Most joints, and some cracks in concrete structures, require sealing against the adverse effects of environmental and service conditions. This report is a guide to better understanding of the properties of joint sealants and to where and how they are used in present practice.

Described and illustrated are: The functioning of joint sealants; required properties, available materials and applicable specifications for field-molded sealants and preformed sealants such as waterstops, gaskets, or compression seals; determination of joint movements, widths, and depths; outline details of joints and sealants used in general structures, fluid containers, and pavements; methods and equipment for sealant installation including preparatory work; performance of sealants; and methods of repairing defective work or maintenance resealing. Finally, improvements needed to insure better joint sealing in the future are indicated.

New developments in field-molded and preformed sealants and their use are described together with means of measuring joint movements. Appendix C provides a list of specifications and their sources.

**Keywords:** bridge decks; bridges (structures); buildings; compression seals; concrete construction; concrete dams; concrete panels; concrete pavements; concrete pipes; concrete slabs; concretes; control joints; cracking (fracturing); gaskets; isolation joints; joint fillers; joint sealers; joints (junctions); linings; mastic; parting agents; precast concrete; reinforced concrete; repairs; sealers; specifications; tanks (containers); thermoplastic resins; thermosetting resins; walls.

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CHAPTER I-GENERAL

1.1-Background
This report is an update of the committee report originally issued in 1970 and revised in 1977.1

Nearly every concrete structure has joints (or cracks) that must be sealed to insure its integrity and serviceability. It is a common experience that satisfactory sealing is not always achieved. The sealant used, or its poor installation, usually receives the blame, whereas often there have been deficiencies in the location or the design of the joint that would have made it impossible for any sealant to have done a good job.

1.2-Purpose
The purpose of this guide is to show that by combining the right type of sealant with proper joint design for a particular application and then carefully installing it, there is every prospect of successfully sealing the joint and keeping it sealed. This report is a guide to what can be done rather than a standard practice, because in most instances there is more than one choice available. Without specific knowledge of the structure, its design, service use, environment, and economic constraints, it is impossible to prescribe a “best joint design” or a “best sealant”. The information contained in this guide is, however, based on current practices and experience judged sound by the committee and used by one or more of the many reputable organizations consulted during its compilation. It should therefore be useful in making an enlightened choice of a suitable joint sealing system and to ensure that it is then properly detailed, specified, installed, and maintained.

No attempt has been made to reference the voluminous literature except for those papers necessary to an understanding of the subject background. The present state of the art of joint sealing and identification of needed research may be found in the proceedings of the 1st and 2nd World Congresses on Joint Sealing and Bearing Systems held in 1981 and 1986.23 A glossary of terms that may not be generally familiar is provided in the appendix.

1.3-Why joints are required
Concrete normally undergoes small changes in dimensions as a result of exposure to the environment or by the imposition or maintenance of loads. The effect may be permanent contractions due to, for example: initial drying, shrinkage, and irreversible creep. Other effects are cyclical and depend on service conditions such as environmental differences in humidity and temperature or the application of loads and may result in either expansions or contractions. In addition, abnormal volume changes, usually permanent expansions, may occur in the concrete due to sulfate attack, alkali-aggregate reactions, and certain aggregates, and other causes.

The results of these changes are movements, both permanent and transient, of the extremities of concrete structural units. If, for any reason, contraction movements are excessively restrained, cracking may occur within the unit. The restraint of expansion movement may result in distortion and cracking within the unit or crushing of its end and the transmission of unanticipated forces to abutting units. In most concrete structures these effects are objectionable from a structural viewpoint. One of the means of minimizing them is to provide joints at which movement can be accommodated without loss of integrity of the structure.

There may be other reasons for providing joints in concrete structures. In many buildings the concrete serves to support or frame curtainwalls, cladding, doors, windows, partitions, mechanical and other services. To prevent development of distress in these sections it is often necessary for them to move to a limited extent independently of overall expansions, contractions and deflections occurring in the concrete. Joints may also be required to facilitate construction without serving any structural purpose.

