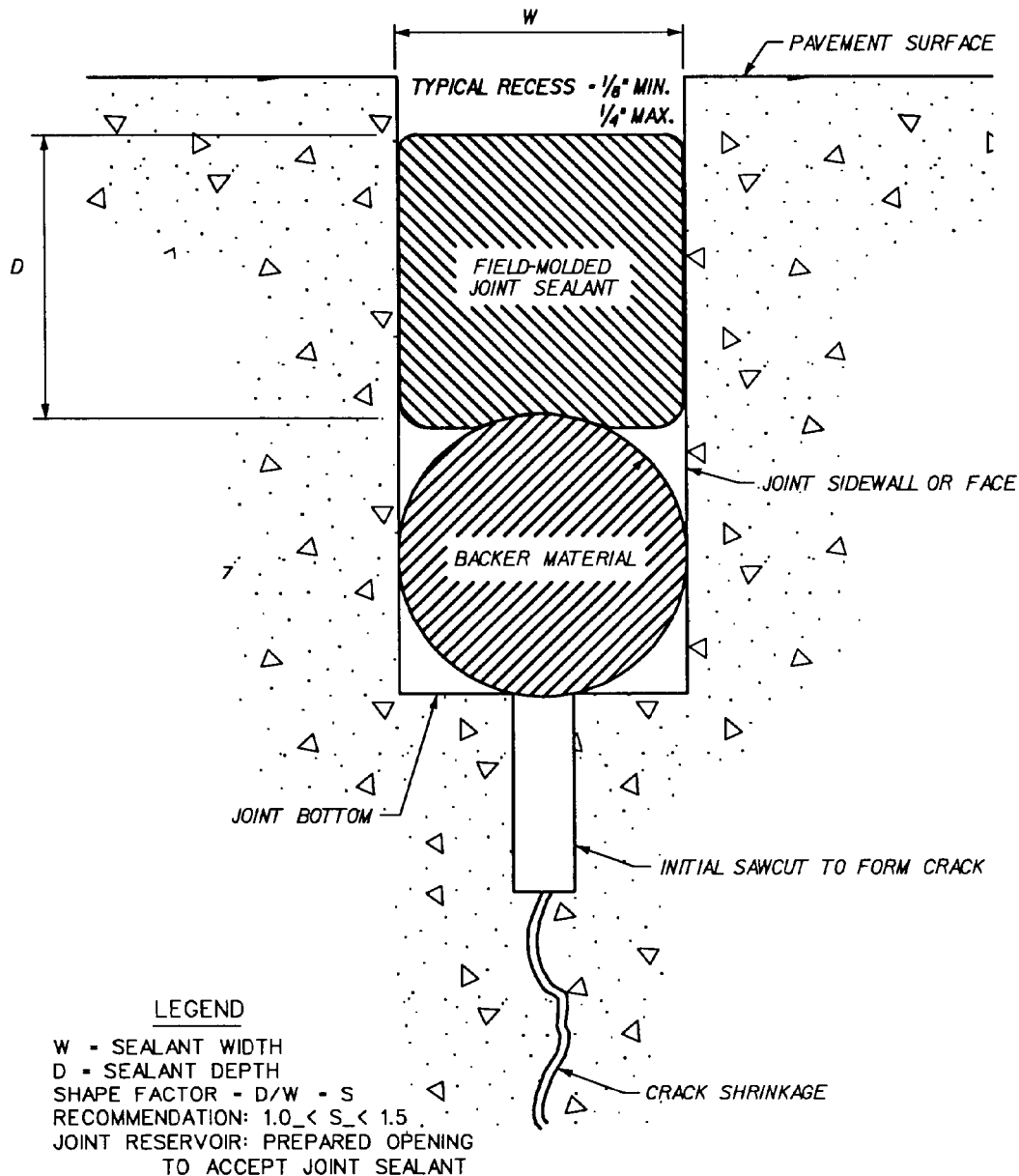


Figure 2-1. Joint Terminology and Shape Factor.

two classifications is combined with rubber materials or polymers that have rubber-like properties to improve performance characteristics. The hot-applied sealants in PCC pavements may cause problems associated with bubbling or the creation of voids in the sealant.

(1) The non-JFR rubberized-asphalt sealant is the most widely used of all joint sealant materials in both bituminous and PCC pavements and is used for highways, streets, and taxiways. The material is made by dispersing a rubber material or a rubberlike polymer in a suitable grade of asphalt cement. The rubber materials vary from new rubber and high-quality reclaimed

rubber down to low-grade waste, such as buffings from tire retreading operations. Because of this variation, the quality of the sealants also vary widely. Federal Specification SS-S-1401C, ASTM D 3405, and ASTM D 1190 cover field-poured hot-applied rubberized asphalt sealants. Federal Specification SS-S-1401C, ASTM D 3405, and ASTM D 1190 can be used in bituminous pavements, but for PCC pavements Federal Specification SS-S-1401C is usually specified. Asphalt based sealants should not be used in areas where fuel or lubricant spillage is expected because the spilled materials are usually petroleum derivatives. Petroleum derivatives have a solvent

reaction with asphalt, which is also derived from petroleum.

(2) JFR sealants are usually made from a tar based material modified with suitable resins or polymers. These sealants are most widely used on PCC pavement subjected to fuel spillage or lubricant leaks. JFR sealants should be used for parking aprons, maintenance areas, and refueling areas. Most tar is produced from coal which gives it a different chemical makeup than asphalt, rendering the tar based sealant less affected by the spillage of petroleum based materials. Federal Specification SS-S-1614A covers field-poured hot-applied JFR sealants. These sealants may be damaged by synthetic hydraulic fluids.

c. Field-Poured Cold Applied Sealants.

(1) Two-component polymer type cold-applied JFR sealants used in PCC pavements are covered in Federal Specification SS-S-200E, under Type H or Type M. These polymer-type sealants are tar, polyurethane, or polysulfide based materials modified with suitable elastomeric polymers or resins. One of the two components contains the polymer in liquid form, and the other component contains the chemical that solidifies the polymer. These sealants are used in areas that are subjected to fuel spillage and jet blast. Although the sealant is not completely jet blast resistant, it is more resistant to the heat from jet blast than the sealants in Federal Specification SS-S-1614A. Some one-component materials are being produced that claim to meet the performance requirements of Federal Specification SS-S-200E. The sealant material must be tested to ensure specification conformance before its use is approved.

(a) *Federal Specification SS-S-200E, Type H.* Type H two-component sealants are designed for hand-mixing. Type H sealants are generally used for small projects and spot repairs of deteriorated sealant in areas where fuel spillage and/or heat blast are expected. Type H sealants are normally not used for major sealing projects; however, some Type H sealants are manufactured for areas that are on steep inclines such as embankment areas. The steep slopes would make it difficult to use sealant application equipment, and therefore, a hand-mix sealant would be desirable.

(b) *Federal Specification SS-S-200E, Type M.* Type M two-component sealants are designed to be machine-mixed in a one-to-one ratio by volume using the appropriate sealant mixing/application equipment described later. Machine-mixed sealants are normally used for large sealing projects in areas where fuel spillage and/or heat blast are expected.

(c) During the storage of two component sealants, the accelerating agent, typically a powder in suspension, can settle to the bottom of the sealant container. The settlement can be minimized by turning the containers upside down at regular intervals, such as 1-week intervals. Even when this procedure is followed, the accelerator should be thoroughly remixed before being placed in the application equipment. The mixing can be accomplished using any suitable hand held device, such as a drill equipped with a mixing paddle, that mixes horizontally and vertically to ensure the curing agent is lifted off of the bottom of the container and resuspended into the liquid.

(2) Single component non-JFR cold applied sealants, such as silicone and nitrile rubber based materials can be used in both bituminous and PCC pavements not subjected to fuel spillage unless they are specifically tested for fuel resistance.

d. Preformed elastomeric (compression) seals are solid at the time of installation and therefore must be sized for a given joint. Not all preformed seals are fuel resistant; therefore, their use in areas where fuel spillage is expected must be restricted to only those fabricated from fuel resistant materials.

e. Preformed elastomeric compression seals have been made of bituminous-impregnated foam rubber, cork, or extruded polychloroprene. The polychloroprene seal is used more often than the others and is a labyrinth or webbed type seal referred to as the elastomeric compression seal. ASTM D 2628 is the specification used in selecting appropriate seals. A lubricant/adhesive is required when installing the preformed seal into the joint. The lubricant coats the seal to allow easier installation of the seal. Once the seal is in place, solvent evaporates from the lubricant and it becomes a very weak adhesive. The specification requirements for the lubricant/adhesive are given in ASTM D 2835. Since the preformed seals must remain in compression in the joint at all times to function properly, it is necessary to properly size the seal. Guidance for sizing preformed compression seals is provided in appendix C. Some preformed seals are not compression seals. Instead, they are applied in the joint with an adhesive which maintains the seal's bond with the concrete. The selected width of the noncompression seal is equal to the width of the joint. The adhesive is applied to the joint faces and to the seal. The seal is inserted into the joint and pressurized until the adhesive cures. The adhesive used for this type of seal is much stronger than the ones which conform to ASTM D 2835.

f. Some joint sealing projects may require that a sealant be compatible with liquid oxygen (LOX), for example LOX storage areas. Sealants that are not LOX compatible could possibly create an explosion when they come in contact with LOX. Some sealants are more resistant to LOX than others; therefore, the major command engineer must be consulted to determine if a sealant is acceptable before using any sealant material in a LOX area. In new construction projects, LOX areas should be designed using continually reinforced concrete.

g. Fillers. Joint and crack fillers are materials that are used to fill joints and cracks, but the material is not pliable or elastic enough to withstand pavement movement. The most common types of fillers are emulsions, cutbacks, asphalt cements, asphalt or emulsion sand mixtures, and for large cracks, asphalt cement pavement mixtures. Choosing which of these materials should be used for the crack sealing project is based upon the expected future use of the pavement and the size of the cracks. If the pavement is to be overlaid within 2 years, then emulsion or sand emulsion mixture could be used. If the pavement is not expected to be overlaid or abandoned in the near future, a high-quality sealant should be used. Some crumb rubber modified asphalt formulations have worked very well as crack sealants; however, they may not meet current federal specifications. Therefore, their use should be thoroughly investigated and approval obtained before they are installed in the pavement.

h. To perform properly, the sealant must prevent intrusion of water and incompressibles. To accomplish this, the sealant must bond to the pavement, remain resilient, and reject incompressibles. It should not harden, crack, split, or separate from the joint or crack faces. Tests used to evaluate these properties are presented in the following section. Normally fillers do not possess sealing abilities which would allow them to fulfill these requirements.

2-4. Sealant Properties.

a. The sealant must be resistant to aging or ultraviolet deterioration, which is evident by a hardening of the sealant or loss of resiliency. Additional properties such as jet ("eat") blast resistance or fuel resistance are related to specific conditions that the sealant will encounter.

b. The properties of a sealant are indicated by the tests that are required for specification compliance. Different tests are required of different sealant types to emphasize the particular properties each sealant should possess. Some sealant

manufacturers recommend a primer to be used to improve the sealant's bond to concrete. If a primer is recommended, it should be used during the acceptance testing and must be applied to the joints in the field. Full compliance with material specification test requirements does not guarantee the desired sealant performance in the field. The requirements involving joint and crack preparation and sealant installation play a significant role in sealant field performance. Poor workmanship will result in poor sealant field performance regardless of the quality of the sealant material. Laboratory tests only indicate the expected relative behavior of sealants that are properly installed.

c. The series of tests conducted on each type of sealant are provided in table 2-1. ASTM tests are included in table 2-1 for reference between federal specifications and the ASTM specifications. The important features of the more critical tests are listed below.

2-5. Backer and Separating Material.

a. Backer Material. The backer material, which is often termed "backer rod," provides support to the sealant material to prevent field-poured sealants from sagging into joint reservoirs deeper than the desired sealant depth. The backer material provides the proper shape factor for the sealant and prevents bonding between the new sealant and any old sealant remaining in the lower portion of the joint reservoir or between the sealant and the lower portion of the joint reservoir, which is known as three-sided adhesion. The backer material must be flexible, compressible, non-shrinkable, nonreactive, and nonmoisture absorptive material such as a closed-cell polychloroprene, polyurethane, polystyrene or polyethylene rod. Paper rods, ropes, or cords and some open-cell foam rods should not be used because of the amount of water they can absorb. The absorption of the backer material should be tested if there is any doubt. The backer material should have a melting temperature of at least 5 degrees Fahrenheit higher than the pouring temperature of the sealant. The uncompressed backer material should be approximately 25 percent wider in diameter than the nominal width of the joint to keep it in position during the installation of the sealant. Different types of backer rod materials are illustrated in figure 2-2.

b. Separating Material. When the joint seal reservoir is sawed or formed to the desired sealant depth, a separating material should be used beneath the sealant. The separating material prevents field-poured sealants from bonding to the bottom of the reservoir or contacting any old

Table 2-1.a. Tests Conducted on Each Field-Poured Sealant Type.

Test*	ASTM D 1190	ASTM D 3405	ASTM D 3406	ASTM D 3569	FS SS-S-1401	FS SS-S-1614	FS SS-S-200
Safe Heating Temperature	**	**	**	**	**	**	--
Penetration							
Nonimmersed	**	**	**	**	**	**	--
Fuel Immersed	--	--	--	**	--	**	--
Flow†	**	**	**	**	**	**	**
Bond to Concrete†							
Nonimmersed	**	**	**	**	**	**	**
Water Immersed	--	--	**	**	**	**	**
Fuel Immersed	--	--	--	**	--	**	**
Resilience							
Unaged Initial Indentation	--	--	--	--	**	--	**
Unaged Percent Recovery	--	**	**	**	**	--	**
Aged Initial Indentation	--	--	--	--	--	--	**
Aged Percent Recovery	--	--	**	**	--	--	**
Asphalt Compatibility	--	**	--	--	**	--	--
Artificial Weathering	--	--	**	**	--	--	**
Tensile Adhesion	--	--	**	**	--	--	--
Flexibility	--	--	**	**	--	--	--

(Continued)

* Consult the appropriate specification for the specific test procedures. Test procedures for specific tests are not identical between the various specifications.

** Indicates the test is applicable.

† Test temperature varies for the different specifications.

Test*	ASTM D 1190	ASTM D 3405	ASTM D 3406	ASTM D 3569	FS SS-S-1401	FS SS-S-1614	FS SS-S-200
Solubility							
(Change in Weight)	--	--	--	**	--	**	**
Application Leveling	--	--	--	--	--	--	**
Change in Volume	--	--	--	--	--	--	**
Swelling	--	--	--	--	--	--	--
Tack-free Time	--	--	--	--	--	--	**
Flame Resistance	--	--	--	--	--	--	**
Viscosity	--	--	--	--	--	--	**
Working Life	--	--	--	--	--	--	**
Accelerated Aging	--	--	--	--	--	--	**

* Consult the appropriate specification for the specific test procedures, test procedures for specific tests are not identical between the various specifications.

** Indicates the test is applicable.

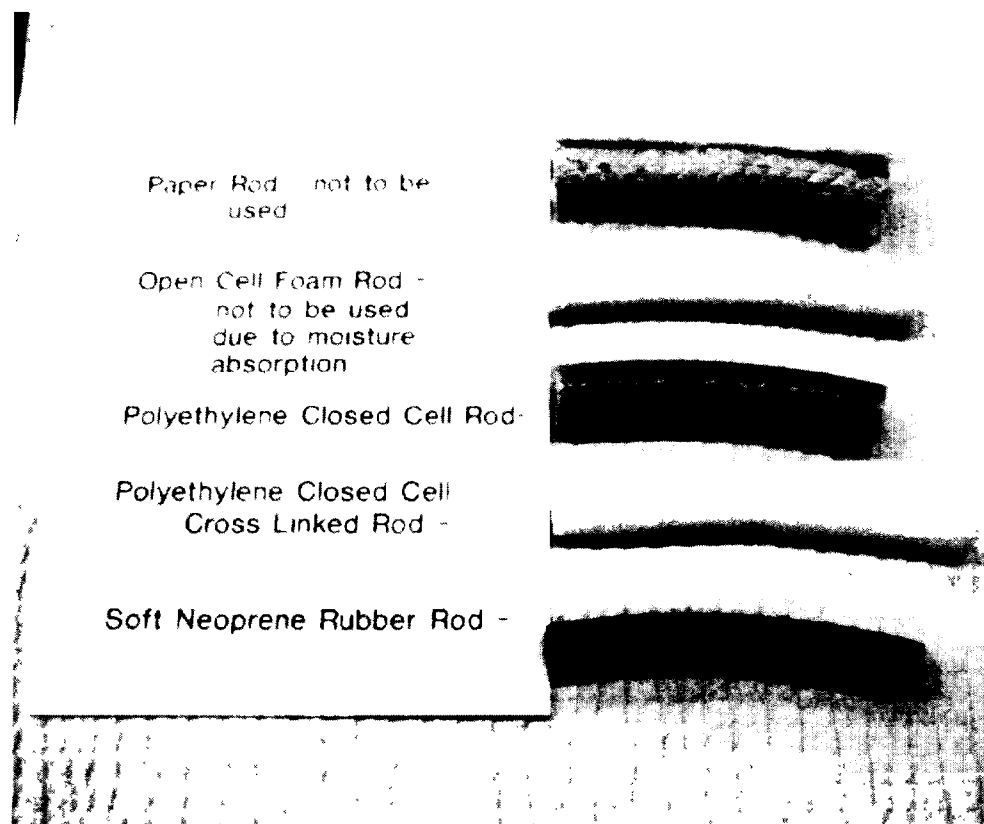


Figure 2-2. Types of Backer Rod Materials.

sealant or filler in the lower portion of the joint reservoir. Separating materials are typically adhesive backed tapes or low strength plastic strips. The material must be low strength to deform with the sealant as the pavement moves. These materials should have a melting point at least 5 degrees Fahrenheit higher than the pouring temperature of the sealant and should be approximately 1/8 inch wider than the nominal width of the joint reservoir. The additional width will help the separating material stay in position as the sealant is being installed, and will prevent the separating material from floating up into the sealant. The separating material should be flexible and non-reactive with the sealant in the same manner as the backer material. If there is any doubt about the compatibility of the separating material or the backer material and the sealant, a trial joint may be sealed during the equipment evaluation to ensure the material will perform as desired. Figure 2-3 illustrates the function of the separating and backer materials.

2-6. Shape Factor.

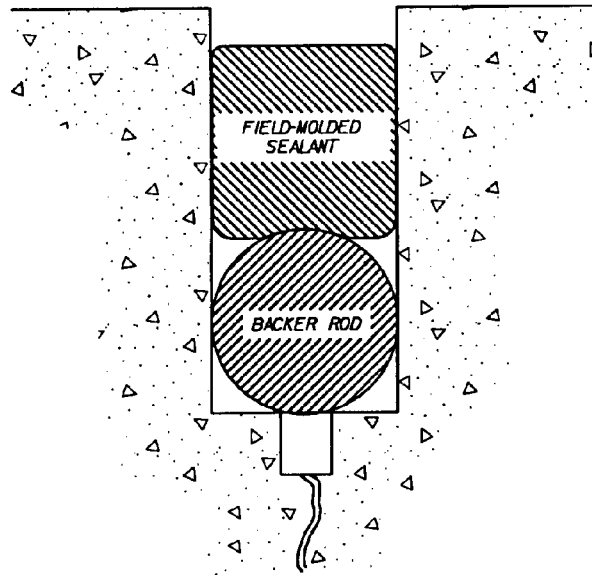
- a. The performance of field-poured sealants, hot

or cold applied, depends in part upon the joint size, shape, and cleanliness for good performance. These sealants rely on a strong bond forming between the sealant and the joint sidewalls or faces. As the joint opens or closes under the effects of daily temperature changes, the sealant is stretched or compressed. An adequate bond is necessary to prevent the sealant from pulling away from the joint face or being forced out of the joint during these movements. Figure 2-4 illustrates the stresses a field-poured sealant undergoes as the joint opens and closes. A brief description of the stresses which develop are as follows:

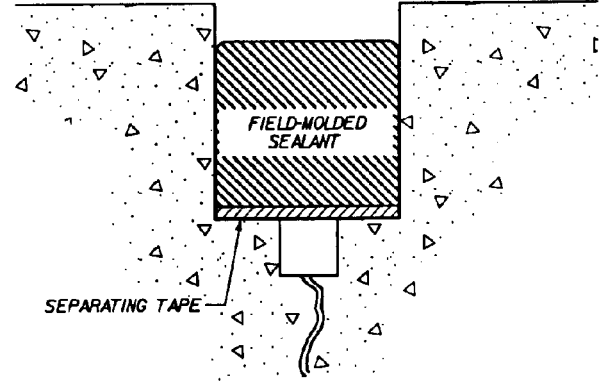
- (1) Adhesive stress is the bond stress between the sealant and joint face caused by tension as the joint expands. The sealant will separate from the joint face if the bond strength is too weak or the tensile stress created by the movement is too large.