1.4-Why sealing is needed
The introduction of joints creates openings which must usually be sealed in order to prevent passage of gases, liquids or other unwanted substances into or through the openings.
JOINT SEALANTS

In buildings, to protect the occupants and the contents, it is important to prevent intrusion of wind and rain. In tanks, most canals, pipes and dams, joints must be sealed to prevent the contents from being lost.

Moreover, in most structures exposed to the weather the concrete itself must be protected against the possibility of damage from freezing and thawing, wetting and drying, leaching or erosion caused by any concentrated or excessive influx of water at joints. Foreign solid matter, including ice, must be prevented from collecting in open joints; otherwise, the joints cannot close freely later. Should this happen, high stresses may be generated and damage to the concrete may occur.

In industrial floors the concrete at the edges of joints often needs the protection of a filler or sealant between armored faces capable of preventing damage from impact of concentrated loads such as steel-wheeled traffic.

In recent years, concern over the spread of flames, smoke and toxic fumes has made the fire resistance of joint sealing systems a consideration, especially in high-rise buildings.

The specific function of sealants is to prevent the intrusion of liquids (sometimes under pressure), solids or gases, and to protect the concrete against damage. In certain applications secondary functions are to improve thermal and acoustical installations, damp vibrations or prevent unwanted matter from collecting in crevices. Sealants must often perform their prime function, while subject to repeated contractions and expansions as the joint opens and closes and while exposed to heat, cold, moisture, sunlight, and sometimes, aggressive chemicals. As discussed in Chapters 2, 3 and 6, these conditions impose special requirements on the properties of the materials and the method of installation.

In most concrete structures all concrete-to-concrete joints (contraction, expansion and construction), and the periphery of openings left for other purposes require sealing. One exception is contraction joints (and cracks) that have very narrow openings, for example, those in certain short plain slab aggregate interlock. Other exceptions are certain construction joints, for example, monolithic joints not subject to fluid pressure or joints between precast units used either internally or externally with intentional open draining joints.

1.5-Joint design as part of overall structural design

In recent years it has become increasingly recognized that there is more to providing an effective seal at a joint than merely filling the “as constructed” gap with an impervious material. The functioning of the sealant, described in Chapter 2, depends as much on the movement to be accommodated at the joint and on the shape of the joint, as on the physical properties of the sealant. Joint design, which broadly covers the interrelationship of these factors, is discussed in some detail in Chapter 4 since it should be an important, sometimes governing, consideration in the design of most concrete structures. It is considered beyond the scope of this guide on sealing joints to venture into the whole field of volume change in concrete and the structural considerations that determine the location and movement of joints. It is, however, pertinent to point out that many years of experience in trying to keep joints sealed indicate that joint movements may vary widely from those postulated by theory alone.

There are probably as many “typical details” of joints in existence as there are structures incorporating them. Faced with the problem of illustrating, from the viewpoint of how they can be sealed, the various types of joints and their uses, it appeared best to present them in schematic form in Chapter 5 to bring out the principles involved for each of the three major groups of application to concrete:

1. Structures not under fluid pressure (most buildings, bridges, storage bins, retaining walls, etc.).
2. Containers subject to fluid pressure (dams, reservoirs, tanks, canal linings, pipe lines, etc.).
3. Pavements (highways and airfield).

From both the structural and sealant viewpoint, irrespective of design detail and end use, all the joints may be classified according to their principal function and configuration.

1.6-Types of joints and their function

1.6.1 Contraction (control) joints-These are purposely made planes of weakness designed to regulate cracking that might otherwise occur due to the unavoidable, often unpredictable, contraction of concrete structural units. They are appropriate only where the net result of the contraction and any subsequent expansion during service is such that the units abutting are always shorter than at the time the concrete was placed. They are frequently used to divide large, relatively thin structural units, for example, pavements, floors, canal linings, retaining and other walls into smaller panels. Contraction joints in structures are often called control joints because they are intended to control crack location.

Contraction joints may form a complete break, dividing the original concrete unit into two or more units. Where the joint is not wide, some continuity may be maintained by aggregate interlock. Where greater continuity is required without restricting freedom to open and close, dowels, and in certain cases steps or keyways, may be used. Where restriction of the joint opening is required for structural stability, appropriate tie bars or continuation of the reinforcing steel across the joint may be provided.

The necessary plane of weakness may be formed either by partly or fully reducing the concrete cross section. This may be done by installing thin metallic, plastic or wooden strips when the concrete is placed or by sawing the concrete soon after it has hardened.

1.6.2 Expansion (isolation) joints-These are designed to prevent the crushing and distortion (including displacement, buckling and warping) of the abutting concrete structural units that might otherwise occur due to the compressive forces that may be developed by expansion, applied loads or differential movements arising from the configuration of the structure or its settlement. They are frequently used to isolate walls from floors or roofs; columns from floors or cladding; pavement slabs and decks from bridge abutments or piers; and in other locations where restraint or transmission of secondary forces is not desired. Many designers consider it good practice to place such joints where walls or slabs change direction as in L-, T-, Y- and U-shaped structures and where different cross sections develop. Expansion joints in structures are often called isolation joints because they are
intended to isolate structural units that behave in different ways.

Expansion joints are made by providing a space for the full cross section between abutting structural units when the concrete is placed through the use of filler strips of the required thickness, bulkheading or by leaving a gap when precast units are positioned. Provision for continuity or for restricting undesired lateral displacement may be made by incorporating dowels, steps or keyways.

1.6.3 Construction joints—These are joints made at the surfaces created before and after interruptions in the placement of concrete or through the positioning of precast units. Locations are usually predetermined by agreement between the design professional and the contractor, so as to limit the work that can be done at one time to a convenient size with the least impairment of the finished structure, though they may also be necessitated by unforeseen conditions in concrete operations. Depending on the structural design they may be required to function later as expansion or contraction joints having the features already described, or they may be required to be monolithic; that is, with the second placement soundly bonded to the first to maintain complete structural integrity. Construction joints may run horizontally or vertically depending on the placing sequence required by the design of the structure.

1.6.4 Combined and special purpose joints—Construction joints (see Section 1.6.3) at which the concrete in the second placement is intentionally separated from that in the preceding placement by a bond-breaking membrane, but without space to accommodate expansion of the abutting units, also function as contraction joints (see Section 1.6.1). Similarly, construction joints in which a filler displaced, or a gap is otherwise formed by bulkheading or the positioning of precast units, function as expansion joints (see Section 1.6.2). Conversely, expansion joints are often convenient for forming nonmonolithic construction joints. Expansion joints automatically function as contraction joints, though the converse is only true to an amount limited to any gap created by initial shrinkage.

Hinge joints are joins that permit hinge action (rotation) but at which the separation of the abutting units is limited by tie bars or the continuation of reinforcing steel across joints. This term has wide usage in, but is not restricted to, pavements where longitudinal joints function in this manner to overcome warping effects while resisting deflections due to wheel loads or settlement of the subgrade. In structures, hinge joints are often referred to as articulated joints.

Sliding joints may be required where one unit of a structure must move in a plane at right angles to the plane of another unit, for example, in certain reservoirs where the walls are permitted to move independently of the floor or roof slab. These joints are usually made with a bond-breaking material such as a bituminous compound, paper or felt that also facilitates sliding.

1.6.5 Cracks—Although joints are placed in concrete so that cracks do not occur elsewhere, it is extremely difficult to prevent occasional cracks between joints. As far as sealing is concerned, cracks may be regarded as contraction joints of irregular line and form. Treatment of cracks is considered in Section 7.2.2.

1.7-Joint configurations

In the schematic joint details for various types of concrete structures shown in Chapter 5, two basic configurations occur from the standpoint of the functioning of the sealant. These are known as butt joints and lap joints.