- (2) Cohesive stress results from the tensile load within the sealant material itself. The sealant will split under this stress if the sealant is not sufficiently elastic or the interparticle bond within the sealant is too weak.

- (3) Peeling stress results from load concentration at the edge of the contact surface between the



SEALANT DOES NOT BOND TO BACKER ROD, OR DOES SO VERY WEAKLY.



SEPARATING TAPE PREVENTS SEALANT FROM BONDING WITH BOTTOM AND IS VERY FLEXIBLE, OFFERING NO RESISTANCE.

BOTH ARE FLEXIBLE AND DO NOT RESTRICT MOVEMENT OF SEALANT AS THE JOINT OPENS AND CLOSES.

Figure 2-3. Schematics of Backer Materials in the Joints.

sealant and the joint face. The sealant peels away from the joint face leading to a loss of bond. Excessive movement of the joint, horizontal or vertical, may produce this stress.

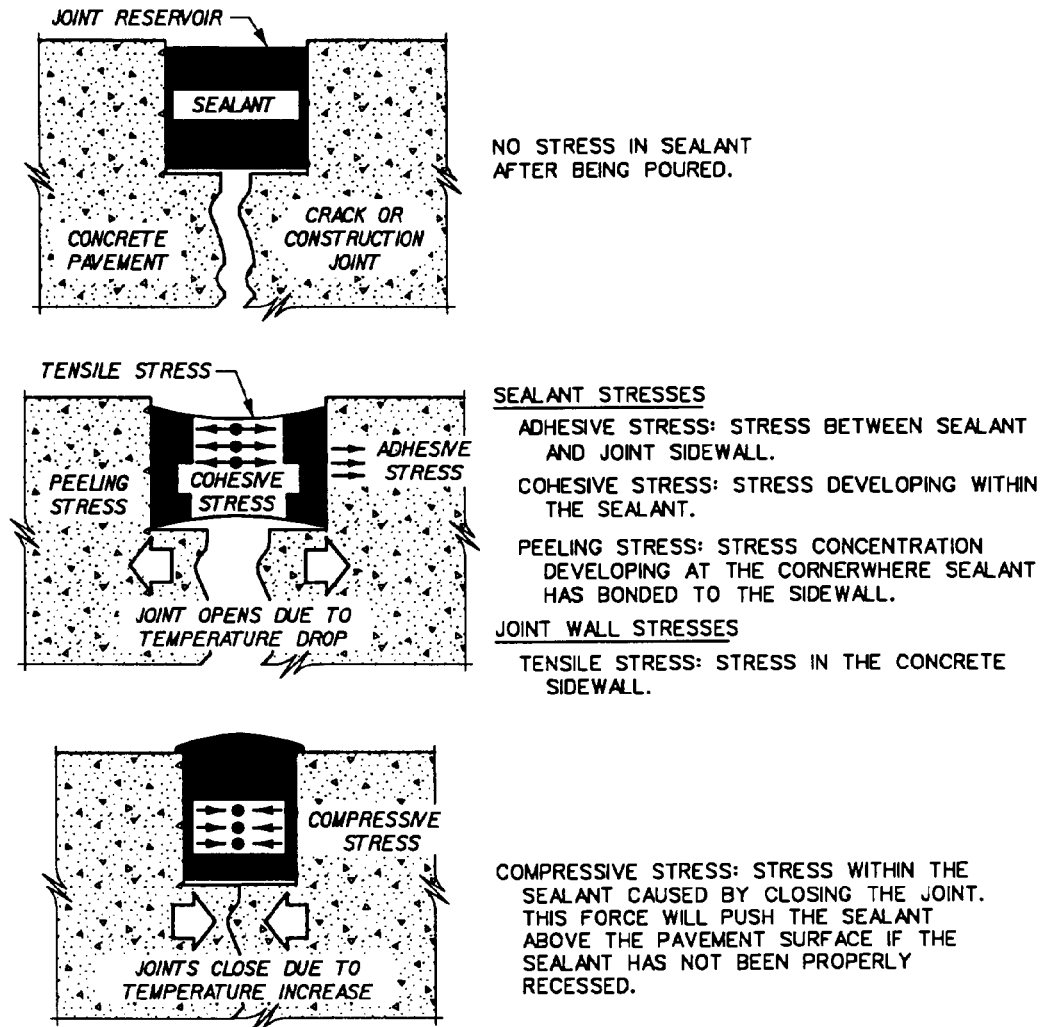
(4) Tensile stress on the joint face material is the tensile stress between the sealant and face of the joint reservoir. When the joint faces have not been properly cleaned or when the concrete is weak, deteriorated, or damaged during joint preparation, the sealant will pull the weaker material apart as the joint opens.

(5) Compressive stress is the stress occurring in the sealant when the joint closes. When under excessive stress, the sealant may be pushed above the pavement surface and tracked onto the pavement or abraded by traffic, or enough of the sealant may be pushed above the pavement surface so that the sealant is pulled completely out of the joint reservoir.

b. The preformed compression seals rely more heavily on the joint size, shape, and condition for good performance than do the field-poured sealants. Compression seals must remain in compression even when the joint is open to its maximum width. This is necessary to maintain the contact pressure required between the seal and the joint face to hold the seal in place. There is essentially no bond between the compression seal and the joint faces except as provided by the friction induced by compressive forces. Only a very weak

bond between the compression seal and the joint is provided by the use of a lubricant/adhesive during installation of the preformed seal. The lubricant/adhesive acts as a lubricant during installation of the seal and then cures to become a weak adhesive. The adhesive is easily damaged if the joint opens wider than the seal. If the joint does open wider than the seal, the compressive force will be lost, and the seal will either fall down into the joint or be pulled out by traffic. It is very critical that the correct seal size be selected and that the seal maintains its elastic properties. The procedural guide for selecting the proper seal size is given in appendix C. Figure 2-5 illustrates the stresses that develop the preformed compression seal as the joint opens and closes. A brief description of the stresses are as follows:

(1) The seal remains in compression by transmitting forces to the joint face through compression of the webs, which act similar to springs. This is known as the web stress of a seal. Compression set is when the joint becomes too narrow and the compression stress becomes too large causing the webs to lose their elasticity. As a result, the webs are no longer able to transmit the required force to the joint face as the joint opens. When compression set occurs, the seal either falls to the bottom of the joint or is pulled out when the joint reopens.



NOTE: BACKER MATERIALS IN JOINT NOT SHOWN.

Figure 2-4. Stresses in Field-Poured Sealants.

(2) Improper web design can produce a vertical component to the web stress which is known as vertical stress. If this stress is not balanced, the seal can work itself out of or deeper into the joint as the joint opens and closes.

c. As joints open and close, field-poured sealants change in shape but not in volume. Therefore, the stresses that occur are primarily a function of the shape of the sealant at the time it is poured. The shape of the field-poured sealant is expressed in terms of the depth (D) to width (W) ratio as shown in figure 2-1. The depth to width ratio (DJW) is known as the shape factor. Providing a small shape factor, small depth versus a large width for an in-place sealant generally reduces the internal strains, hence improving the elasticity of the field-poured sealant. However, a relatively large sealant depth is desirable to ensure adequate bonding of the sealant to the joint face.

To maintain adequate adhesion and to reduce the internal strains of a sealant, a shape factor between 1.0 and 1.5 is recommended ($1.0 \leq S \leq 1.5$, where $S = DJW$) for most field-poured sealants. Some single-component cold-applied sealants require a shape factor of less than 1 to perform properly; therefore, particular care in designing the joints and selecting the depth to install backer material should be taken when these materials are used. The shape factor of the preformed compression seal is determined by the manufacturer.

d. The depth of a field-poured sealant can be controlled by the use of a backer material if the joint reservoir depth is deeper than the depth required to maintain the proper shape factor. The backer material helps support the sealant during curing and prevents sagging of the sealant into the lower portion of the joint. The backer material

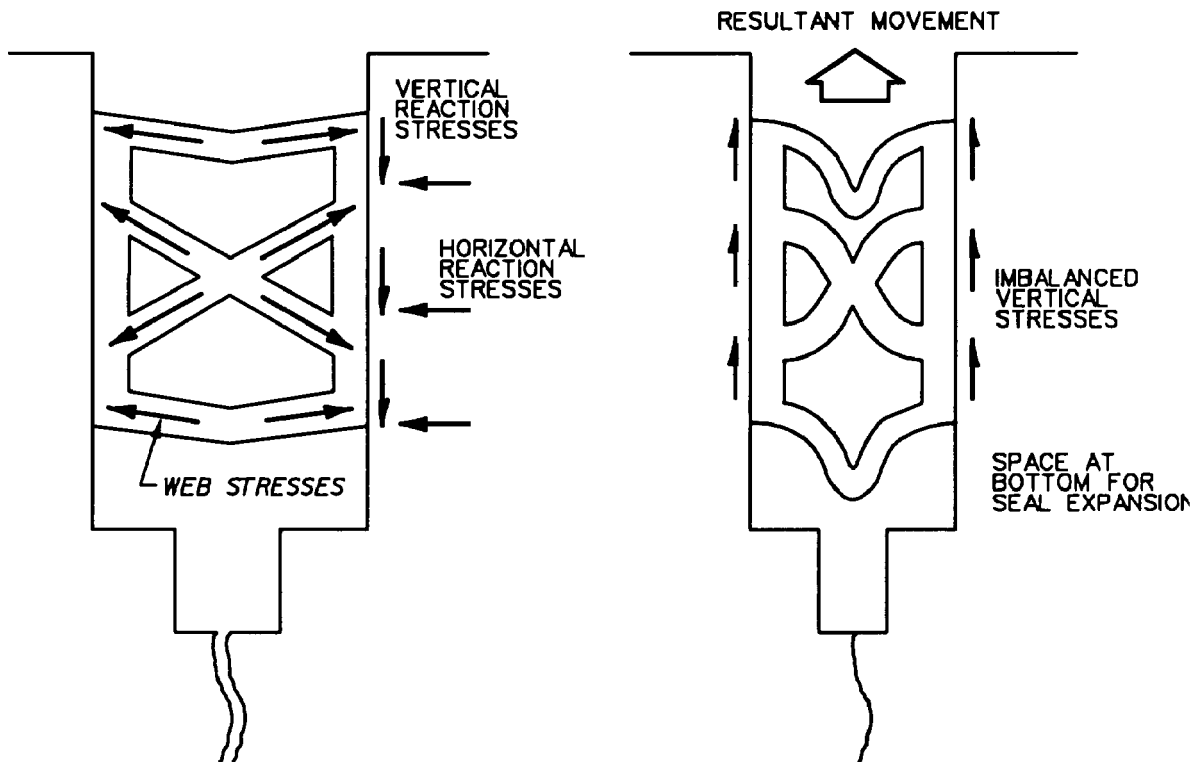


Figure 2-5. Stresses in Preformed Elastomeric Compression Seals.

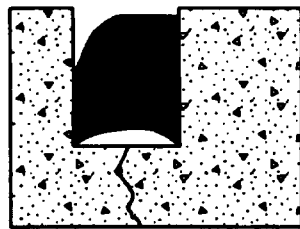
should not bond with the sealant. If the sealant adheres to a stiff backer material, the sealant will not be as free to move at the bottom as it is at the top. This causes higher stresses in the sealant and can lead to premature failure of the sealant. Therefore, the backer material should be as soft and flexible as possible, but stiff enough to stay in position in the joint to maintain the correct shape factor. Backer materials that absorb water and expand must not be used, since the moisture can damage the effectiveness of the sealant.

2-7. Common Sealant Defects.

a. *Field-Poured Sealants.* Figure 2-6 illustrates common sealant defects in field-poured sealants and lists some of their possible causes. The defects result from excessive stresses as discussed earlier

and result in loss of bond between the sealant and joint or crack face, internal rupture of the sealant, extrusion of the sealant from the joint or crack, and intrusion of debris into the sealant. Defects can be reduced or eliminated by one or more of the following:

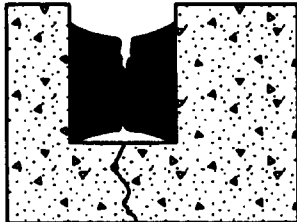
- (1) Reduce the strains in the sealant by using better shape factors either by sawing or forming the joint reservoir to the proper size and shape.
- (2) Use the proper backer materials to support the sealant and prevent sagging, provide a suitable shape factor, and provide a weak bond along the bottom of the joint to prevent three-sided adhesion.
- (3) Reduce movement at the joints by using shorter joint spacings.
- (4) Ensure joint and crack faces are properly cleaned before sealing.



FAILURE DUE TO
ADHESION (BOND)
OR PEELING
STRESSES

POSSIBLE CAUSES:

1. INSUFFICIENT DEPTH TO DEVELOP BOND STRENGTH
2. IMPROPER CLEANING OF SIDEWALL
3. HARDENED SEALANT
4. WEAK SEALANT



FAILURE DUE
TO COHESION
STRESS WITHIN
THE SEALANT

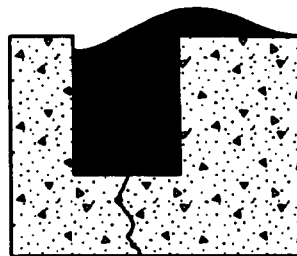
1. IMPROPER SHAPE
2. WEAK SEALANT
3. LACK OF SEPARATING OR BACKER MATERIAL
4. HARDENED SEALANT



INTRUSION OF
DEBRIS

MAY PRODUCE
SPALLING AT
THE CORNER OF
THE JOINT

1. IMPROPER FINAL CLEANUP
2. SOFT SEALANT (NON-RESILIENT)



EXTRUSION OF
SEALANT ONTO
PAVEMENT

1. IMPROPER SHAPE FACTOR
2. IMPROPER RESERVOIR SIZE FOR JOINT SPACING
3. OVERFILLED JOINT
4. CONTAMINATED SEALANT
5. NO JET BLAST RESISTANCE
6. IMPROPER SEALANT PREPARATION--NOT CURED PROPERLY
7. SEALANT USED IN IMPROPER CLIMATIC AREA

NOTE: BACKER MATERIALS NOT SHOWN IN JOINT.

Figure 2-6. Defects in Field-Poured Sealants.

(5) Select a sealant that resists intrusion of debris.

(6) Select a sealant that resists hardening or oxidizing and remains elastic.

(7) Ensure the sealant conforms to the appropriate specification by having it tested by an independent laboratory.

(8) Remove debris from the surface of the pavement as much as possible.

(9) Avoid trapping air and moisture in the sealant during installation.

(10) Recess the sealant below the pavement surface.

b. Preformed Compression Seals. Figure 2-7 illustrates common defects and lists their possible causes for preformed compression seals. The defects include slip down, twisting, extrusion, and compression set of the seal. The defects can be reduced or eliminated as follows:

(1) Size the seals properly (see app C).

(2) Use seals with characteristics that provide better low temperature recovery and resistance to permanent set at high temperatures.

(3) Use care during installation and use the manufacturer's recommended installation equipment.

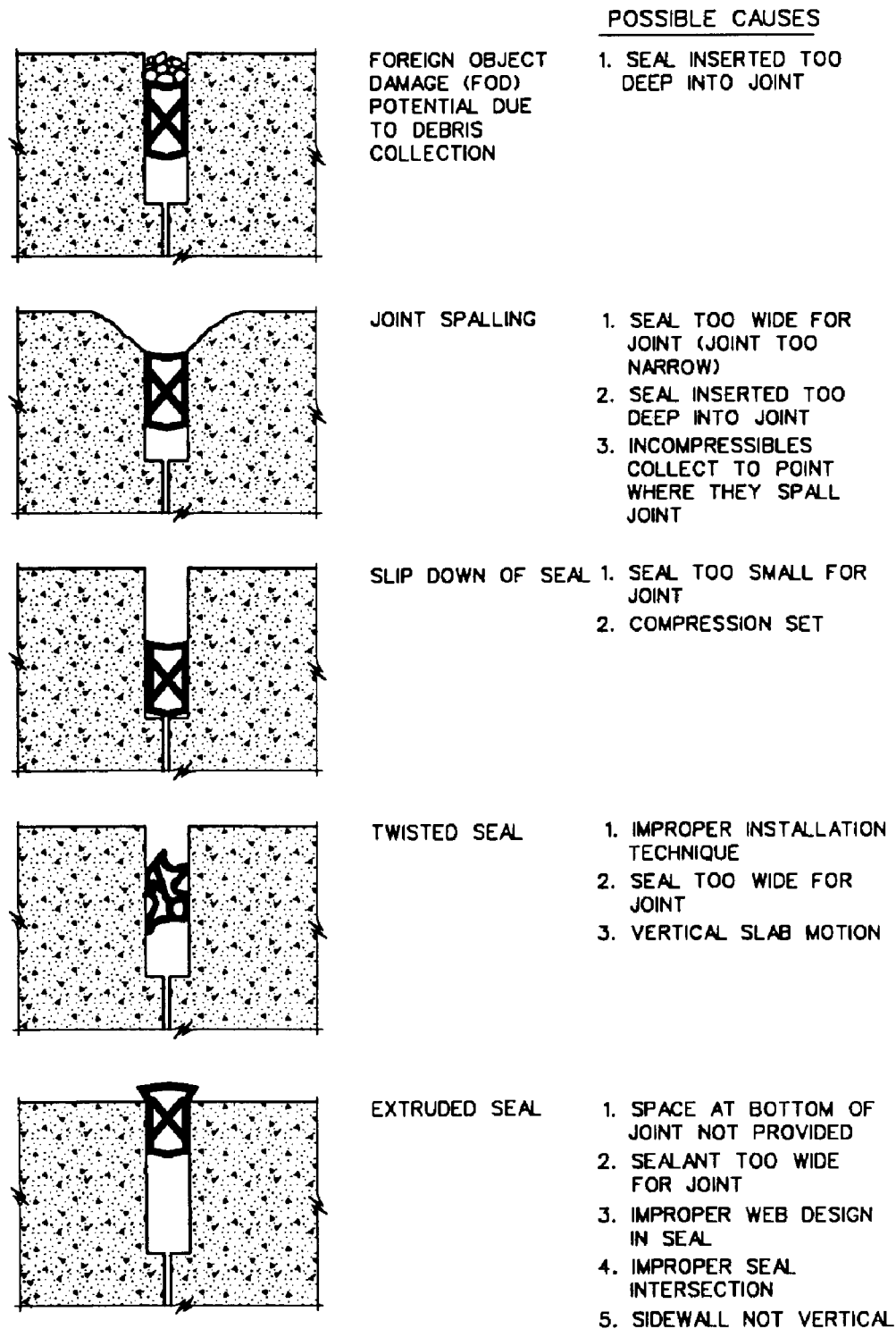


Figure 2-7. Defects in Preformed Elastomeric Compression Seals.

(4) In new construction, specify joint widths of 1/2 inch minimum and 5/8 inch maximum, setting the joint spacing accordingly. TM 5-825-3/AFP 88-6, chapter 3, gives appropriate joint spacings.

(5) In resealing operations, repair all spalls

before placing the seal. Preformed compression seals are not generally used for resealing projects because of irregularities in the shape of the joint. When using preformed compression seals, the joint faces must be vertical and uniform.

CHAPTER 3

DETERMINING SEALING NEEDS

3-1. General. The information provided in this chapter can be used to help determine the sealing requirements of an existing pavement. TM 5-826-6/AFR 93-5 provides definitions of terms used in pavement evaluation. The steps to determine if a pavement should be resealed and the sealant and procedures that are used in resealing are explained in the following paragraphs.