In butt joints, the structural units being joined abut each other and any movement is largely at right angles to the plan of the joint. In lap joints, the units being joined override each other and any relative movement is one of sliding. Butt joints, and these include most stepped joints, are by far the most common. Lap joints may occur in certain sliding joints (see Section 1.6.4), between precast units or panels in curtain-walls, and at the junctions of these and of cladding and glazing with their concrete or other framing. As explained in Chapter 2, the difference in the mode of the relative movement between structural units at butt joints and lap joints, in part, controls the functioning of the sealant. In many of the applications of concern to this guide, pure lap joints do not occur, and the functioning of the lap joint is in practice a combination of butt and lap joint action.

From the viewpoint of the sealant, two sealing systems should be recognized. First, there are open surface joints, as in pavements and buildings in which the joint sealant is exposed to outside conditions on at least one face. Second, there are joints, as in containers, dams, and pipe lines, in which the primary line of defense against the passage of water is a sealant such as a waterstop or gasket buried deeper in the joint. The functioning and type of sealant material that is suitable and the method of installation are affected by these considerations.

In conclusion, two terms should be mentioned since they are in wide, though imprecise use. Irrespective of their type or configuration, joints are often spoken of as “working joints” where significant movement occurs and as “nonworking joints” where movement does not occur or is negligible.
2.3-Behavior of sealants in butt joints

As a sealed butt joint opens and closes, one of three functional conditions of stress can exist. These are:

1. The sealant is always in tension. Some waterstops [Fig. 1 (2A)] function to a large degree in this way though compressive forces may be present at their sealing faces and anchorage areas.

2. The sealant is always in compression. This principle, as illustrated in Fig. 1 (1A, B, C), is the one on which compression seals and gaskets are based.

3. The sealant is cyclically in tension or compression. Most field-molded and certain preformed sealants work in this way. The behavior of a field-molded sealant is illustrated in Fig. 2 (1A, B, C) and an example of a preformed tension-compression seal is shown in Fig. 9 (4).

A sealant that is always in tension presupposes that the sealant was installed when the joint was in its fully closed position so that thereafter, as the joint opens and closes, the sealant is always extended. This is only possible with preformed seals such as waterstops which are buried in the freshly mixed concrete and have mechanical end anchors. Field-molded sealants cannot be used this way and the magnitude of the tension effects shown in Fig. 2 (1B) would likely lead to failure as the joint opened in service. Most sealing systems used in open surface joints are therefore designed to function under either sealant in compression or a condition of cyclically in compression and tension to take best advantage of the properties of the available sealant materials and permit ease of installation.

2.4-Malfunctions of sealants

Malfunction of a sealant under conditions of stress consists of a tensile failure within the sealant or its connection to the joint face. These are known as cohesive and adhesive failures, respectively.

In the case of preformed sealants that are intended to be always in compression, malfunctioning usually results in failure to generate sufficient contact pressure with the joint faces. This leads to the defects shown in Fig. 3 (1). This figure also shows defects in water stops. Splits, punctures or leakage at the anchorage may also occur with strip (gland) seals.

Malfunctioning of a field-molded sealant, intended to function cyclically in tension or compression, may develop with repetitive cycles of stress reversal or under sustained stress at constant deformation. The resulting failure will then be shown as one of the defects illustrated in Fig. 4.

Where secondary movements occur in either or both directions at right angles to the main movement, including impact at joints under traffic, shear forces occur across the sealants. The depth (and width) of the sealant required to accommodate the primary movement can more than provide any shear resistance required.

2.5 Behavior of sealants in lap joints

The sealant as illustrated in Fig. 2 (2A, B, C) is always in shear as the joint opens and closes. Tension and compression effects may, however, be added in the modified type of lap joint used in many building applications.

2.6-Effect of temperature

Changes in temperature between that at installation and the maximum and minimum experienced in service affect sealant behavior. This is explained by reference to Fig. 5.

The service range of temperature that affects the sealant is not the same as the ambient air temperature range. It is the actual temperature of the units being joined by the sealant that govern the magnitude of joint movements that must be accommodated by the sealant. By absorption and transfer of heat from the sun and loss due to radiation, etc., depending on the location, exposure, and materials being joined, the difference between service range of temperature and the range of ambient air temperature can be considerable.

For the purpose of this guide, the service range or temperatures has been assumed to vary from -20 to + 130 F (-29 to + 54 C) for a total range of 150 F (83C). In very hot or cold climates or where the joint is between concrete and another material that absorbs or loses heat more readily than concrete, the maximum and minimum values may be greater. This is particularly true in building walls, roofs and in pavements. On the other hand, inside a temperature-controlled building or in structures below ground the range of service temperatures can be quite small. This applies also to containers below water line. However, where part of a container is permanently out of the water, or is exposed by frequent dewatering, the effects of a wider range of temperatures must be taken into account.

The rate of movement due to temperature change for short periods (ie: an hr, a day) is quite as important as the total movement over a year. Sealants generally perform better, that is, respond to and follow joint opening and closing when this movement occurs at a slow and uniform rate. Unfortunately, joints in structures rarely behave this way; where restraint is present, sufficient force to cause movement must be generated before any movement occurs. When movement is inhibited due to frictional forces, it is likely to occur with a sudden jerk that might rupture a brittle sealant. Flexibility in the sealant over a wide range of temperatures is therefore important, particularly at low temperatures where undue hardening or loss of elasticity occurs with many materials that would otherwise be suitable as sealants. Generally all materials perform better at higher temperatures, though with certain thermoplastics softening may lead to problems of sag, flow and indentation.

Furthermore, in structures having a considerable number of similar joints in series, for example, retaining walls, canal linings and pavements, it might be expected that an equal share of the total movement might take place at each joint. However, one joint in the series may initially take more movement than others and therefore the sealant should be able to handle the worst combination.

These considerations are discussed in detail in Chapter 4.

2.7-Shape factor in field-molded sealants

Field-molded sealants should be 100 percent solids (or semi-solids) at service temperatures and as shown in Fig. 2, they alter their shape but not their volume as the joint opens and closes. These strains in the sealant and hence the adhesive and cohesive stresses developed are a critical function of the shape of the sealant. For a given sealant then, its elastic
The behavior of these preformed sealants depends on a combination of their elastic and plastic properties acting under sustained compression.

1. COMPRESSION SEALS AND GASKETS

(A) AS INSTALLED

Sealant is: ............................................
Sealant must: ............................................

(B) JOINT OPEN

Always in compression

(C) JOINT CLOSED

Always in compression

Change its shape as its width changes (Note 1)

(ii) Material requirements for good performance:

(A)
(a) Good contact (bond not needed)
(b) Correct size
(c) Suitable configuration

(B)
(d) Rubber-like properties

(C)
(e) Low compression set
(f) Webs should not weld
(g) Should not extrude from the joint

Also required (see Section 3.1) (1) Impermeability (3) Recovery (7) Nonembrittlement (8) Not deteriorate

(iii) Deficiencies in (b) (d) (e) (f) predisposes to loss of contact pressure. See Fig. 3 for consequences

Note 1
Compression seals in working joints require to be compartmentalized or foldable to meet this criterion, gaskets in nonworking joints may not.

2. WATERSTOPS

These seals are normally in tension during their working range.

(A) WORKING JOINT

AS INSTALLED

(Labyrinth ribs to anchor and form long path seal; or Dumbbell end to anchor and form cork-in-a-bottle seal.

JOINT OPEN

Center bulb or fold facilitates normal joint movements

TO WATER

(B) NONWORKING JOINT

Asphalt coating may be needed to assist seal and prevent bond at one end.

(ii) Material requirements

(A) (i) Flexible materials with properties similar to 1 above

(ii) Rigid flat plates also used where movement is comparatively small (otherwise sliding end or fold needed to permit movement). Must resist deformation due to fluid pressure. High durability since replacement not practical

(B) (i) Rigid noncorrosive materials suitable, some ductility and flexibility may be desirable

(ii) Flexible materials may be convenient but not essential

(iii) Deficiencies lead to failures shown in Fig. 3

Fig. 3 - How preformed compression seals, gaskets, and waterstops work
The behavior of field-molded sealants in service depends upon a combination of their elastic and plastic properties. Elasto-meric sealants should behave largely elastically to regain after deformation their original width and shape, that is full strain recovery (no permanent set) is desirable. However due to plastic behavior some set, flow, and stress relaxation occurs. The extent of its effect depends on the properties of the particular materials used and conditions such as temperature, repetition and rapidity of cycles of stress reversal and duration of deformation at constant strain. Largely plastic behavior, that is, returns to original shape by flow, is only acceptable for sealants used in joints with small and relatively slow movements.