3-2. Factors to be Considered. There are many factors that should be considered when answering the "to seal or not to seal" question. Once this question has been answered, there are other factors that need to be considered in selecting the best sealant and the proper installation procedures for a project. A brief discussion of each factor is presented in the general order in which they should be considered. The relative importance of these factors will vary from site to site and from feature to feature.

a. Purpose of a Sealant. A sealant which must prevent both water infiltration and incompressible intrusion must be in better condition than a sealant which is only required to prevent incompressible intrusion. If the pavement is in an area with high annual rainfall or has a moisture susceptible subgrade, the sealant is needed to minimize water intrusion. If the pavement is in an area with low annual rainfall or has a fast draining subbase, the sealant may be needed more to prevent intrusion of incompressibles.

b. Sealant Condition. The most important factor in evaluating pavement sealant requirements is the existing sealant condition. TM 5-826-6/AFR 93-5 defines joint seal damage as any condition that enables soil or rocks to accumulate in the joints or allows significant infiltration of water. Accumulation of incompressible materials that prevent the slabs from expanding any may result in buckling, shattering, or spalling. A pliable joint sealant, bonded to the edges of the slabs, prevents the collection of incompressibles and the seepage of water into the joint weakening the foundation that is supporting the slab. Typical types of joint seal damage include:

- (1) Extrusion of the joint sealant.
- (2) Growth of vegetation in the joints.
- (3) Hardening or oxidation of the sealant.
- (4) Loss of bond between the sealant and pavement or adhesion failure.

(5) Splitting of the sealant material or cohesion failure.

(6) Lack or absence of sealant in the joint.

(7) Sealant placed too low in the joint.

(8) Uncured sealant.

c. Severity Levels. The description of severity levels listed below are discussed in TM 5-826-6/AFR 93-5 and are given in general terms below for each sample unit and individual joints. The types of joint seal damage were previously presented in figures 2-6 and 2-7.

(1) *Low Severity.* The joint sealant is generally in good condition throughout the section. The sealant is performing well with only a minor amount of any of the above types of damage present. For individual joints being examined, low severity is when the sealant is in-place, but has no incompressible material intrusion and little loss of bond, cracking, splitting, or slip down that would allow water infiltration. No other distresses have occurred.

(2) *Medium Severity.* The joint sealant is generally in fair condition over the entire surveyed section with one or more of the above types of damage occurring to a moderate degree. The sealant will need replacing within 2 years. For individual joints, the medium severity level has a small amount of debris retention or incompressible material intrusion, a moderate amount of extrusion, twisting, slip down, cracking, splitting, or loss of resiliency has occurred.

(3) *High Severity.* The joint sealant is generally in poor condition over the entire surveyed section with one or more of the above types of damage occurring to a severe degree. The sealant needs immediate replacement. High severity for individual joints means that some joint sealant is missing from the joint, a considerable amount of debris retention is present, and incompressible intrusion occurs which has caused spalling or allowed the free inflow of water.

(4) *Joints with no Defects.* If none of the listed damage types have occurred, the sample unit is not rated as having a severity level which means that the joint and sealant are in excellent condition.

d. Variation of Sealant Condition. The sealant condition may vary throughout the pavement feature. This will be noted by variance in the joint seal condition for the sample units in the pavement feature. This variance is important in deter-

mining whether routine sealing by in-house maintenance personnel will suffice.

e. Joint and Crack Condition. The condition of the joint or crack affects how the sealant will perform in the future and also indicates the relative need for joint repair before sealing. Several distress types such as spalling, faulting, settlement or heave, corner spalls, and keyway failure may have to be repaired before effectively resealing the joint or crack. In extreme cases, it may be necessary to completely rebuild the joint before it can be successfully sealed. For example, joints with keyway failures or spalling require the failure to be repaired before it is resealed. The repair will reduce the potential for FOD and reduce the susceptibility of debris retention in the joint. The incompressible materials and debris in a joint create nonuniform, high-compressive stresses on the joint faces as the joint tries to close. The compressive stresses can cause spalls, blowups, or slab shoving. Joints that have only minor spalling or widening due to intrusion of incompressibles require only cleaning and then resealing. The joint condition also influences the selection of the sealant to be used when resealing. A liquid (field-poured) sealant can perform satisfactorily in a joint that has small spalls or other joint shape irregularities while a preformed compression seal cannot. The difference in performance results from the method each seal uses to bond with the joint faces. The preformed compression seal must have a uniform joint shape. Otherwise, uneven pressures will be placed on the seal and force it out of the joint (see fig 2-5), and a field-poured sealant will take the shape of the existing joint.

f. Moisture Accelerated Distress Types. The infiltration of water through joints or cracks into a moisture susceptible subbase or subgrade can cause or accelerate moisture related distresses. In concrete pavement, the moisture related distresses may be indicated by pumping, corner breaks, settlement or faulting, or cracking caused by subgrade volume change. In bituminous pavement, the moisture related distresses include medium- to high-severity alligator cracking, depressions and swells, and medium- to high-severity transverse and longitudinal cracking. If a significant amount of these distress types occur, resealing should be done immediately before the distress develops in other areas of the pavement. The damaged pavement area should be removed and replaced to maintain the load-carrying capability of the pavement.

g. Overall Pavement Condition. The pavement surface condition is measured using the pavement condition index (PCI). It is directly related to the

maintenance and repair needs of a pavement. If the PCI is 40 to 60 or lower, the pavement has deteriorated to the point where it may need major repair in the near future. Resealing should always be included as part of any major repair work. PCI prediction programs available in PAVER and Micro-PAVER should be used to determine if resealing the joints will raise the PCI of the pavement feature enough to justify the cost determined from a life-cycle cost analysis (see app D).

h. Joint and Slab Design. The joint sealant reservoir and the pavement slab size must be considered when resealing, especially in selecting the type of sealant and determining the amount of preparation required before resealing. The amount of horizontal movement at a joint (the working range of the joint) depends upon several factors such as the size of the slab, the seasonal temperature changes, friction between the slab and underlying material, and the type of joint (transverse or longitudinal). Therefore, longer slabs and greater seasonal temperature changes cause more horizontal joint movement. The working range of the sealant, which is controlled by the sealant properties and the width of the joint reservoir, must be larger than the working range of the joint. A sealant is more likely to fail in a narrow joint sealant reservoir than a wider one as described in chapter 2. It may be necessary to widen a joint sealant reservoir before resealing to obtain adequate width and depth for satisfactory sealant performance. Appendix C provides the working range calculations for joints and sealants.

i. Current and Future Mission of the Pavement Feature. The type of traffic and pavement use must be considered when determining the need to reseal and the type of sealant to use. The amount of allowable FOD depends upon the type of aircraft or other traffic using the pavement. The pavement use will determine the expected amount of fuel, hydraulic, and other fluid spillages which the sealant must withstand. Any expected changes in either type of traffic or pavement use may require a different type of sealant to be used instead of the type indicated by present conditions.

j. Performance of Previous Sealant. Hot- and cold-applied sealants meeting current specifications should last 4 to 6 years, and preformed elastomeric compression seals should last 10 to 15 years. Some improved liquid sealants have lasted much longer than the 4- to 6-year time frame and some have failed in less than 1 year. The age of the existing sealant should be determined, and if it failed rapidly, the cause of deterioration should be determined. If possible, the cause of deterioration should be eliminated before resealing. Failure to remedy the problem will probably cause the new

sealant to fail prematurely in the same manner as the previous sealant. Examples of possible causes of premature sealant failure may include but are not limited to incorrect sealant reservoir shape factors, excessive vertical movement or too large of a working range at the joint, and improper sealing techniques used during sealant installation.

3-3. Condition Survey.

a. The pavement must be surveyed according to the procedures in TM 5-826-6/AFP 93-5 to determine the current condition of the sealant, the joint and crack condition, moisture related distress types, and the overall pavement condition. Field measurements may be required to determine the existing joint shape factor. The measurements should be made during the condition survey by physically removing some of the old sealant and recording its shape and hardness. Tables 3-1 and 3-2 contain the items that should be collected to allow evaluation of the sealant and pavement.

Table 3-1. Sealant Condition Rating.

	0	1	2	Very Poor 3
Overall Rating (circle one):				
Variation (% of joints in each category):				
% Low Severity:				
% Medium Severity:				
% High Severity:				
% Excellent:				
Total = 100%				

b. *Determining Sealant Condition.* The procedures in TM 5-826-6/AFP 93-5 rate the average joint condition within each sample unit at a low-, medium-, or high-severity level. A more accurate but more time-consuming method would be to rate the sealant condition in each joint as the survey is conducted. In either case, the overall joint sealant condition rating may be calculated using the following equation:

$$\text{Rating} = [(\%L)(1.0) + (\%M)(2.0) + (\%H)(3.0)]/100.0$$

where

- %L = percent of sample units having low severity joint seal damage or percent of total length having low severity joint seal damage.
- %M = percent of sample units having medium severity joint seal damage or percent of total joint length having medium severity joint seal damage.
- %H = percent of sample units having high severity joint seal damage or percent of total joint length having high severity joint seal damage.

The equation produces a rating from 0 to 3 that indicates the general condition and can be presented on a condition rating scale, as shown in

table 3-1, to show the overall condition of the joint sealant. The relative amounts of each level of severity present can be recorded to show the variability of the joint seal damage.

c. *Determine Joint or Crack Condition.* The condition of the joints or cracks is recorded as the percentage of slabs with the specified severity of spalling. The data for severity of spalling are used to determine the existing pavement condition. The general condition of the pavement feature being evaluated and the secondary factors of environment and soil type which influence joint sealant performance must be recorded. The data provide the information needed to evaluate sealant needs and function. Historical data and future use are recorded to provide an indication of past performance and future requirements of the sealant and feature. The data collected can be presented on the pavement evaluation checklist shown in table 3-2.

3-4. Evaluation to Justify Sealing Work.

After the survey data and other factors affecting sealant performance have been collected, it must be evaluated. The results from the analysis will determine if resealing is justified. The checklists shown in tables 3-1 and 3-2 provide the step-by-step approach to the evaluation. The following guidelines indicate the relative need to seal a given pavement based upon the ratings obtained from the checklists. The overall sealant ratings are given in the following paragraphs.

a. *Excellent to Very Good (0 to 1).* Resealing is not required. Some routine sealing may be needed in localized areas of high-severity damage.

b. *Good to Fair (1 to 2).* Resealing can be considered. Any of the following items would indicate that remedial action should be considered to prevent the distress from progressing.

(1) A moisture susceptible subgrade and annual rainfall of more than 15 inches or a monthly rainfall of more than 3 inches.

(2) More than 10 percent of the slabs with medium or high-severity joint and corner spalls.

(3) Evidence of incompressibles in the joints.

(4) More than 10 percent of the slabs with medium or high-severity faulting.

(5) More than 30 percent of the deduct values caused by moisture accelerated distress types.

(6) Significant or potential FOD problems due to spalling joints or cracks have developed.

(7) More than 30 percent of the joint sealant damage is at a high-severity level.

(8) The change in the PCI when calculated assuming no joint seal damage present is significant.

Table 3-2. Pavement Evaluation Checklist.

1. Joint Condition.			
% Slabs Low Joint Spall	_____		
Medium Joint Spall	_____		
High Joint Spall	_____		
2. Joint Design - Existing (average of joints)			
Shape Factor	_____		
Joint Width, inches	_____		
Slab Size, feet	_____		
3. Incompressible Infiltration	L	M	H
4. Water Infiltration	L	M	H
Subgrade Susceptibility to Moisture	L	M	H
5. Type of Distress and PCI			
Moisture Accelerated Distress	Deduct Values		Type
	_____		_____
	_____		_____
	_____		_____
% Deduct Values of Total PCI of Feature	_____		_____
	_____		_____
6. Local Environment			
Climatic Zone	_____		
Annual Precipitation	_____		
Annual Temp. Range	_____		
Freezing Index	_____		
7. Current and Future Use of Feature			
Current	Primary	Secondary	
Future	Primary	Secondary	Abandon
(5 - 10 Years)			
8. Type of Existing Sealant _____			
(for example; 1401, 1614, 200, other)			
9. Date of Last Major Sealant Project _____			

(9) The feature was not previously subjected to fuel spillage or jet blast but will be in the future.

c. *Poor to Very Poor (2 to 3)*. Resealing should be programmed immediately unless the pavement feature is scheduled for major repair or abandonment in the near future.

3-5. Selecting Appropriate Sealant.

a. The sealant must have properties that will withstand the horizontal movement required as

well as jet blast, jet fuel, hydraulic fluid, and other fluids as required. The annual horizontal movement of the joint should be less than the working range of the joint sealant. For example, if the joint is expected to have a minimum width of 0.40 inches and a maximum width of 0.60 inches, the working range of the joint sealant should allow it to be compressed less than 0.40 inches and extended greater than 0.60 inches without damaging the sealant (see app C).

b. If the sealant is to be placed in a pavement feature which will be subjected to jet fuel or hydraulic fluid spillage, the sealant should be a JFR type. Pavement features that will be subjected to fluid spillage include aprons, hardstands, and washracks. Likewise, if the sealant is to be placed in a pavement feature that will be subjected to jet blast, the sealant should be resistant to jet blast. Features that are subjected to jet blast include runway ends and warmup or holding pads.

c. The condition of the joints must be considered when selecting a sealant. Joints with spalling require more extensive repair before resealing with a preformed elastomeric compression seal than they would when resealing with a field-poured sealant.

d. The performance history of different sealants at the installation should be examined and if enough information is available, the past performance can be used to prepare an actual life-cycle cost of the sealants. A life-cycle cost should also be performed to determine which procedures and sealants are best suited for providing the most cost-effective solution over the life of the feature being sealed. Appendix D contains a procedure for performing these analyses. One of the major drawbacks of life-cycle cost analysis at the present time is the lack of information on the field performance of sealants.

3-6. Selecting Sealing Procedures.

a. The present condition of the joint sealant reservoir and the type of sealant selected will determine the sealing procedures. The joint shape factor must provide enough width to allow the working range of the sealant to exceed the horizontal movement of the joint. If the joint is not wide or deep enough to meet the shape factor requirements, the joint sealant reservoir must be enlarged by saw cutting. If the existing shape factor is adequate, only cleaning is required. Sand-blasting, high pressure water stream (water-blasting), or other approved procedures must be

used to remove all of the sealant residue from the sides of the sealant reservoir after the old joint sealant has been removed. The removal of the sealant residue will provide a clean surface to allow the new sealant to bond to the concrete joint faces. The existing sealant must be removed completely from the joint sidewalls, but it only has to be removed to a depth that will allow the new sealant to be installed with the correct shape factor. Special care must be taken to ensure that the existing sealant is completely separated from the new sealant. This is accomplished by using a separating tape or a backer material.

b. Only medium- or high-severity cracks in concrete pavement should be sealed. It is difficult to properly seal low-severity cracks in concrete pavement due to the width of the crack; therefore, they should not be sealed. Most high-severity cracks will require some type of repair before sealing. All severity levels of cracks should be sealed in bituminous pavement.

c. Both in-house crews and contractors can perform sealing projects. Sealing by in-house crews is limited by availability of equipment, man-hours available, and trained personnel. Therefore, in-house crews normally handle routine spot sealing, and larger projects are contracted out.

d. When in-house crews perform routine spot sealing, the new sealant must be compatible with the existing sealant. For example, asphalt based sealants should be used when the existing sealant contains asphalt. Tar based sealants should be used when the existing sealant contains tar. Sealants that contain coal tar should not be used in asphalt pavement, and sealants that contain asphalt should not be used in tar pavement. The existing type of sealant can usually be found in construction records. If there is any question about the type of in-place sealant, sealants made with coal tar can usually be identified in the field by their distinctive coal tar (creosote) odor. Table 3-3 provides guidance on the compatibility of various sealants.

Table 3-3. Guidance on the Compatibility of Various Sealants.

Existing Sealant	Compatible New Sealant
Hot Applied	
SS-S-1401	Asphalt Based Sealant
SS-S-1614	Tar Based Sealant
Cold Applied	
SS-S-200	Check Manufacturer's Literature*
CRD-C 527	Check Manufacturer's Literature*
Preformed Elastomeric	Any Sealant
Compression Seal**	

Note: Tar based sealants must not be used on asphalt pavement and asphalt based sealants must not be used on tar pavement.

* Sealants in these categories may have different chemicals as their base constituent; therefore, all of the sealants in the categories may or may not be compatible with another sealant.

** Sometimes this seal is placed too low in the joint and thus creates a FOD problem with materials collecting in the reservoir. The seal can then be topped with a hot-applied or cold-applied sealant. However, the "top" sealant must have enough room to properly bond to the joint faces.

CHAPTER 4

JOINT AND CRACK PREPARATION

4-1. Equipment Used. All machines, tools, and equipment used to complete a joint or crack sealing or resealing project must be inspected before work is started. The inspector must make these checks before the start of the project and continue the inspections as work progresses to ensure that the equipment is being maintained in satisfactory condition at all times. Test sections should be required to demonstrate the equipment's capability of performing the designated work without damaging the pavement.

a. *Concrete Saw.* The concrete saw is usually a self-propelled, water-cooled power saw that uses diamond or abrasive saw blades to cut the pavement without damaging it. A typical saw is shown in figure 4-1. The blades must have rigid spacers or "dummy" blades to separate the two cutting blades or must have a solid blade of the specified

width of the joint to ensure a uniform joint reservoir. The saw is used primarily for forming new joints and refacing existing joints. Using the saw to reface existing joints helps to provide a clean surface. When the saw is being used to prepare cracks, a small diameter diamond blade (6 inch or less) as shown in figure 4-2 should be used to follow closely the crack. This produces a sealant reservoir similar to those of a prepared joint.

b. *Joint Plow.* The joint plow is a tractor mounted cutting tool, such as the one shown in figure 4-3, used to remove old joint sealant from joints in PCC. The cutting tool is pulled through the joint, removing the sealant from the joint walls. The shape of the cutting tool is very important. The tool face must be rectangular and the tool's width should be close to but narrower



Figure 4-1. Concrete Saw Refacing Joint.

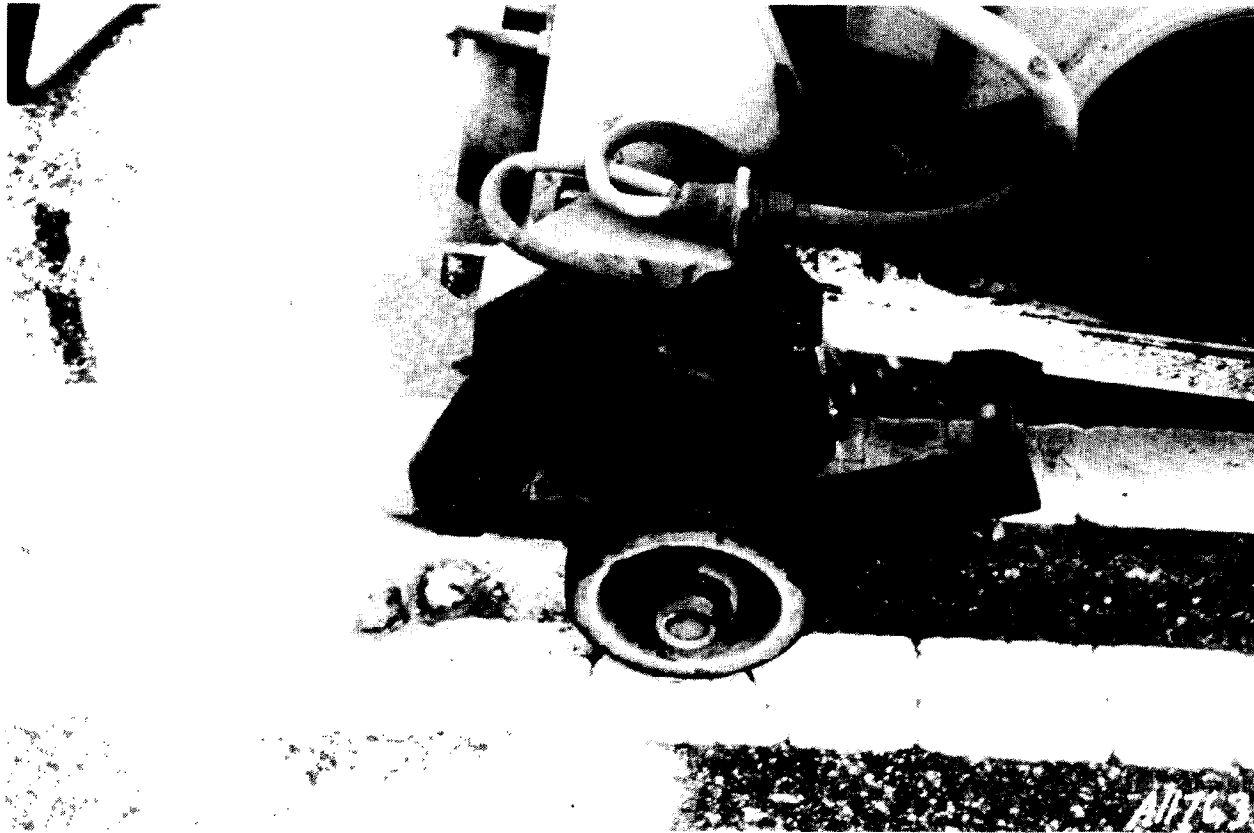


Figure 4-2. Concrete Saw with a 6-Inch Diameter Blade.

than the width of the joint being cleaned. The use of V-shaped plows should never be allowed. The V-shaped plow can chip the pavement damaging the joint face. Several sizes of tools should be on the jobsite to match changes in joint sizes. Thin cutting tools may be used if a multiple pass technique is used and extreme care is taken by the operator to prevent damage to the concrete pavement. The tool should be mounted to allow for setting the proper depth control and provide both lateral and vertical movement of the tool. The allowable movement will help avoid spalling of the concrete around the joint. The joint plow is usually outfitted with a spring or hydraulic mechanism that releases pressure on the tool before spalling of the concrete occurs.

c. *Sandblasting Equipment.* The sandblasting equipment must include an air compressor, hose, and long wearing 0.25-inch verturi type nozzle of the proper shape and size for the joints and/or cracks in the pavement. The use of sandblasting equipment must comply with occupational and health standards, and protective clothing must be worn by the operator at all times. The standards must be thoroughly discussed and reviewed before

the sealing project begins. Sandblasting equipment is shown in figure 4-4. The nozzle should have an adjustable guide that holds the nozzle approximately 1 inch above the pavement aligned directly at one of the joint or crack faces. The height, angle of inclination, and size of the nozzle must be adjusted as necessary to obtain satisfactory results. A small section of angle iron may be attached to the nozzle to aid in directing the blast at the joint or crack faces. Great care must be exercised if the sandblast equipment is used for cracks in bituminous pavements because overblasting can easily occur. Overblasting can damage bituminous pavement causing raveling and premature bond failure of the sealant.

d. *Air Compressor.* The air compressor is used with the sandblasting equipment, and it airblows loose debris from the joints or cracks. For sandblasting, the compressor should furnish approximately 150 cubic feet per minute while maintaining a line pressure of approximately 90 psi at the nozzle during actual use. The compressor must have in-line traps that will maintain the air free of water and oil. Both moisture and oil interfere with the sealant bonding to the joint or crack face.



Figure 4-3. Joint Plow Removing Old Sealant.

e. *Waterblasting.* Waterblasting has been used successfully in areas where sandblasting was not permitted due to local atmospheric pollution statutes or when the sand could drift into areas where it would be objectionable. The waterblasting equipment must include a trailer-mounted water tank, pumps, high-pressure hoses, auxiliary water resupply equipment, a wand with a safety release cutoff control, and nozzle of the proper size for the joints in the pavement. The use of waterblasting equipment must comply with occupational and health standards at all times. Protective clothing must be worn by the operator at all times. The nozzle should be adjustable to obtain satisfactory results. Waterblasting equipment is shown in figure 4-5.

f. *Routing Equipment.* There are two types of routing equipment that may be used on sealing projects; the vertical spindle router (fig 4-6) and the rotary impact router (fig 4-7).

(1) The vertical spindle router is equipped with a bit that rotates around its vertical axis similar to a drill. The spindle is mounted on the chassis in such a manner that it can maneuver along the irregular dimensions of the crack to

clean the crack and to form a sealant reservoir with a minimum amount of spalling. Vertical spindle routers may be used in asphalt and, to a limited extent, in PCC the vertical spindle router can become jammed in the pavement if the operator tries to force the router along the crack. This is especially true when the router is used in PCC pavements. It is therefore important that the bit be belt driven to prevent injury to the operator if the bit becomes jammed.

(2) Rotary impact routers are equipped with bits that are mounted to a vertical wheel that rotates forcing the bits to impact the pavement. Rotary impact routers should not be used on PCC pavement. Rotary impact routers spall the PCC adjacent to the crack, damaging the pavement and producing an inadequate sealant reservoir. However, rotary impact routers equipped with carbide tipped bits (fig 4-8) may be used to rout cracks in bituminous pavement. The rotary impact routers equipped with carbide tipped bits provide a relatively quick method to form an adequate sealant reservoir. If carbide tipped bits are not used, the router can damage pavement surfaces adjacent to the crack. Rotary impact routers, even equipped



Figure 4-4. Sandblasting Equipment Cleaning Joints.

with carbide tipped bits, chip and damage PCC pavements.

g. Handtools. Enough handtools should be on hand to allow for work to continue in areas where mechanized equipment cannot be used during the preparation of the joint or crack. This equipment can be straight or hooked bars with chisel shaped ends. Extra care must be used to ensure the concrete is not damaged.

h. Power Brooms. A vacuum type power broom should be present to keep the pavement surface free from all debris. A typical unit is shown in figure 4-9.

4-2. Preparing New Joints in PCC.

a. Initial Sawing. New PCC slabs will have joints sawed or formed while the concrete is green (after it has taken initial set) to control cracking. Concrete that cracks before the initial sawing must not be sawed. Instead, the resulting crack must be prepared and sealed. The initial cuts or dummy joints must be prepared to function as a joint. This preparation begins after the curing period of the concrete has ended. Figure 4-10 provides the sawing sequence in new concrete.

b. Initial inspection. After the initial sawing to control cracking of the concrete, the saw cuts should be inspected for spalling. Excessive spalling of new concrete should not be found in normal construction. Spalls that extend more than 1/4 inch horizontally from the sidewall of the initial cut should be repaired, since normally they would not be removed during the widening operation. Void areas caused by honeycombing of the concrete must also be patched to provide a solid joint sidewall for the sealant to bond.

c. Sawing Reservoir. After the required curing period, the initial saw cut for crack control must be widened to the size joint specified in the project specifications using a self-propelled concrete saw. The depth of the cut should be uniform, and the width should not vary along the length of the joint. A freshly sawn joint is shown in figure 4-11.

d. Cleaning. Following the sawing operation, the joint should be sandblasted to remove laitance, curing compound, sawing dust, and other foreign debris from the joint sidewalls and from the pavement surface adjacent to the joint to a width of approximately 1 to 2 inches. A multiple pass

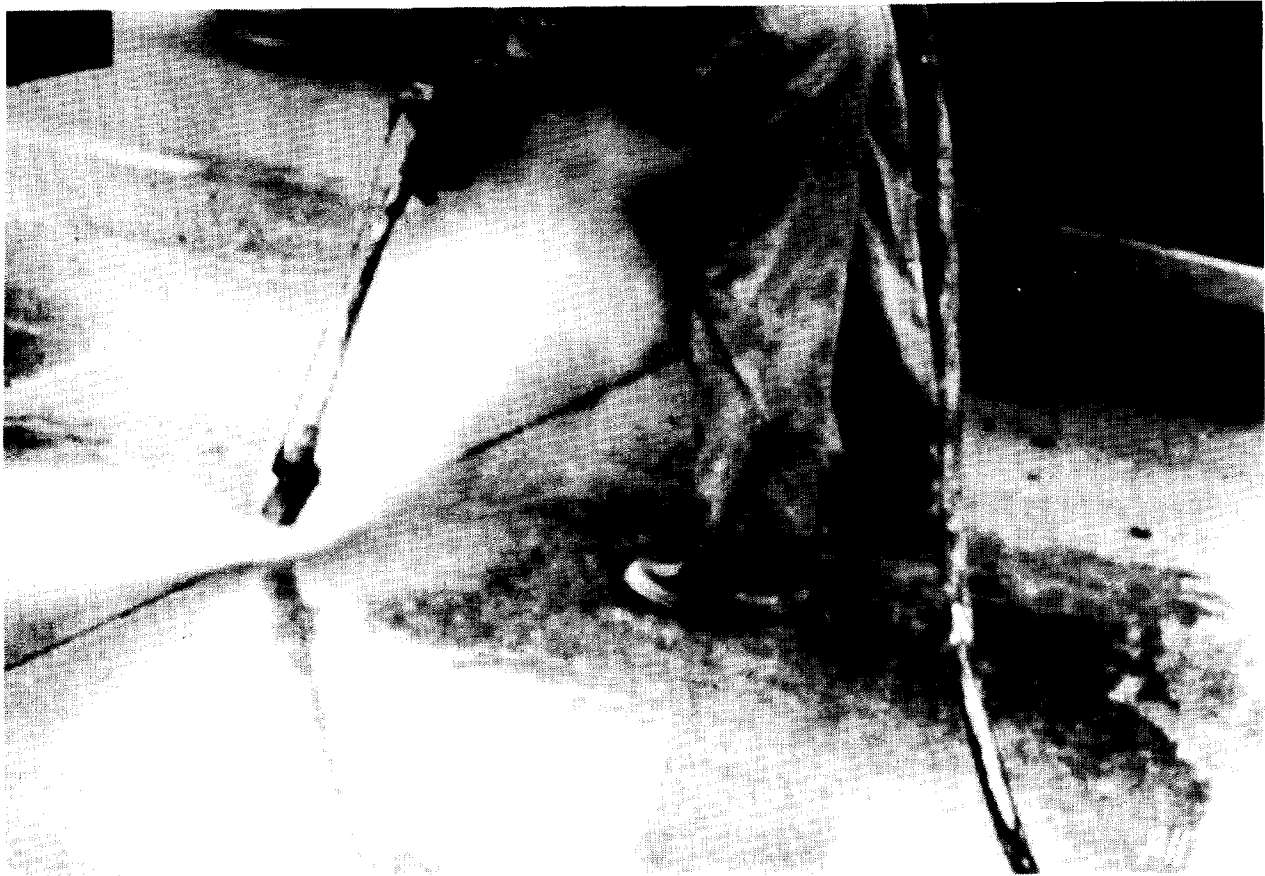


Figure 4-5. Waterblasting Equipment Cleaning Joints.

technique has proven very successful in removing foreign debris. When using the multiple pass technique, the nozzle is directed at one of the joint faces, and that face is sandblasted the entire length of the slab. After one face has been completed, the nozzle is directed at the other joint face, and it is sandblasted for the entire length of the slab. The pavement surface adjacent to the joint is then sandblasted to remove all surface debris. If waterblasting is used instead of sand-blasting, a multiple pass technique should still be employed and the joints will have to dry before the sealing operation continues. Cleaning the joint is one of the most important steps in obtaining a high-quality sealing project. If the joints are not clean and dry before the sealant is installed, the sealant will usually fail prematurely. An example of a sandblasted joint is shown in figure 4-12. After the joint has been sandblasted, it must be airblown to remove any remaining sand or dust. However, the final air blowing of the joint should be completed immediately before sealing to prevent more sand and dust from blowing back into the joint. A vacuum sweeper can be used to clean around the joints, which will help reduce the

amount of debris that blows back into the joints.

e. Backer or Separating Material. The backer rod or separating material is installed after the joint is air blown. The backer materials should not be left in the joint for an extended period of time before sealing. The materials may work loose and move up or down in the joint or may even come completely out yielding results similar to that shown in figure 4-13. These materials must not be twisted, stretched, or otherwise damaged when they are installed in the joint. Damaging the backer material can cause sealant failure or a poor sealing job. The backer or separating material should be inspected after installation to ensure that it has been placed at the proper depth and that it has not been damaged. After installation of the backer or separating material, the joint is ready for the sealant material. However, the joint should be sealed only if all steps have been performed properly. Detailed inspection guidelines are presented later in this manual.

4-3. Preparing Old Joints in PCC.

a. General. Joints that have been previously sealed require additional work to remove the old



Figure 4-6. Vertical Spindle Router.

sealant. Because of the pavement age, the likelihood of spalling being present is much greater than for new joints. The procedures necessary for sealing old joints are as follows:

- (1) Remove the old sealant.
- (2) Reface the joints (as required).
- (3) Rebuild any defective joints.
- (4) Clean the joints.
- (5) Apply appropriate backer material.

b. Sealant Removal

(1) Field-poured sealant removal is usually accomplished using a joint plow attachment. An alternative method of removal is to use the water-blasting equipment as shown in figure 4-5. The depth of the sealant to be removed is usually indicated on the plans with typical removal being twice the final width of the joint or approximately 1-1/2 inches deep. The actual depth of sealant that must be removed from the joint depends upon space required to install the backer material, the sealant, and the required recess of the sealant. Care must be taken to prevent damage to the concrete when the joint plow is used. If the plow tools are sized properly, it will not be necessary to exert excess force to remove the old sealant. If excess force is being used, a smaller size tool

should be used. V-shaped plow tools, as shown in figure 4-14, must not be used because chipping and spalling of the concrete will occur without completely removing the sealant from the joint. Figure 4-15 shows a joint that was spalled using a V-shaped plow. Handtools are required to remove the existing sealant in areas where mechanized removal equipment cannot operate. Compressed air is used to remove the loose debris from the joint, and a power broom is used to remove the debris from the pavement surface.

(2) Preformed elastomeric compression seals can be removed by hand when the lengths are short. Longer lengths can be started by hand and then use a tractor to pull the seal out of the joint.

c. Sawing or Refacing. Some joints will require sawing to clean the joint faces and/or to produce the depth and width specified in the plans. The sawing will allow the proper shape factor to be obtained and will provide clean joint faces to which the field-poured sealant can bond. Refacing the joint will also provide a vertical sidewall which will help prevent the new sealant from being pushed out of the joint. Joints that are greater than 1 inch wide should not be widened unless they are expansion joints. When preformed

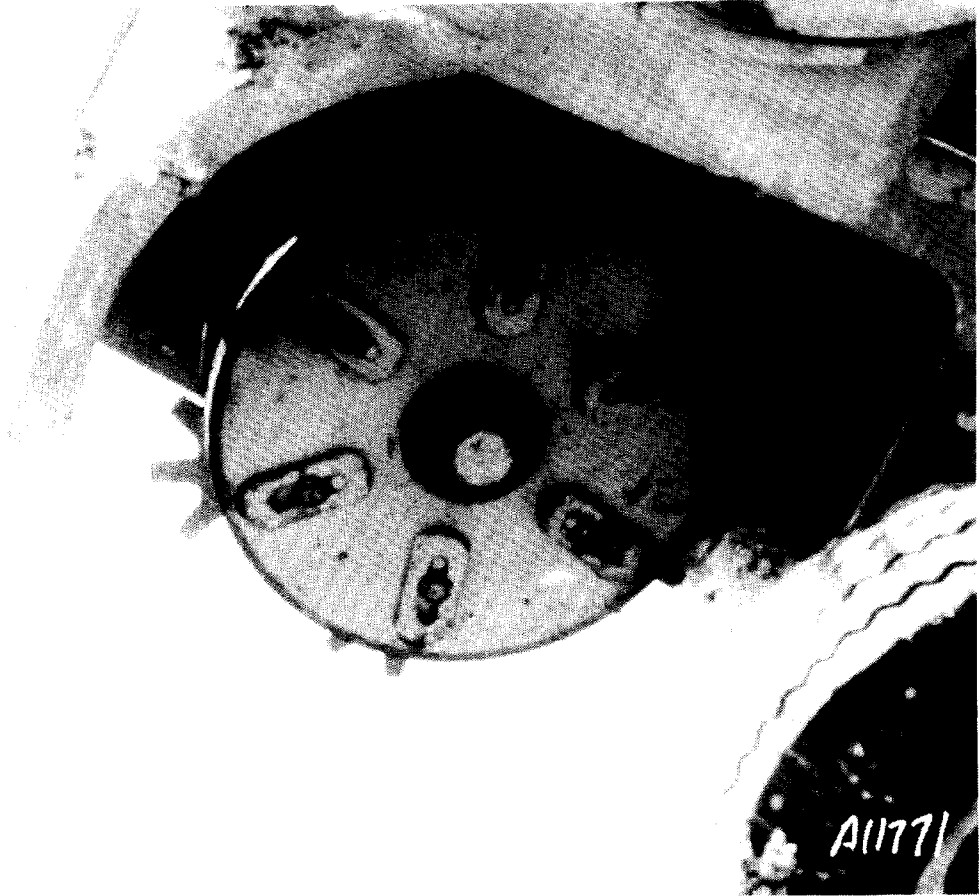


Figure 4-7. Rotary Impact Router.

compression seals are removed, refacing is generally not required unless the joint width is smaller than specified in the plans.

d. *Rebuilding Defective Joints.* Joints that are wider than 1 inch or that are severely spalled should be examined to determine if rebuilding is required. If preformed elastomeric compression seals are being considered, the joint sidewalls must be vertical and parallel. In contrast, field-poured sealants may perform adequately with some minor spalling present. Joints should be rebuilt in accordance with TM 5-624/AFR 85-8 using appropriate materials. A rebuilt joint is shown in figure 4-16.

e. *Cleaning Joints.* Once the old sealant has been removed and any required refacing or rebuilding of the joints has been accomplished, the joints are ready for cleaning. The joints can be cleaned using the multiple pass sandblasting or waterblasting technique previously described. If waterblasting is used, the joint must be thoroughly dried to remove all moisture before inserting the backer material and sealant. Another technique

that has been used successfully to remove residual sealant and debris is "dry" sawing. Dry sawing is accomplished by using a diamond blade concrete saw without water. The blade of the concrete saw is placed against one of the joint faces to allow the removal of a minimal amount of concrete. After one joint face is completed, the opposite joint face is dry sawed. The blades should be inspected often to ensure they have not become damaged. Cleaned joints should appear as shown in figure 4-12. A rotary wire brush should not be used to clean joints especially when the joint contains residual joint sealant. The wire brush scrapes the joint faces producing cement dust. The brush may also become coated with old joint sealant which will be smeared over the joint faces covering the cement dust. The smeared joint sealant and dust produces a layer that prevents the new sealant from contacting the joint faces and developing a bond to the concrete. The final step of cleaning the joint is airblowing to remove remaining dust and debris. Airblowing should be accomplished immediately prior to installing the backer or separating

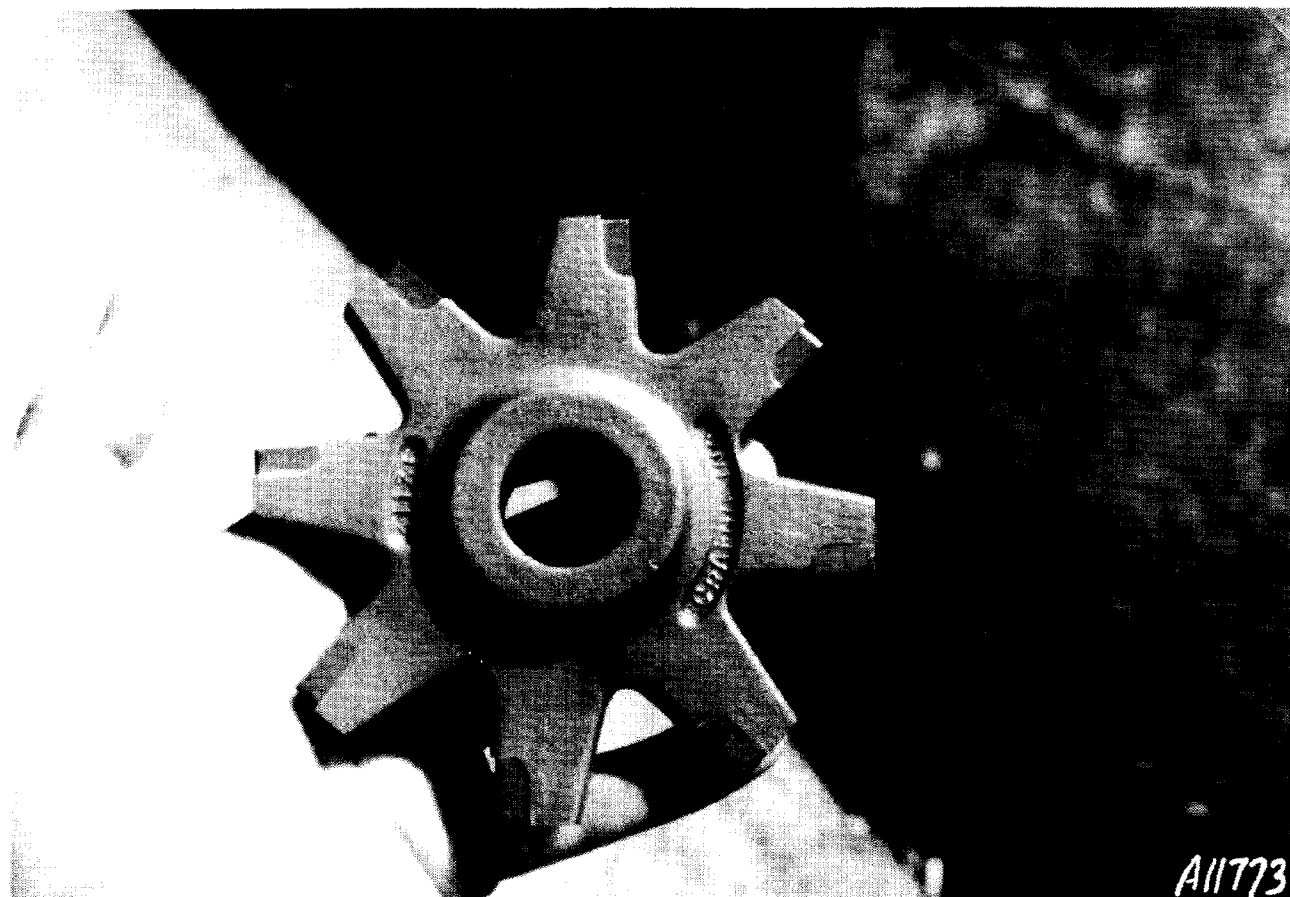


Figure 4-8. Carbide Tipped Bit for Rotary Impact Router.

material and sealing the joint. All debris on the pavement surface should be removed using a vacuum sweeper.

f. Applying Backer or Separating Material. Once the joint has been thoroughly cleaned, the backer or separating material is inserted to prevent three-sided adhesion and provide the correct shape factor. In the old joint, the backer or separating material also prevents compatibility problems between the new sealant and any old sealant that remains in the bottom of the joint.

4-4. Preparing Cracks in PCC.

a. Procedures for Preparing Cracks. Cracks, unlike joints, are irregular in dimension and direction, making them more difficult to prepare and seal. Because of the irregular nature, the equipment used to prepare joints may not be suitable to prepare cracks. The techniques change; however, the procedures remain virtually the same. The procedures include sealant removal (from previously sealed cracks), routing, crack repair, and cleaning.

b. Sealant Removal. Sealant removal from

cracks is usually accomplished using handtools. Mechanical devices often do not adequately remove the sealant because the sealant becomes too tacky when subjected to the action of mechanical bits.

c. Routing or Sawing. Routing of the crack is accomplished using a vertical spindle router similar to the one shown in figure 4-6. The router produces a reservoir for the sealant. An option to using the router is to use a concrete saw. If the crack is straight enough, a standard self-propelled concrete saw may be used to cut a series of intersecting straight lines that roughly follow the crack. For more meandering cracks, a 6-inch diameter blade can be used to enable the crack to be followed. The sealant reservoir dimensions of the crack should be similar to those of a normal joint and should be specified in the plans.

d. Crack Repair. The variable width and amount of spalling typically found on cracks necessitates different procedures for different classifications of cracks. TM 5-624/AFR 85-8 provides the procedures to follow for spall repair. General recommended procedures are as follows:

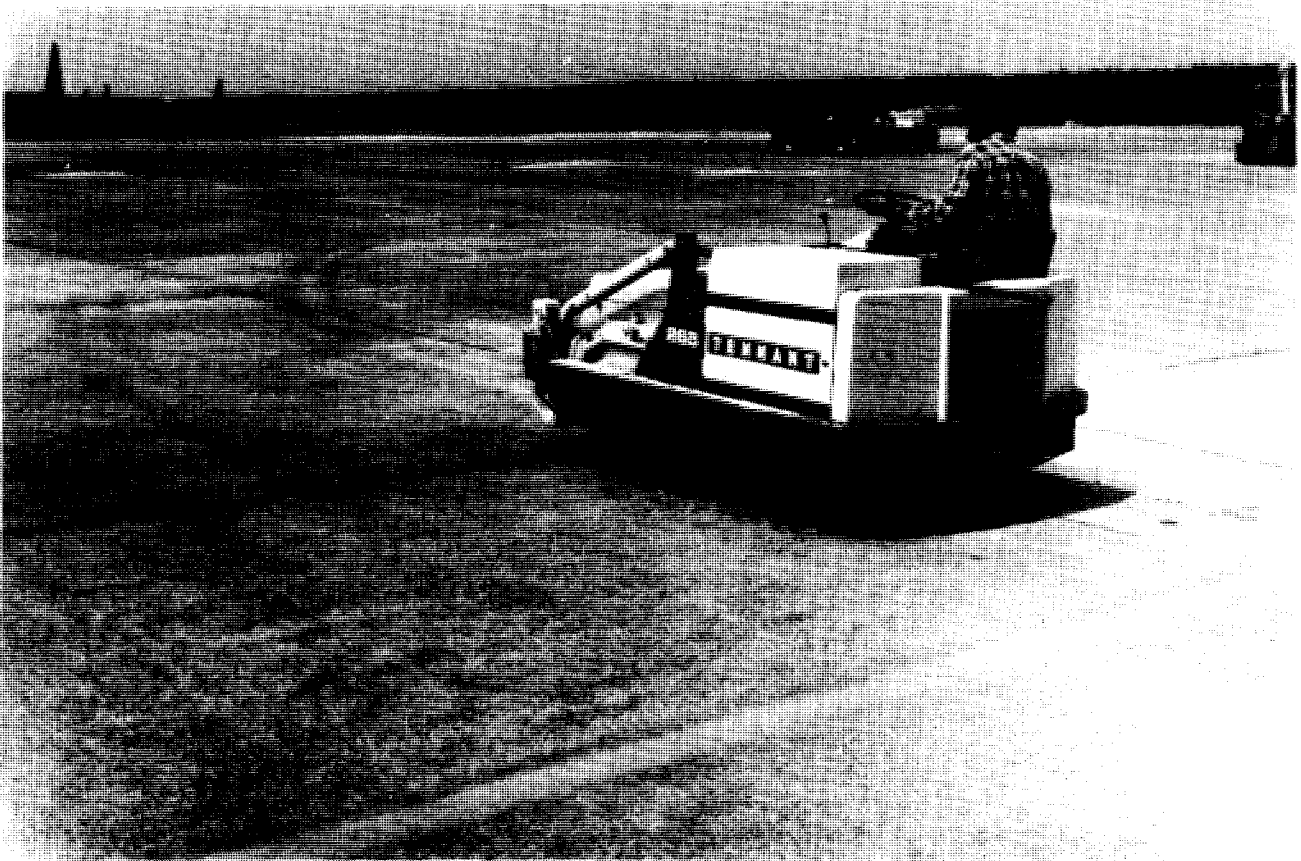


Figure 4-9. Power Vacuum Removing Debris from Pavement Surface.

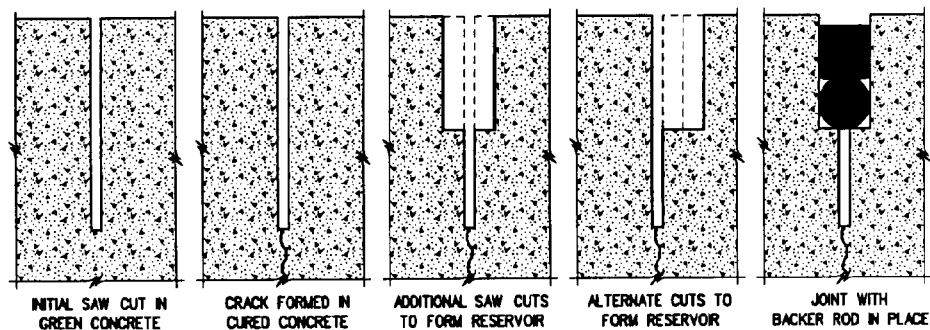


Figure 4-10. Sequence for Sawing New Joints in Fresh Concrete.

(1) Low severity crack, hairline to $\frac{1}{4}$ inch wide with no spalling does not require widening or sealing.

(2) Hairline crack to $\frac{1}{4}$ inch wide with minor spalling should be widened with a router or concrete saw and sealed.

(3) Cracks $\frac{1}{4}$ to $\frac{1}{2}$ inch wide with no spalling and rough edges or with minor spalling should be widened with a router or concrete saw and sealed.

(4) Cracks $\frac{3}{8}$ to $\frac{3}{4}$ inch wide with major spalling should have the spalls repaired in the

same manner as for a joint. The integrity of the crack should be maintained through the repaired area.

(5) Cracks $\frac{3}{4}$ to $1\frac{1}{2}$ inch wide with no spalling should be routed and sealed. Backer rod material should be used if the crack is greater than $\frac{3}{4}$ inch deep or a separating tape if it is less than $\frac{3}{4}$ inch deep.

(6) Cracks $\frac{3}{4}$ to $1\frac{1}{2}$ inch wide with major spalling should be rebuilt as if the crack were a joint.



Figure 4-11. A Freshly Sawn Joint.

(7) Cracks greater than 1½ inch wide can be temporarily repaired using bituminous concrete as a patch. Bituminous concrete is an incompressible material and will give adequate performance for only a limited time. The patched crack must be observed carefully to ensure that the crack is functioning properly and the bituminous mix is not creating problems. For a permanent repair, the crack must be rebuilt as a joint.

e. *Cleaning.* Once the crack has been routed and damaged areas have been repaired, it is cleaned in the same manner as the joints (i.e. sandblasted or waterblasted and air blown), to achieve the same level of cleanliness attained in joint cleaning.

f. *Backer Material.* Cracks that have a depth greater than ¾ inch will require a backer material to maintain the proper shape factor and to support the sealant.

4-5. Preparing Cracks in Bituminous Pavement.

a. Cracks often have irregular dimensions and directions that make them difficult to properly

prepare for sealing. However, if the crack is not correctly prepared, the sealant will not function much beyond the first cold season. The procedure for sealing cracks in bituminous pavement is similar to sealing cracks in concrete pavement and includes sealant removal (when resealing), routing, crack repair, and cleaning.

b. *Sealant Removal or Routing.* Sometimes it is possible to remove the old sealant and form the new sealant reservoir in the same operation. In most cases, however, the old sealant has to be removed using hand tools and then the crack is routed. The crack can be routed using a vertical spindle router or a rotary impact router equipped with carbide tipped bits. These devices are designed to form a sealant reservoir while maneuvering along the irregular direction of the crack. Routing is also required when the edges of the crack are raveled or contain loose aggregate in order to provide sound asphalt concrete for the sealant to adhere. General guidelines for routing cracks are based upon the width of the crack. The general guidelines are as follows.

(1) Hairline cracks (less than ¼ inch) are not routed.

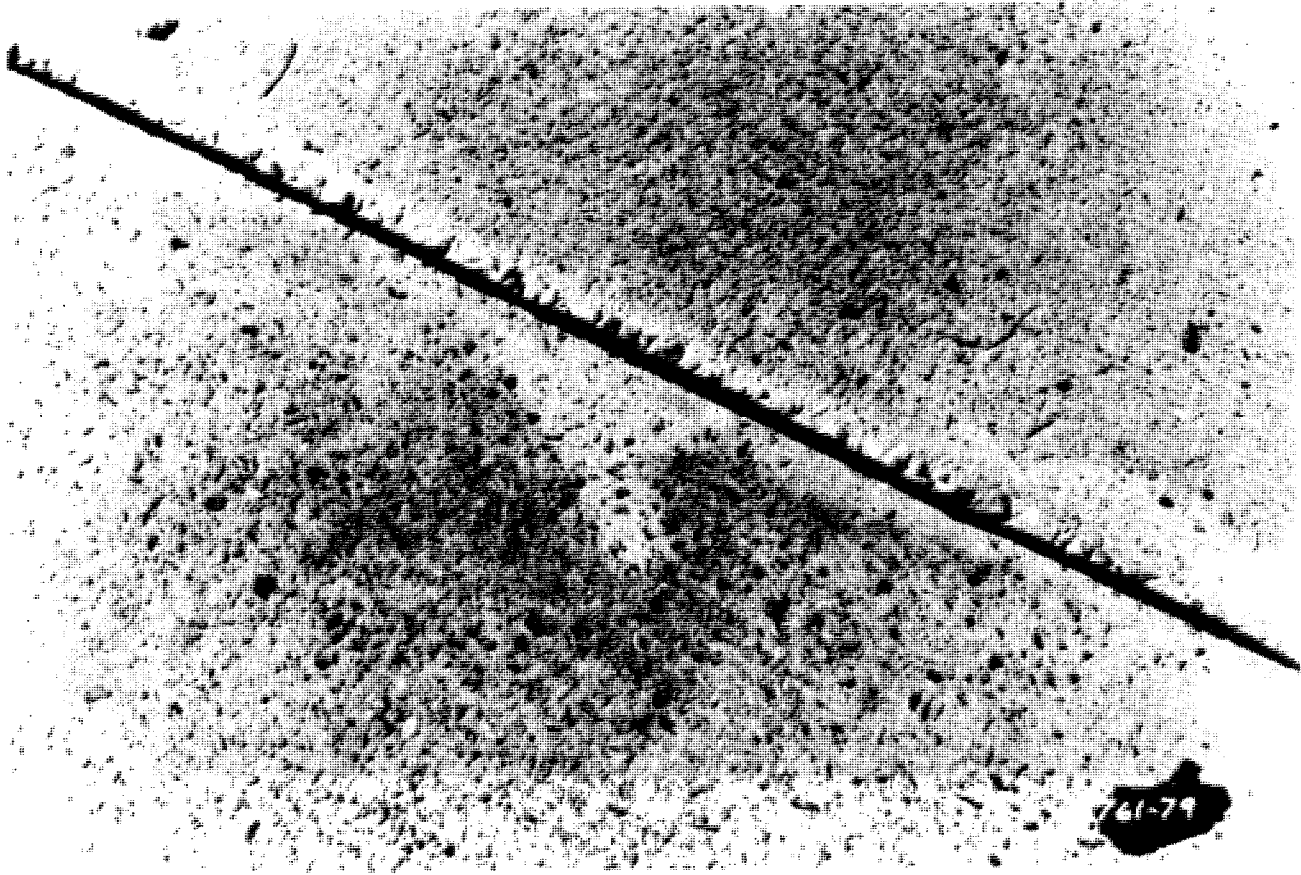


Figure 4-12. Joint after Sandblasting.

(2) *Small cracks ($\frac{1}{4}$ to $\frac{3}{4}$ inch)* should be widened to a nominal width of $\frac{1}{8}$ inch greater than the existing nominal or average width using a router. Widening the cracks $\frac{1}{8}$ inch will help eliminate the potential for raveling of the pavement along the edges of the crack and will provide a sealant reservoir that has vertical faces. The depth of the routed crack should be approximately $\frac{3}{4}$ inch.

(3) *Medium Cracks ($\frac{3}{4}$ to 2 inches)* generally require no routing, but some repair may be required.

(4) *Large Cracks (greater than 2 inches)* require crack repair instead of routing. Cracks greater than $\frac{3}{4}$ inch with medium or high severity raveling should be repaired in accordance with TM 5-624/AFR 85-8.

c. *Cleaning.* Once the damaged areas have been repaired and the cracks routed, the cracks can be

cleaned using compressed air. In some instances, it may be necessary to use a sandblaster or wire brushes to remove debris that cannot be removed by compressed air.

(1) If sandblasting equipment is used, a technique that enables both faces of the crack to be cleaned should be established. A multiple pass technique, as described for cleaning joints and cracks in PCC, should be used. The pavement surface approximately 1 to 2 inches on both sides of the crack should also be sandblasted to remove debris away from the crack. Extreme care must be used to prevent the cracks from being overblasted.

(2) Once the crack has been sandblasted or wire brushed, the crack should be blown out with compressed air to remove sand or any debris that was loosened during the cleaning. The compressed air also aids in the removal of moisture.

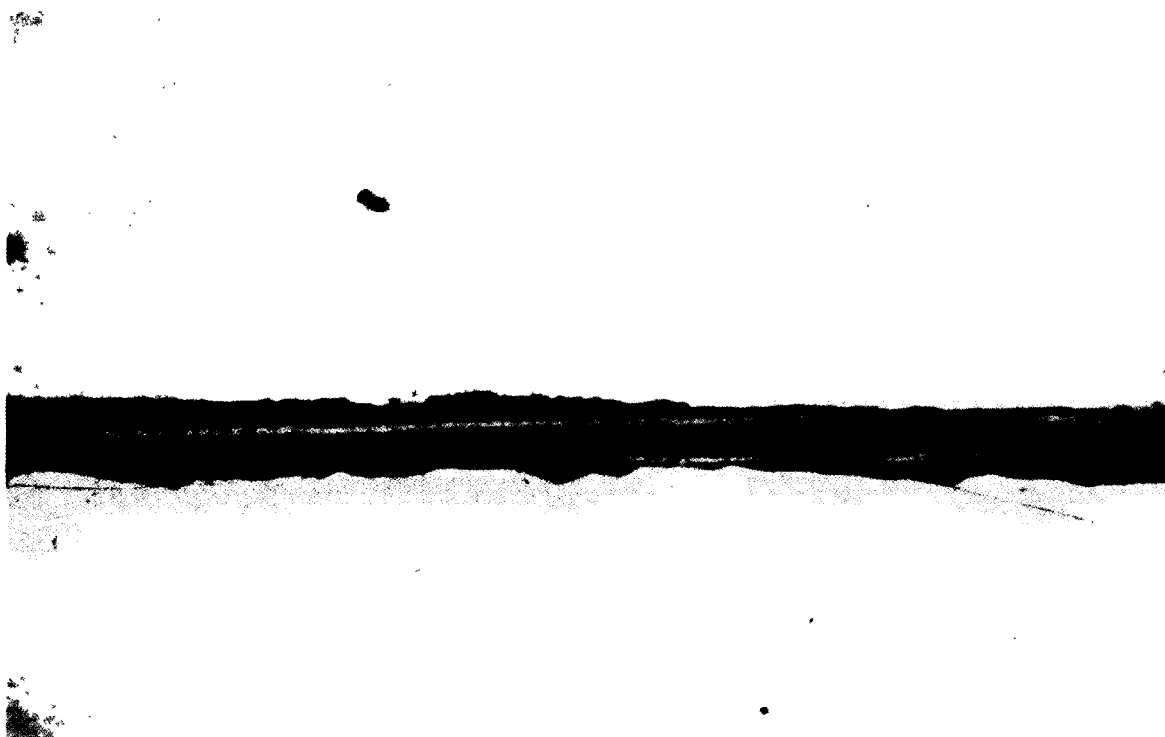


Figure 4-13. Backer Rod Protruding above Sealant.



Figure 4-14. V-shaped Plow Tool.

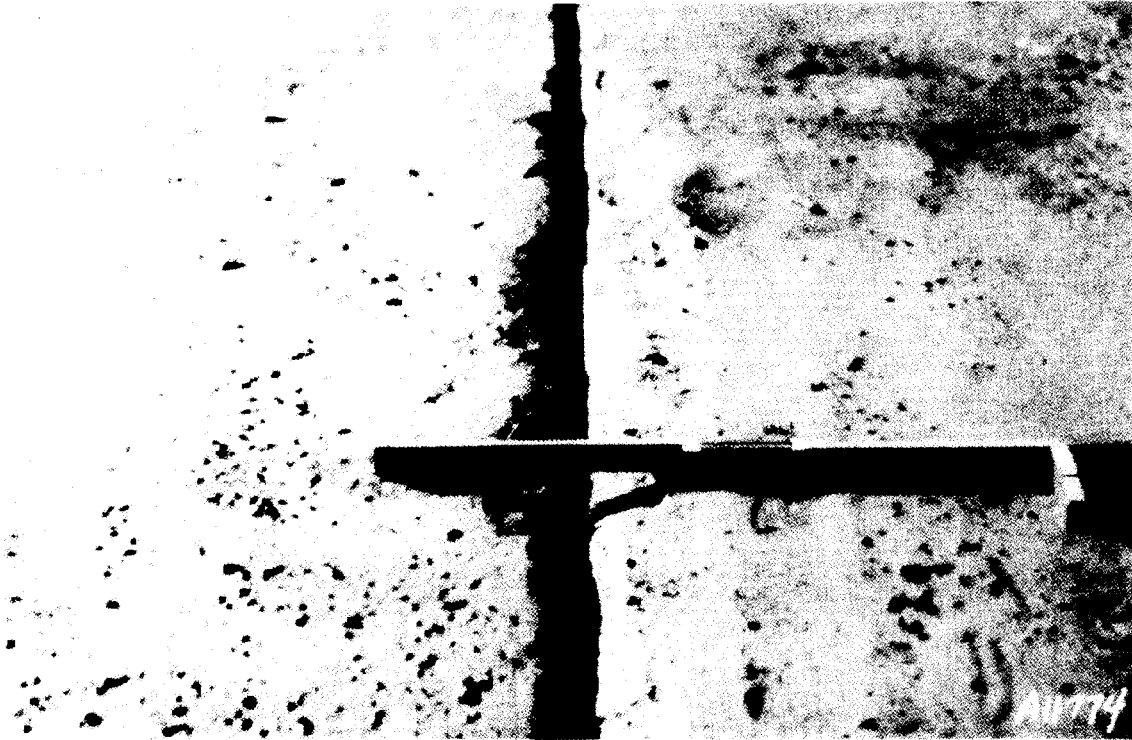


Figure 4-15. Spalling Produced during Sealant Removal.

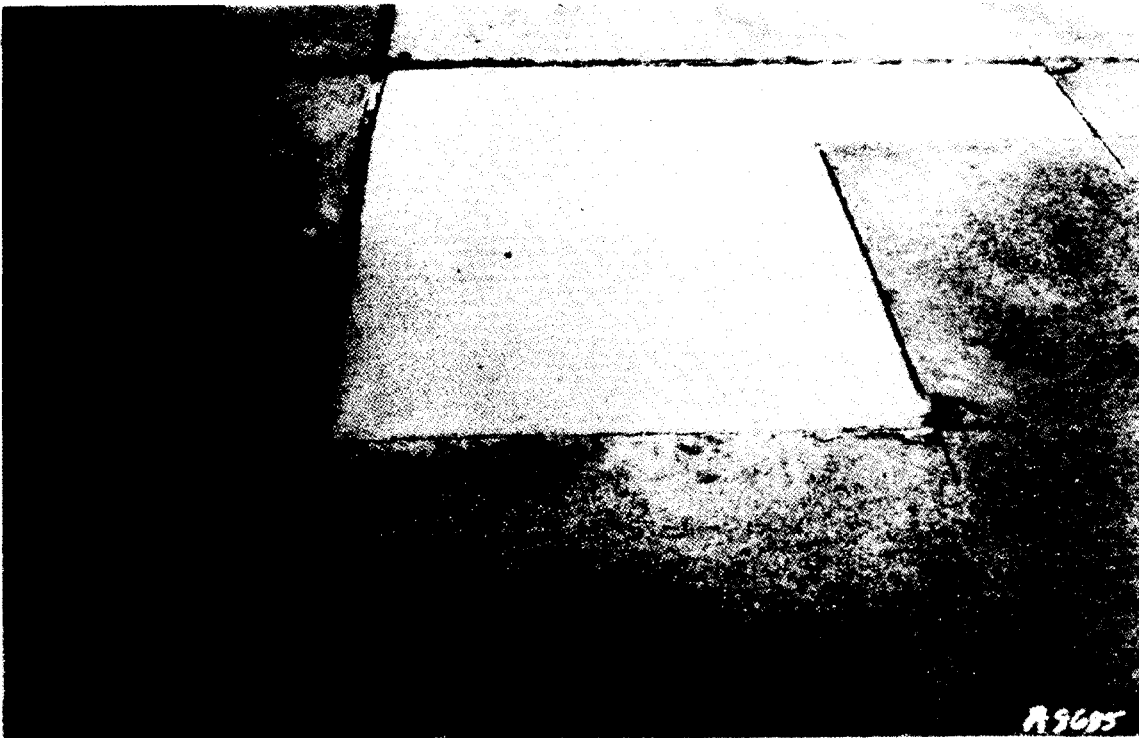


Figure 4-16. Example of a Rebuilt Joint.

CHAPTER 5

JOINT AND CRACK SEALING

5-1. SEALING OPERATION.

a. General Information. When the joints and cracks have been properly prepared and the materials and equipment approved, the actual sealing can proceed. The joint or crack preparation and the sealing operation are a continuous process. Prepared joints or cracks should not be left unsealed for more than 1 day, and it is recommended that preparation not be completed on more joints or cracks than can be sealed in the same working day. Sealing the joints or cracks the same day they are prepared prevents unnecessary intrusion of moisture, incompressibles, and dust that will require further cleaning the next day. The sealing operation for field molded sealants is the same whether sealing joints or cracks in PCC or bituminous pavements. The operation consists of installing the backer or separating material, the equipment used to install the sealant, and the actual application of the sealant into the pavement.

b. Backer Material. The backer material must be inspected continually during the sealing operation to ensure it is firmly seated in the joint at the proper depth. The backer material is cut where two joints intersect to allow the material to lay flat. Backer material is not required for preformed seals, and they are generally not required for cracks in bituminous pavements unless the crack depth is greater than 1 inch.

5-2. Application Equipment.

a. Hot-Applied Sealing Equipment (Melter). There are basically two types of hot-applied sealing equipment. One is for the application of hot-applied sealants that are solid at room temperature and the other is for the application of hot-applied sealants that are liquid at room temperature. The two types of equipment are not interchangeable. Figure 5-1 contains a schematic drawing of each in which the differences can be easily seen. All applicators should be equipped with nozzles that are shaped to allow the sealant to seal the joint from the bottom to the top of the reservoir. Field-poured hot-applied sealants must be heated to a

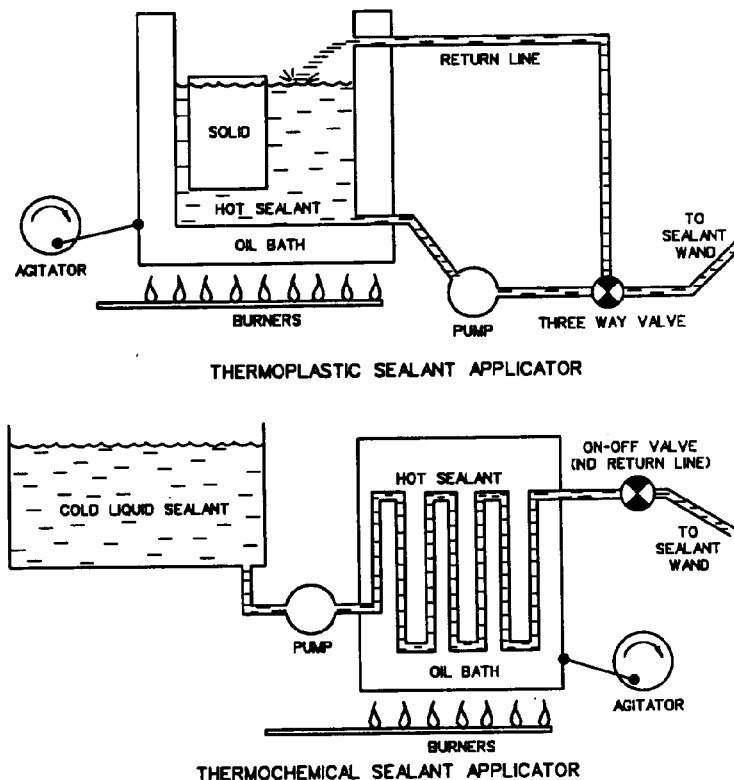


Figure 5-1. Schematics of Different Hot-Applied Sealant Applicators.

specific temperature for application into a joint or crack. If the sealant is installed using an application temperature that is too low, adequate bonding to the joint or crack face will not occur, and in some cases, the sealant will not cure. This is particularly true for hot-applied sealants that are liquids at room temperature. Some liquid sealants require heat to chemically change the sealant allowing it to cure. If the correct temperature is not achieved during application, the sealant will have to be removed from the joint. If the sealant is installed using an application temperature that is too high, the sealant will be damaged and can lose its resiliency and bonding ability. Therefore, one of the most important characteristics of a melter is its ability to heat the sealant to the proper temperature and maintain that application temperature.

(1) *Solid Hot-Applied Sealing Equipment.* The equipment used for heating and installing solid hot-applied joint sealant materials (fig 5-2) must be equipped with a double-boiler, agitator-type kettle to prevent localized overheating. Thermometers for indicating the temperature of

the sealant and the oil bath should be calibrated and located where they can be easily read. The melter should be designed to circulate the sealant through the delivery hose and return to the inner kettle when not in use.

(2) *Liquid Hot-Applied Sealing Equipment.* The equipment used for heating and installing the liquid hot-applied joint sealant materials is equipped with a reservoir tank that is not maintained at the application temperature. The sealant is drawn from this tank and is pumped through tubes in a heated oil bath which brings the sealant to the application temperature. Once at the application temperature, the sealant is inserted into the joint. This type of equipment is not designed to recirculate the sealant.

b. *Cold-Applied Sealing Equipment.* The type of equipment used to install cold-applied sealants will depend upon the type of sealant, two-component or single component, hand mix or machine mix. All applicators should be equipped with nozzles that are shaped to allow the sealant to seal the joint reservoir from the bottom to the top.

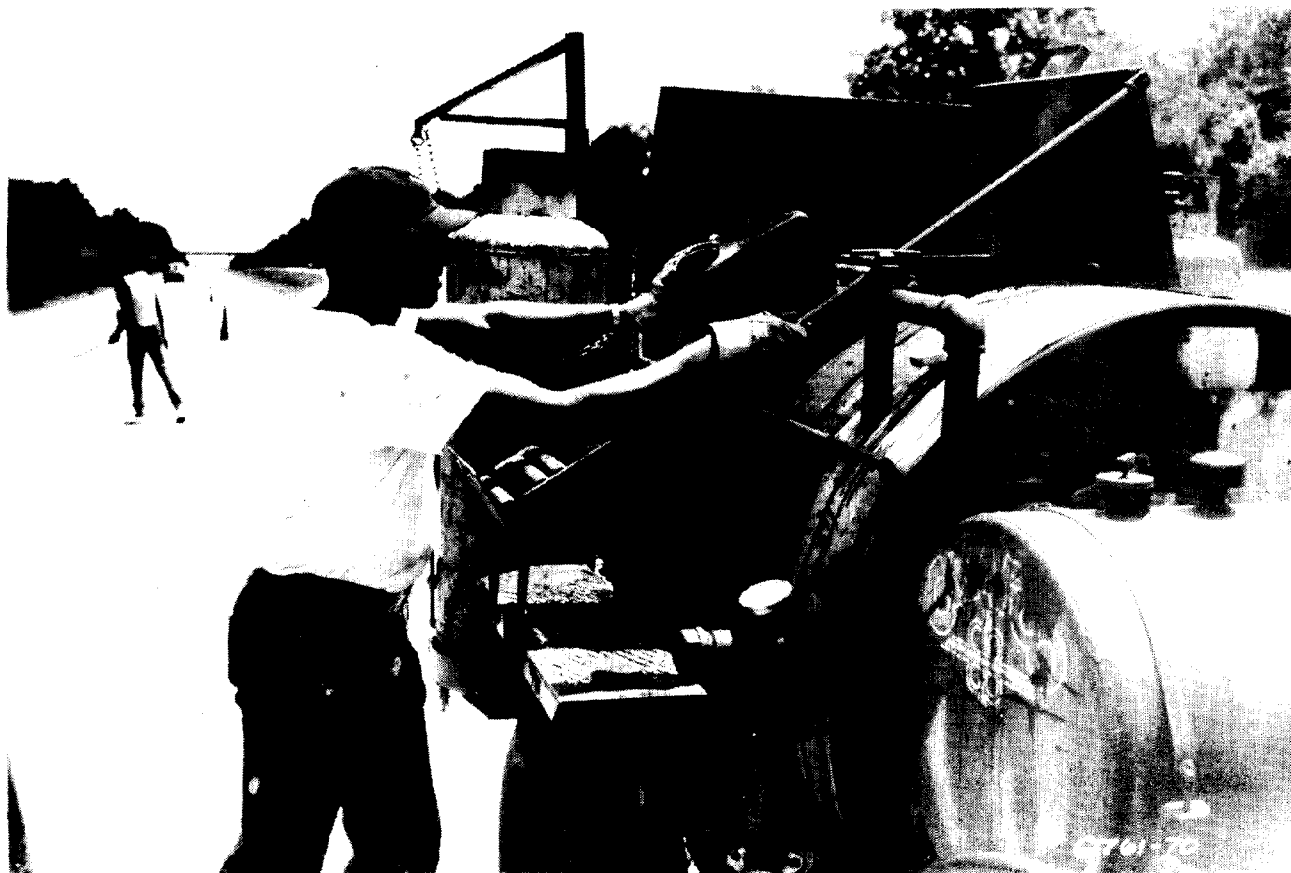


Figure 5-2. Hot-Applied Sealant Application Equipment.

(1) **Cold-Applied, Two-Component Machine Mix Sealing Equipment.** The equipment used for proportioning, mixing, and installing cold-applied, two-component machine mix joint sealants (fig 5-3) is designed to deliver two liquid components through separate hoses to a portable mixer. The components are pumped at a preset ratio of 1 to 1 by volume. The reservoir for each component is mechanically agitated to maintain the materials in a uniform condition without entrapping air. When required, thermo-statistically controlled indirect heating of the components is permitted. Screens should be located near the top of each reservoir to remove debris from the components as they are being poured into the reservoir.

(2) **Cold-Applied, Two-Component Hand Mix Sealing Equipment.** Mixing equipment for cold-applied, two-component hand mix sealants normally consists of a slow-speed electric drill or air-driven mixer with a stirrer meeting the manufacturer's recommendations.

(3) **Cold-Applied, Single-Component Sealing Equipment.** The equipment for installing cold-applied, single component joint sealants (fig 5-4) consists of an extrusion pump, air

compressor, following plate, hoses, and nozzle. Small hand-held air-powered equipment (i.e., caulking guns) may be used for small applications.

c. Preformed Compression Seal Application Equipment. Equipment used to install the preformed seal must be able to install the preformed seal to the specified depth without damaging or stretching the seal.

(1) **Self-Propelled Preformed Compression Seal Application Equipment.** The automatic self-propelled joint seal application equipment (fig 5-5) must include a reservoir for the lubricant, a device for dispensing the lubricant to the sides of the preformed seal, a reel capable of holding one full spool of preformed seal and an apparatus for inserting the seal into the joint. The equipment should also include a guide to keep it aligned with the joint being sealed.

(2) **Hand Operated Preformed Compression Seal Application Equipment.** The hand operated joint seal application equipment must be a two-axle, four-wheel machine that includes an apparatus for compressing and inserting the preformed seal into the joint as well as a reel capable of holding one full spool of preformed seal. Auxiliary equipment must be



Figure 5-3. Cold-Applied, Two-Component Sealant Application Equipment.

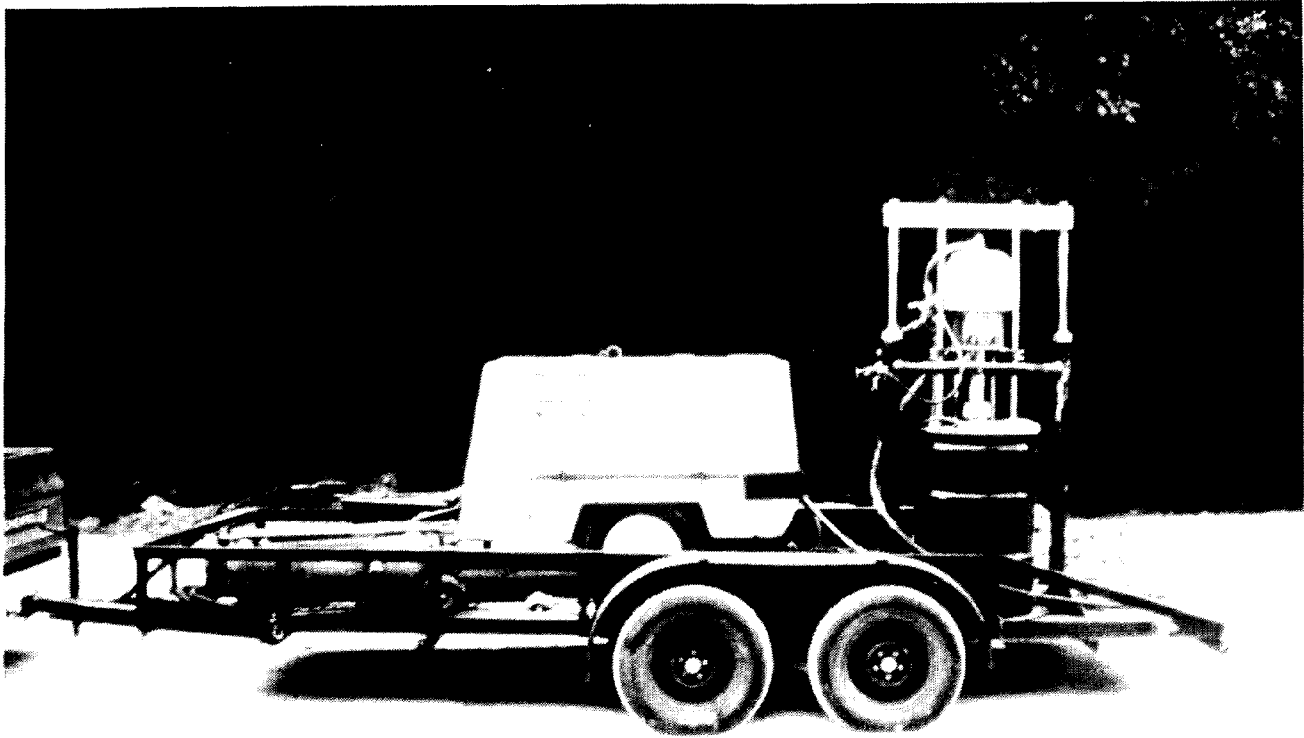


Figure 5-4. Cold-Applied, Single Component Sealant Application Equipment.

provided to coat both sides of the joint with lubricant prior to the installation of the preformed seal.

5-3. Application Procedure.

a. Field-Molded Application Procedure. Apply the sealant in the joint or crack reservoir from the bottom to the top to prevent trapping air bubbles in the sealant. The sealant should be recessed 1/8 to 1/4 inch below the pavement surface. The joint or crack must not be overfilled with sealant. The recess of the sealant prevents it from being pushed out of the reservoir and becoming damaged by traffic when the pavement expands. Any excess hot-applied sealant that gets on the pavement surface can be removed using heated blades, the cold-applied sealants may be simply scrapped off before the sealant cures. In no instance should a joint or crack be overfilled. Also, when sealing cracks in bituminous pavements that are to be overlaid, it is important to recess the sealant 1/4 to 1/2 inch below the pavement surface. The recess will help prevent bleeding of the sealant material through the overlay.

b. Preformed Compression Seals Application Procedure. The sides of the joint seal and/or the sides of the joint shall be covered with a coating of lubricant/adhesive and the seal installed into the joint leaving a 1/8 to 1/4 inch recess below the pavement surface. Longitudinal joints shall be sealed first, followed by transverse contraction joints. The seal in the longitudinal joints shall be cut where the transverse joints intersect to allow placement in the transverse direction. The lubricant/adhesive should be allowed to dry prior to cutting the seal at the joint intersections. Any lubricant/adhesive spilled on the pavement shall be removed immediately to prevent setting on the pavement. The in-place joint seal should be in an upright position, free from damage, and without stretching or compression of the seal in excess of 2 percent. Stretching the seal by greater than 2 percent can create the forming of gaps where the seal has to be cut.

c. Weather Limitations. The weather conditions during a sealing project will affect the performance of the sealant material. Weather considerations during the project include the following:

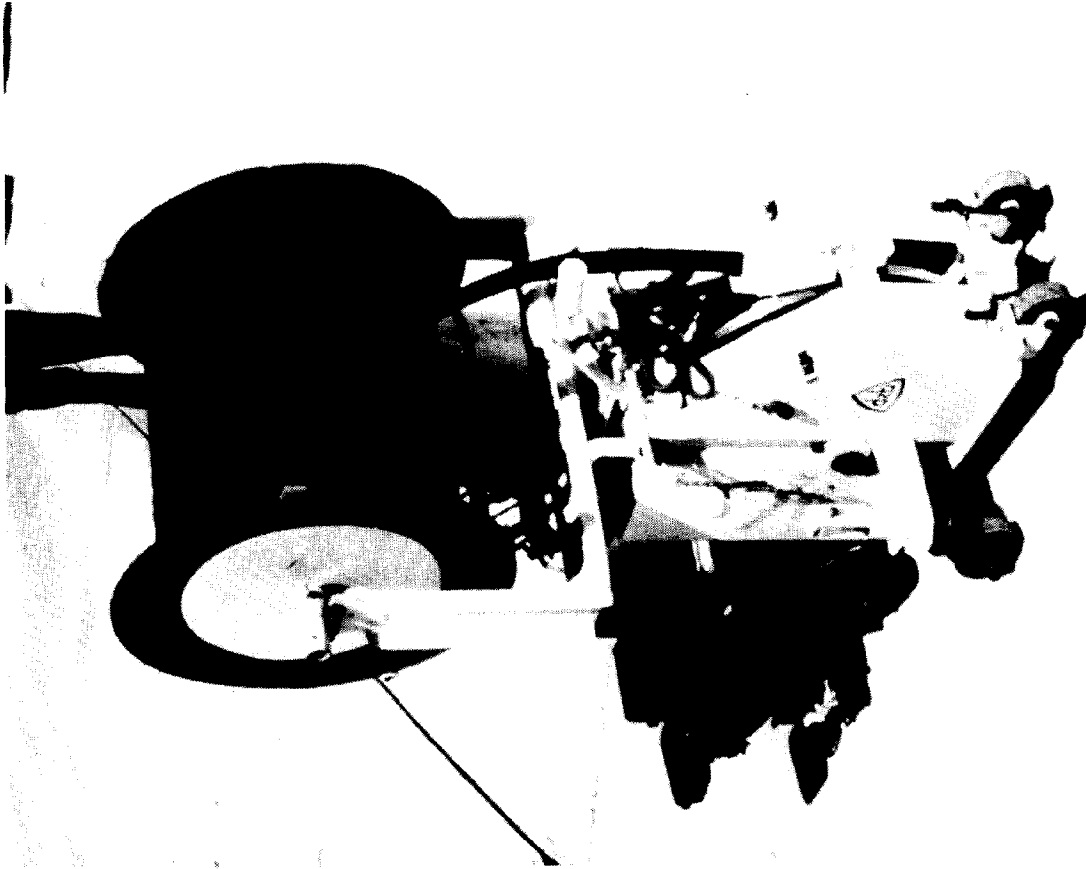


Figure 5-5. Preformed Elastomeric Compression Seal Application Equipment.

(1) The joint or crack must be visibly dry before sealing is allowed to proceed. Visible moisture includes rainfall and even a heavy dew which may produce condensation on the pavement. If the moisture is not allowed to fully evaporate before the sealant is applied, the sealant may not adequately bond to the joint face leading to adhesion failure.

(2) The temperature of the concrete and the ambient temperature will influence the bonding of hot-applied sealants to the concrete and can retard the curing of cold-applied sealants. A general recommendation is that the air and pavement temperature be 50 degrees Fahrenheit (35 degrees Fahrenheit) and rising before sealant application is allowed. If the joint walls are too cold, they will chill the hot sealant as it is applied. This chilling prevents the sealant from developing intimate contact with the concrete and filling all the pores on the joint surface which develops the bond between the sealant and the concrete. Adhesion failures are more likely to develop when a hot-applied sealant is placed in cool weather.

(3) The curing of some cold-applied

sealants are highly temperature dependent. Cool temperatures increase the amount of time it takes for the sealant to cure. A good seal can normally be obtained when the sealant finally cures, but the sealant will remain tacky for an excessively long period of time. While the sealant is still tacky, it can be pulled out of the joint by traffic and tracked onto the pavement surface. When the sealant does cure and develop bonding strength, there may not be enough sealant remaining in the joint to maintain the required shape factor and performance will suffer.

d. Sealant Type Location. It is possible that two different sealant types, JFR and non-JFR, hot-applied and cold-applied, or field molded and pre-formed, may have to be applied during the same sealing project if the contract overlaps different pavement features. These features must be clearly noted on the plans and should be indicated on the pavement sections. The equipment operators and all personnel involved with inspection should know the areas where sealant types change and should physically verify these locations before the beginning of the project.

CHAPTER 6

INSPECTION PROCEDURES

6-1. Plans, Specifications, and Contracts.

a. General. The inspector must be familiar with all documents prepared for a particular sealing project. The documents should be considered to be a set of instructions that the inspector uses to evaluate the project since they contain the information that the inspector must apply to the project to evaluate the quality of work being performed. The contractor should also have these documents and should be performing the same type of evaluation on the work as part of the quality control program. The application of standards must be consistent from both the inspector and the contractor. The topics in this section serve as highlights and background information on the specific items the inspector will find in the documents to support the sealant project.

b. Plans. The plans show the location of all sealing. When different sealant reservoir sizes, preparation methods, or sealant types are required, the sealant project should be subdivided for each change. The plans should identify the typical existing joint reservoir size and shape and the required final reservoir size and shape for each phase or subdivision of the project. An estimated lineal footage for each type of sealant should also be included in the plans.

c. Specifications. The project specifications should be prepared using the applicable guide specifications as much as possible. Several items need to be covered in detail to make sure that all contractors bid on the same basis, and all inspection of the job is consistent. These items include the following:

(1) The exact shape factor, sealant type, and size of the existing joints or cracks should be shown as well as the shape factor and size of the finished joint or crack.

(2) If sawing the joints is required, it must be specifically stated. If sawing is not required, the method to prepare the joint or crack before sealing should be stated. Acceptable alternatives can also be provided in the specifications. When providing alternatives, an important consideration is to determine if the desired result can be obtained using the method.

(3) When resealing, the procedures required to separate the old sealant below the desired shape factor from the new sealant must be

specified. This is needed when removing sealant to a specified depth. If the sealant is to be removed full depth or there is no sealant remaining in the joint, the depth to which the backer material is to be inserted must be specified.

(4) Specify the type of sealant material required.

(5) When more than one preparation process, reservoir size, or sealant type is required, state the amount of lineal footage of each and show the location on the plans.

(6) Acceptance or rejection criteria and inspection guidelines should be outlined in the specifications.

(7) The standard military construction contracts contain a 1 year "Warranty of Construction" clause. This clause should be used to ensure the sealant performance is satisfactory. For the clause to be legally binding, the defects and failures of sealant performance must be defined. The following is an example of what the completed joint sealant installation should accomplish:

(a) Help prevent water infiltration through the joint or crack.

(b) Prevent intrusion of incompressibles into the joint or crack.

(c) No adhesion failure (loose bond with the sidewalls of the joint or crack).

(d) No cohesion failure (splitting or cracking of the sealant material).

(e) No excessive bubbling or blisters. In some cases, surface bubbles may be acceptable to the finished product; however, bubbles that have a depth of greater than 1/8 inch are not acceptable.

(f) Remain resilient and capable of rejecting incompressibles at all pavement temperatures.

(g) Not be picked up by or tracked on adjacent horizontal pavement surfaces by rubber-tired vehicle traffic, pedestrian traffic, or the action of a power vacuum rotary brush pavement cleaning equipment after the specified cure time.

(h) Provide a finish exposed joint surface that is nontacky and will not permit the adherence of dust, dirt, small stones, and similar contaminants encountered with airfield pavement.

(8) Repairs to joints or cracks that are required before sealing should be specified.

6-2. Equipment Used.

a. Joint Plow. If a joint plow is being used, sufficient cutting tools of various widths must be

on hand for the various joint sizes. The tools must be rectangular, not V-shaped, and the mounting assembly must not be rigid. The tool should have some mobility to move laterally and vertically to prevent the tool from chipping and spalling the joint.

b. Vertical Spindle Router. If a router is to be used to clean and open cracks in PCC, there should be sufficient bits of various sizes on hand to work with the cracks that exist. The equipment must be able to follow the crack and widen it to the desired width without spalling the concrete around the crack.

c. Sawing or Refacing. The blades must be on the same arbor and spaced to produce a joint or prepare a crack to the necessary depth and width. A water supply must be available to cool the blades during operation. The saw cuts must not spall the concrete. The depth and width must be uniform along the joint and the saw cut must be straight (i.e., the cut must not wander from one side of the joint to the other). When dry sawing is used, only one blade is used and the water supply is not necessary. It should be noted that dry sawing is a cleaning or scrapping of the joint face and is not an actual sawing. This is the reason water is not needed when dry sawing; however, the blades should be inspected often to ensure they are not damaged.

d. Sandblasting or Air Blowing. The physical requirements of the sandblasting equipment have been previously discussed. Before sandblasting begins, one should make certain that the operator is wearing all of the required protective clothing. When sandblasting begins, one should examine all pressure gauges to ensure the correct line pressure is being maintained. The positioning fixtures on the nozzles should also be examined to ensure the nozzle is being supported over the joint or crack, allowing the sand to thoroughly clean the faces. The joint faces and the pavement surface up to approximately 1/2 inch away from the joint or crack must be dry and free from any dirt, film, or oil. If oil or water is present on the joint face, one should check the compressor to ensure that all of the traps are clean and working and that none have been removed or bypassed. The same considerations apply to the compressor used for airblowing the joints or cracks.

e. Hot-Applied Sealant Applicator. The equipment must be examined to determine if the correct applicator is being used. Applicators that are designed to melt and install solid hot-applied sealants cannot be used to heat and install liquid hot-applied sealants and vice-versa. The length of time it takes the equipment to reach the application

temperature should be noted, and the sealant agitator and temperature devices should be examined to ensure they are operating. If possible, a direct reading on the sealant temperature should be made to verify the reading on the in-place thermometers. The sealant will often form an insulation around the in-place thermometer yielding incorrect readings. The continuous agitators should be examined to prevent overheating and ensure the entrapment of air in the sealant does not occur. The manufacturer's recommended safety procedures for installing the sealant should be followed. Safety cannot be overemphasized. Some hot-applied sealants can emit toxic fumes when they are heated; therefore, the manufacturer's recommendations concerning operator safety must be followed.

f. Cold-applied Sealant Applicator. Two-component applicators will have two reservoirs to observe with the items being evaluated similar to those evaluated for a hot-applied sealant. A critical factor in applying two-component sealants is the mixing head on the sealant wand and the proportioning of the sealant. The proportions being mixed must be checked periodically by collecting the two components in separate cans and measuring the volume of sealant collected in each can. The proportions should be checked against the manufacturer's recommendations. Single component materials normally use an air compressor and an extrusion system to insert the sealant into the joint. The evaluation of the air compressor is the same as listed for sandblasting. Neither the two-component nor the single-component equipment should have a recirculating system.

g. Preformed Compression Seal Applicator. The preformed seal can be installed by hand or with automated equipment. Both operations require placing the lubricant/adhesive on the joint faces and the seal. The seal must be placed at the correct depth without twisting, compressing, or stretching the seal by more than 2 percent. For example, a 50-foot long seal should be no longer than 51 feet or shorter than 49 feet when installed. The applicator must have two axles for proper stability during the installation of the seal. One-axle applicators have a tendency to wobble and place the seal unevenly.

h. Power Broom. The sweeping equipment must be vacuum equipped to pick up debris on the pavement surface that could contaminate the joint or crack.

6-3. Joint Preparation.

a. Once the equipment has been evaluated and approved, the sealing project can begin. If any

deficiencies are noted during the project, they should be brought to the attention of the supervisor and recorded in the project log book. Any time the inspector notes a deficiency and calls it to the attention of the contractor, it should be noted in the log book along with exactly to whom the inspector talked. It is advisable to reference the noted deficiencies to permanent features of the pavement.

b. Sealant Removal. The joints should be inspected before removal begins as well as after the removal. This will allow the determination of how much, if any, concrete was spalled by the contractor. Surface spalling that does not extend beyond 1/8 to 1/4 inch may be allowable for field-poured sealants. Larger and deeper spalls must be repaired before sealing. The larger spalls should be marked with spray paint on the pavement surface and the deficiency recorded. Excessive force should not be allowed on the removal tool. The contractor should change cutting tools, bring in another piece of equipment, or slow the removal process if damage to the concrete is occurring.

When specialized sealants such as preformed seals are being removed, several passes with hand work in between the passes of the joint plow may be required for complete removal without damaging the concrete.

c. Sawing or Refacing.

(1) The following items should be examined after the sawing operation:

- (a) Joint width.
- (b) Joint depth.
- (c) Straightness of the joint.
- (d) Cleanliness of joint sidewalls.
- (e) Damage to joint sidewalls.

(2) A template made from metal such as the one shown in figure 6-1 should be obtained to aid in determining if the joints meet the specifications. If the template cannot be inserted into the joint perpendicular to the bottom and sidewalls, the joint must be resawn to meet the specification value. The dimensions of the template will depend upon the tolerances allowed in the specifications.

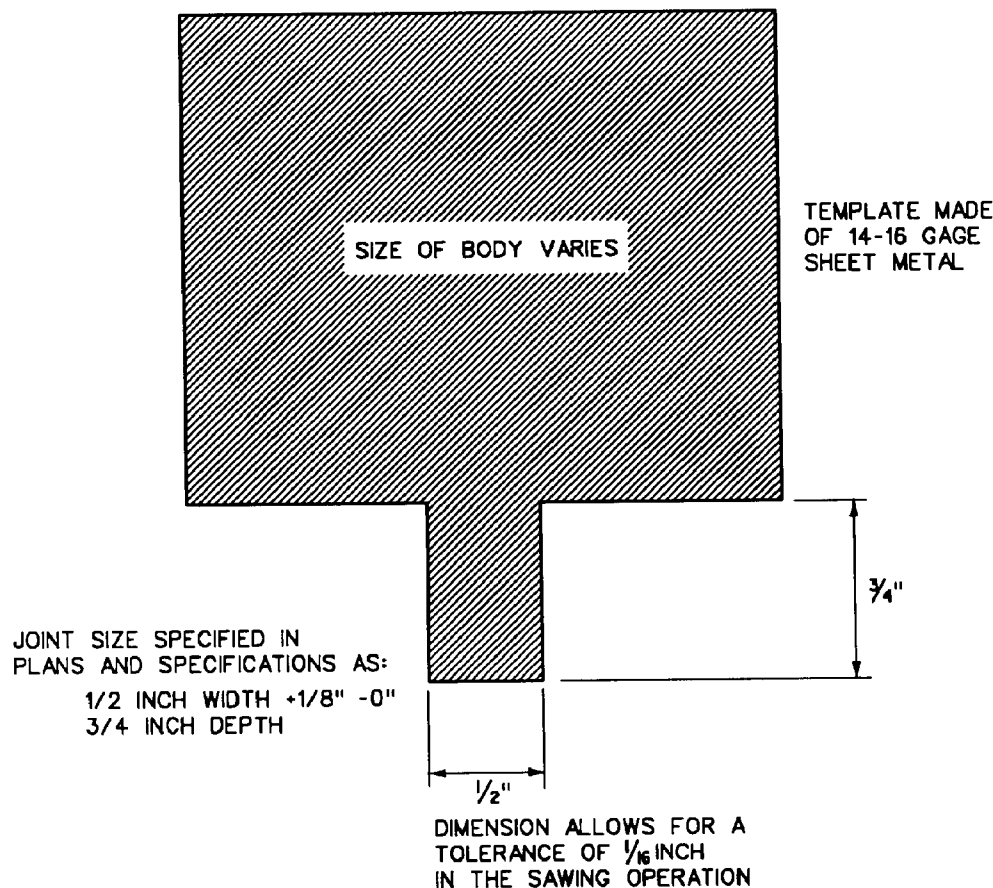


Figure 6-1. Joint Template.

d. Check for Horizontal Alignment. A joint that does not follow a straight line after being cut may leave sealant residue on one of the joint faces. If the saw cut is not straight, it should be brought to the attention of the contractor. The joint should be checked to ensure that all of the old joint sealant has been removed. The joint should be resawn or sandblasted to remove the sealant.

e. Cleaning. The joints and cracks must be sandblasted and airblown to remove any remaining debris that could interfere with the bonding of the sealant to the concrete. If there is any dust remaining on the joint faces when wiped by a finger along the edge of the joint, the joint must be marked for sandblasting and airblowing again.

f. Check for Moisture. The joints must be dry before they can be sealed. If a joint appears moist anywhere along its length, do not allow that joint to be sealed before the entire length of the joint has been airblown until it is dry.

g. Joint or Crack Repair. After cleaning, the joints or cracks should be repaired where necessary using the standard procedures described earlier. The spalled areas that need repair should have been marked before cleaning began. Any damage to the concrete caused by the contractor during preparation should also be marked and repaired at this time. The joint or crack must be continuous through the repaired area and must have the same shape factor as the remainder of the joint or crack. Any spall not repaired will affect sealant performance, even minor spalls will affect field performance when preformed compression seals are used. Therefore, all repairs must be made before the joint is sealed. Additional cleaning will be required after spall repair.

h. Separating or Backer Material. Following the cleaning operation, the backer or separating material should be placed in the joint. These materials should be examined to determine if they are nonmoisture absorptive, nonshrinking, and flexible. The material should also have a melting point at least 5 degrees Fahrenheit greater than the pouring temperature of the sealant. The material, once approved, should not be changed without the approval of the contracting officer. The material must fit firmly into the joint and should not be twisted or stretched when inserted into the joint. The backer material must be placed to a depth that will provide the specified shape factor uniformly throughout the joint. If the material does not fit firmly into the joint or the correct shape factor is not obtained, the material must be removed and the problem corrected.

6-4. Sealing Operation.

a. Ambient Temperature. The pavement temperature should be measured and recorded during start-up and periodically if the temperature is dropping. Do not allow sealing to begin until the pavement temperature is 50 degrees Fahrenheit and rising.

b. Sealing. During the sealing operation the application equipment should be inspected at regular intervals to obtain the sealant temperature. The sealant must be applied to depth of 1/8 to 1/4 inch below the surface of the pavement. The operator should apply the sealant in a continuous motion while moving the wand in a way that the sealant flows out behind the wand leaving a smooth surface on the sealant. The joint or crack should be sealed from the bottom of the sealant reservoir to the top and in such a manner to prevent air entrapment in the sealant.

c. Curing. The sealant can be punctured with a pin or wire to determine if the sealant is curing or not. If the sealant adheres to the pin, the sealant has not cured and the project cannot be considered complete. If the sealant does not cure in the recommended time, the uncured sealant must be replaced.

d. Bond. When the sealant has cured, several joints should be examined to determine if the sealant has bonded to the concrete. The sealant should not separate from the joint faces when pulled lightly across the joint with the fingertips. If the sealant separates easily from the joint face, the area of the sealant that was in contact with the concrete should be examined for debris. Traces of debris indicate that the joint was probably not prepared adequately.

e. Deficiencies. All deficiencies must be noted in a log book and referenced to a permanent pavement feature as mentioned earlier. All conversations with the contractor are required to note the deficiency by initialing the log book. This procedure will help reduce arguments over discrepancies arising later.

6-5. Final Inspection.

a. All joints should be examined to ensure that they meet specifications from a visual standpoint. Items that should be examined include:

(1) No backer material floating in the sealant.

(2) Joints not over or underfilled.

(3) All spilled sealant has been removed.

(4) No debris left on the pavement surface.

(5) Joint sealant has cured and is bonding.

b. The general procedure described is a continuous process and each of the steps must be

conducted several times under varying circumstances. It is essential that the procedure be established the first day of the project and that the inspector is present continually so that problems can be corrected as they occur. This will help reduce conflicts created when the contractor is required to remove an inferior product that was placed when the inspector was not present.

c. Continual observation of the work being performed ensures the contractor is following the quality control plan and may decrease the amount of testing and examination required by the inspector. Because all operations described in this section occur at the same time, the inspector must continually move from one operation to another. The contractor must be advised at the preconstruction meeting that the contractor is required to repair anything that is found out of specification regardless of when the error is found; for example, a joint that is not wide enough may not

be discovered until final inspection.

d. One technique that can be used to identify deficiencies is to identify each step of the joint sealing operation with a separate paint color denoting the problem found. A sample program might use the following:

- (1) Orange--improper joint size.
- (2) Red--joint not properly cleaned.
- (3) Yellow--repairs must be made to the joint before sealing.
- (4) Brown--improper sealing technique, joint overfilled, underfilled, improper backer material, tacky or uncured sealant.
- (5) Green--contractor has corrected the problem area and the inspector should reexamine the joint or crack for approval.

e. The inspector must not do the quality control work for the contractor, but quality assurance work must be done daily.

APPENDIX A

REFERENCES

A-1. Government Publications

Departments of the Army and the Air Force

TM 5-624/AFR 85-8	Maintenance and Repair of Surfaced Areas
TM 5-825-3/AFM 88-6, Chap. 3	Rigid Pavements for Airfields
TM 5-826-6/AFR 93-5	Airfield Pavement Evaluation Program

General Services Administration

Federal Specifications

SS-S-200E	Sealants, Joint, Two-Component, Jet-Blast Resistant, Cold Applied, for Portland Cement Concrete
SS-S-1401C	Sealant, Joint, Non-Jet-Fuel-Resistant, Hot-Applied, for Portland Cement and Asphalt Concrete Pavements
SS-S-1614A	Sealants, Joint, Jet-Fuel-Resistant, Hot-Applied, for Portland Cement and Tar Concrete Pavements

A-2. Nongovernment Publications

American Society for Testing and Materials (ASTM), 1916 Race Street, Philadelphia, PA 19103

D 1190 1974; R 1980	Concrete Joint Sealer, Hot-Poured Elastic Type
D 2628 1981	Preformed Polychloroprene Elastomeric Joint Seals for Concrete Pavements
D 2835 1989	Lubricant for Installation of Preformed Compression Seals in Concrete Pavements
D 3405 1978	Joint Sealants, Hot-Poured, for Concrete and Asphalt Pavements
D 3406 1985; R 1991	Standard Specification for Joint Sealant, Hot-Applied, Elastomeric-Type, for Portland Cement Concrete
D 3569 1985; R 1991	Standard Specification for Joint Sealant, Hot-Applied, Elastomeric, Jet-Fuel-Resistant-Type for Portland Cement Concrete Pavements

APPENDIX B

SEALANT REFERENCE TABLE

<i>Sealant Type</i>	<i>General Characteristics</i>	<i>Generic Use</i>
ASTM D 1190	Hot-applied, elastic-type sealant. Asphalt based sealant containing ground rubber from tires and reinforcing fillers. May be tracked on pavement by traffic or pedestrians. Sealant solid at room temperature.	Sealing joints and cracks in asphalt and portland cement concrete pavements. Not intended for use in areas where fuel spillage is expected.
ASTM D 3405	Hot-applied sealant. Asphalt based sealant containing virgin ground rubber, plasticizers and reinforcing fillers. Similar to FS SS-S-1401 sealants. Sealant solid at room temperature.	Sealing joints and cracks in asphalt and portland cement concrete pavements. Not intended for use in areas where fuel spillage is expected. Generally this sealant is of higher quality than ASTM D 1190 sealants.
ASTM D 3406	Hot-applied sealant. Coal tar based sealant containing plasticizers and fillers. Sealant normally liquid at room temperature. Requires heating to become solid.	Sealing joints and cracks in portland cement concrete pavement. Should not be used to seal cracks in asphalt pavement due to possible incompatibility of coal tar and asphalt.
ASTM D 3569	Hot-applied, jet-fuel-resistant sealant. Coal tar based sealant containing polyvinyl chloride (PVC), plasticizers, and fillers. Similar to FS 55-5-1614 sealants. Sealant liquid at room temperature. Requires heating to become solid.	Sealing joints and cracks in portland cement concrete pavement where fuel spillage is expected. Should not be used to seal cracks in asphalt pavement due to possible incompatibility of coal tar and asphalt.
ASTM D 2628	Preformed polychloroprene elastomeric joint seals, also known as compression seals. Consists of a multiple web design which requires the seal to remain in compression to function properly. The seal is installed using a lubricant/adhesive.	Sealing joints in new portland cement concrete. Not normally used for sealing cracks or resealing joints due to nonuniformity of seal reservoir. Can be used in areas where fuel spillage and heat such as aircraft blast are expected. Seal should also conform to ASTM D 2628.
FS SS-S-1401	Hot-applied sealant. Asphalt based sealant containing virgin ground rubber, plasticizers, and reinforcing fillers. Similar to ASTM D 3405 sealants. Sealant solid at room temperature.	Sealing joints and cracks in asphalt and portland cement concrete pavements. Not intended for use in areas where fuel spillage is expected.
FS SS-S-1614	Hot-applied, jet-fuel-resistant sealant. Coal tar based sealant containing polyvinyl chloride (PVC), plasticizers, and fillers. Similar to ASTM D 3569 except sealant can be either a solid at room temperature that requires heat to become solid.	Sealing joints and cracks in portland cement concrete pavement where fuel spillage is expected. Should not be used to seal cracks in asphalt pavement due to possible incompatibility between coal tar and asphalt.
FS SS-S-200	Cold-applied, two-component jet-fuel-resistant and heat resistant sealant. May be polyurethane, polysulfide, or coal tar base. Individual components are liquid at room temperature and become solid upon mixing.	Sealing joints or cracks in portland cement pavement subjected to fuel spillage and heat such as aircraft exhaust.
FS SS-S-164*	Hot-applied nonfuel-resistant sealant.	Specification was canceled 17 July 1975. FS SS-S-1401 supersedes this specification.
FS SS-S-167*	Hot-applied jet-fuel resistant sealant.	Specification was canceled 11 August 1975. FS SS-S-1614 supersedes this specification.
FS SS-S-195*	Cold-applied, two-component, nonfuel and nonblast-resistant sealant.	Specification was canceled in 1976.

* Have been deleted.

APPENDIX C

COMPUTING THE WORKING RANGE OF JOINTS AND SEALANTS

C-1. Working Range Calculations.

a. The stresses that develop in field-poured sealants and compression seals are the direct result of the joints opening and closing as the slabs move due to temperature changes. The amount of deformation that the seal can withstand before failure occurs is dependent upon the joint size and type of seal. The following formulas are used in determining the joint and seal size.

b. The first step is to calculate the amount of joint opening likely to occur in the pavement using the following equation:

$$dL = 12 \cdot C \cdot L \cdot (\alpha \cdot dT + \epsilon)$$

where

dL = Joint opening (in inches) caused by the temperature change dT and drying shrinkage of portland cement concrete.

α = Thermal coefficient of contraction for concrete (approximately 5 to $6 \cdot 10^{-6}/^{\circ}\text{F}$).

ϵ = Drying shrinkage coefficient of concrete (approximately 0.50 to $2.50 \cdot 10^{-4}$ inch/inch for new concrete; 0.0 for old concrete).

L = Joint spacing (in feet).

dT = Temperature range ($T - T_{\min}$) or ($T_{\max} - T$), where T is the temperature of the pavement at the time of sealing.

T_{\max} = Maximum pavement temperature.

T_{\min} = Minimum pavement temperature.

C = Adjustment factor due to slab or base friction restraint (0.65 for stabilized base, 0.80 for granular base, and 1.0 for the subgrade).

12 = a constant to convert joint spacing in feet to inches.

c. The following example demonstrates how to compute joint movement of an old concrete pavement ($\epsilon=0.0$). The necessary data include:

(1) Maximum pavement temperature = $140^{\circ}\text{F} = T_{\max}$.

(2) Minimum pavement temperature = $20^{\circ}\text{F} = T_{\min}$.

(3) Joint spacing = 25 feet = L .

(4) Subbase type is granular; therefore, $C = 0.80$.

(5) Temperature at sealing time = $90^{\circ}\text{F} = T$.

(6) Thermal coefficient of contraction = $\alpha = 5 \cdot 10^{-6}/^{\circ}\text{F}$.

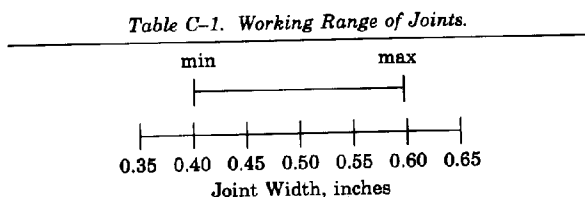
d. Using the above data the following is provided:

$$\begin{aligned} (1) \quad dL_{\text{opening}} &= 12 \cdot C \cdot L \cdot (\alpha \cdot (T - T_{\text{min}}) + \epsilon) \\ dL_{\text{opening}} &= (12)(0.80)(25)(5 \cdot 10^{-5}(90 - 20)) \\ dL_{\text{opening}} &= \underline{0.084 \text{ inches}} \\ (2) \quad dL_{\text{closing}} &= 12 \cdot C \cdot L \cdot (\alpha \cdot (T_{\text{max}} - T) + \epsilon) \\ dL_{\text{closing}} &= (12)(0.80)(25)(5 \cdot 10^{-5}(140 - 90)) \\ dL_{\text{closing}} &= \underline{0.060 \text{ inches}} \end{aligned}$$

e. The joint width is typically 0.5 inches at the time of sealing. This or the current measured width of a joint can be used to calculate the maximum and minimum width of that joint during the year. Using the openings calculated above and assuming 0.5 inches to be the width of the joint, the maximum and minimum widths are calculated as follows:

$$\begin{aligned} (1) \quad D_{\text{max}} &= 0.5 + 0.084 = \underline{0.584 \text{ inches}} \\ D_{\text{max}} &= \text{maximum joint width.} \\ (2) \quad D_{\text{min}} &= 0.5 - 0.060 = \underline{0.440 \text{ inches}} \\ D_{\text{min}} &= \text{minimum joint width.} \end{aligned}$$

f. The joint width or working range of a joint is illustrated on a linear scale in table C-1.

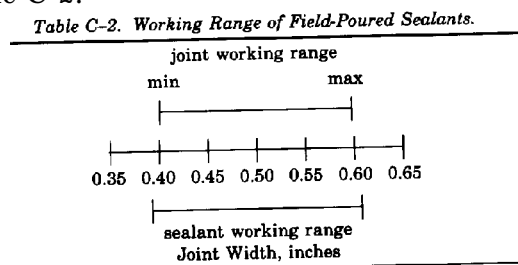


C-2. Field-Poured Sealants.

a. Field-poured sealants have a working expansion-compression range of approximately 20 percent. For a joint width of 0.5 inches, the working range of the sealant would be:

$$0.5 \pm 0.5(0.2) = \underline{0.6 \text{ to } 0.4 \text{ inches}}$$

The working range of the sealant is illustrated in table C-2.



b. If the working range of the sealant is less than the working range of the joint, the sealant will be overstressed and fail. When it is determined that the working range of the joint is larger than the sealant working range, the joint width should be increased to allow the working range of the sealant to be larger than the working range of the joint.

C-3. Preformed Elastomeric Compression Seals.

a. *Working Range.* Preformed elastomeric compression seals must remain in compression at all times, whether the joint is opened or closed. The seal must remain compressed at least 20 percent when the joint is open but not compressed more than 80 percent of the seal width when the joint is closed. The working range of the joint can be used to calculate the maximum and minimum width of the seal that may be used in a joint. The calculations are as follows:

- (1) Seal Width_{max} = (Minimum Joint Width)
(5.0) (not compressed more than 80 percent)
- (2) Seal Width_{min} = (Maximum Joint Width)
(1.2) (remains in compression at least 20 percent)

b. *Seal Width.* Using the joint width from the previous example, the following results are obtained:

(1) Seal Width_{max} = (0.440X5.0) = 2.20 inches

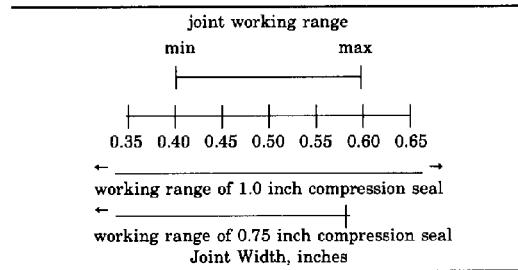
(2) Seal Width_{min} = (0.584X1.2) = 0.70 inches The width of the seal selected should be approximately the average of these two extremes (1.45 inches). A general rule of thumb is to select a seal twice the joint width at the time of sealing if it meets the above criteria. In this case, a 1-inch seal would meet the requirements. The working range of the seal would be:

(a) Max = 1.0 - (0.2)(1.0) = 0.80 inches
(20 percent compression)

(b) Mm = 1.0 - (0.6)(1.0) = 0.40 inches
(60 percent compression)

The working range of the seal is illustrated in table C-3.

Table C-3. Working Range of Preformed Elastomeric Compression Seals



Again, the working range of the seal must be larger than the working range of the joint for the seal to perform properly.

c. A seal width of 3/4 inch would also meet the range requirements at a cheaper cost although it would be very close to being undercompressed. These guidelines must be followed if the seals are to perform properly. If the size restrictions are not properly considered, the seal in even the most well prepared joint will not exhibit a normal life span.

APPENDIX D

LIFE-CYCLE COST ANALYSIS

D-1. Procedure.

a. In any rehabilitation project, the decision criterion used to select an alternative must evaluate that alternative over a future time period. This analysis is usually termed a "life-cycle cost analysis." Short term repairs that may be inexpensive initially may end up costing more than another alternative after repairs to the alternative have been made several times over the life of the pavement. The life-cycle cost analysis clearly shows which alternative will give the least cost over the life of the pavement. After completion of life-cycle costing, one should consider the impact of each alternative on interference with mission operations.

b. *Required Data.* To perform the life-cycle cost analysis, certain data are required for each of the sealing alternatives. The data required includes:

(1) Unit cost of the sealant in place. This can be broken into material cost and installation.

(2) The expected remaining life, in years, of the pavement feature being resealed before major rehabilitation or abandonment is scheduled.

(3) The expected lives of the sealants are being considered as alternatives. Because some installations may have adequate data on the service life of sealants while others may not, the major command engineers must have input in setting life expectancy levels for a life-cycle cost analysis compatible with paragraph (2) as mentioned.

(4) The interest rate in effect over the life of the pavement must be selected. Depending upon the economic climate, this value may be very difficult to estimate for any time in the future.

(5) The use of inflation in a life-cycle cost analysis is somewhat controversial; however, it should be used by the installation when evaluating alternatives. One method to obtain inflation is to use the expected future cost of materials and labor.

c. *Procedure.* A life-cycle cost analysis can be performed by completing the following steps:

(1) Determine how many times the pavement must be resealed over the analysis period.

(2) Determine the cost of each resealing operation.

(3) Determine the present worth of the re-sealing costs by using the following formula:

$$PW = R * [1.0 / (1 + i)^n]$$

where

PW = the present worth.

i = the annual interest rate.

R = the cost of each sealant installation.

n = the number of years from the present time until resealing will be required again.

(4) Repeat the formula for every sealing period and sum the total present worth of each alternative.

d. *Selecting the Best Alternative.* Select the alternative with the least present worth. This cost indicates the alternative that would cost the least over the entire life expressed as dollars at today's value. In this manner, a relatively expensive sealant with long life may be more economical over the life of the pavement than a series of less costly procedures. The decision on whether this higher initial investment is affordable must be made separately, considering more than just life-cycle cost.

D-2. Example.

a. *Data.* A pavement has a life of 16 years before major rehabilitation in the form of an overlay is performed. The interest rate for this period is estimated to be 12 percent a year. Inflation is not considered in this initial analysis. There are two alternatives for sealing the pavement. The two alternatives are:

(1) Seal every 3 years at a cost of \$0.60 per linear foot.

(2) Use a seal with a life expectancy of 15 years at a cost of \$2.00 per linear foot.

b. *Calculations.* For the first alternative, there will be six costs of \$0.60 per foot. The joints must be resealed before the overlay in year 16 so that there are five time increments. For the second alternative, there will be one initial payment at time zero and one resealing job before the overlay with the least expensive method. The computation of the present worth for both alternatives is as follows:

(1) Alternative 1

- (a) $PW_{\text{time } 0} = 0.60 \cdot [1/(1.12)^0] = \underline{\$0.60 \text{ per ft}}$
- (b) $PW_{3 \text{ yrs}} = 0.60 \cdot [1/(1.12)^3] = \underline{\$0.427 \text{ per ft}}$
- (c) $PW_{6 \text{ yrs}} = 0.60 \cdot [1/(1.12)^6] = \underline{\$0.304 \text{ per ft}}$
- (d) $PW_{9 \text{ yrs}} = 0.60 \cdot [1/(1.12)^9] = \underline{\$0.216 \text{ per ft}}$
- (e) $PW_{12 \text{ yrs}} = 0.60 \cdot [1/(1.12)^{12}] = \underline{\$0.154 \text{ per ft}}$
- (f) $PW_{15 \text{ yrs}} = 0.60 \cdot [1/(1.12)^{15}] = \underline{\$0.110 \text{ per ft}}$
- (g) Total present worth = \$1.856 per ft

(2) Alternative 2

- (a) $PW_{\text{time } 0} = 2.00 \cdot [1/(1.12)^0] = \underline{\$2.00 \text{ per ft}}$
- (b) $PW_{15 \text{ yrs}} = 0.60 \cdot [1/(1.12)^{15}] = \underline{\$0.110 \text{ per ft}}$
- (c) Total present worth = \$2.11 per ft

c. *Comparison.* The seal with the lowest initial cost was the least expensive alternative over the life of the pavement for this example; however,

before alternative 1, which has the least present worth, is selected, other considerations must be made. The considerations are called decision factors and they include:

(1) How certain are the prices that have been selected for future years (inflation)?

(2) How certain are the life expectancies that have been assigned for the various alternatives?

(3) If the higher initial cost alternative had the lowest present worth, is funding available now to perform the alternative with the highest initial cost?

(4) What is the influence of each alternative on mission operations?

d. *Inflation.* When inflation is included in the analysis, it can drastically alter the selection process. The inflation rate must apply to the materials and procedures being investigated. It must not be a general economy inflation factor. Instead, each present worth calculation must be multiplied by an inflation factor:

$$(1) \text{ IF} = (1 + \text{if})^n$$

where

IF = calculated inflation factor.

if = inflation rate, percent.

n = number of years to calculation.

(2) Using an assumed inflation rate of 12 percent,

alternative 1 would change as follows:

- (a) $PW_{\text{time } 0} = 0.60 \cdot 1.0 = \underline{\$0.60 \text{ per ft}}$
- (b) $PW_{3 \text{ yrs}} = 0.472 \cdot 1.405 = \underline{\$0.663 \text{ per ft}}$
- (c) $PW_{6 \text{ yrs}} = 0.304 \cdot 1.974 = \underline{\$0.600 \text{ per ft}}$
- (d) $PW_{9 \text{ yrs}} = 0.216 \cdot 2.773 = \underline{\$0.599 \text{ per ft}}$
- (e) $PW_{12 \text{ yrs}} = 0.154 \cdot 3.896 = \underline{\$0.599 \text{ per ft}}$
- (f) $PW_{15 \text{ yrs}} = 0.110 \cdot 5.474 = \underline{\$0.607 \text{ per ft}}$
- (g) Total present worth = \$3.668 per ft

(3) Using an assumed inflation rate of 12 percent,

alternative 2 would change as follows:

$$(a) \text{ PW} = \$2.00 + 0.607 = \underline{\$2.607 \text{ per ft}}$$

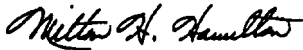
(4) The use of inflation favors the higher initial cost that usually has a lower cost over the period being inflated, which in this case would be alternative 2. Again, the decision factors must be considered before selecting the more preferred alternative for a given situation.

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