**IN BUTT JOINTS**

(A) AS INSTALLED

(B) JOINT OPEN

(C) JOINT CLOSED

(i) Sealant is: . . . . . . .
Sealant should: . . . . . .
Sometimes in tension and sometimes in compression
Change its shape without changing its volume

![Diagram of sealant behavior in butt joints](image)

(ii) Material requirements for good performance:

(A) (a) Ease of installation
(b) Good bond to faces
(c) Homogeneity
(d) Low shrinkage

(B) (e) High ultimate strength in rubberlike materials
(f) Low elastic modulus in rubberlike materials
(g) Resistance to flow and stress relaxation

(C) (g) Resistance to flow and stress relaxation
(h) Low compression set

Also required (see Section 3.1) (1) Impermeability (3) Recovery (6) Resist flow (7) Not harden (8) Not deteriorate

(iii) Deficiencies in (b) (c) (f) predispose towards adhesion failure
(c) (d) (e) predispose towards cohesive failure
(h) (3) (6) predispose towards permanent deformation
(g) (3) (6) predispose towards flow and stress relaxation
(a) (7) (8) accelerate failures due to above causes

**IN LAP JOINTS**

(A) AS INSTALLED

(B) JOINT OPEN

(C) JOINT CLOSED

(i) Sealant is: . . . . . . .
Always in shear (Note 1)
Always in shear (Note 1)

(ii) Material Requirements: These are generally similar to those above for butt joints. Same materials used (see Chapter 3) with thickness of sealant (distance between the overlapping faces) equal to 2 times the deformation of sealant in shear (which is the joint movement) depending on installation temperature (See Fig. 5).

**Note 1:** If, as lap joint opens or closes, units move closer together or farther apart in plane at right angles to main movement then compression or tension of the sealant will also occur. This combination of movements is common in many applications to buildings (see Fig. 8). Where both types of movement are expected, the combined movement should be considered to determine the thickness of sealant, required in the joint design.

![Diagram of sealant behavior in lap joints](image)
Compression Seal Defects:

- Seal too small
- Seal lost ability to recover
- Seal is out of compression in cold weather
- Folded or twisted at installation
- Over compressed and extruded at expansion joints

**Failure noticed in hot weather**

**Improve Performance by:**

- A(i) Use wider seal
- A(ii) Form or saw cut joint with shoulder support seal
- A(iii) Avoid stretching during installation
- B Use seal with better properties to provide low temperature recovery and avoid compression set
- C Install seal straight, lubricate joint faces and also to prevent breaks avoid stretching
- D Usually occurs in pavements with mixed system of expansion-contraction joints, avoid this design
  - D(i) Form or saw groove wider
  - D(ii) Leave air gap on top of filler

Waterstop Defects:

- Over extended at joint - may split
- Honeycomb concrete areas permit leakage

**Improve Performance by:**

- A(i) Selecting size suitable for joint movement
- A(ii) Avoid rigid anchored flat types
- B [Diagram of Contamination of surface prevents bond to concrete]
- C Complete break due to poor or no splice
- D Honeycomb concrete areas permit leakage

**Fig. 3 - Defects in preformed sealants**
Defects
Gainly
Associated with
Elastic
Behavior

A) Too deep compared to width. Bonded at bottom
B) Overextended; may lead to fatigue failure
C) Peeling at points of stress concentration such as edges

D) Adhesion (bond to joint face) failure
E) Cohesion (internal rupture) failure
F) Impact spall if concrete is weak

WATER AND DEBRIS CAN NOW PENETRATE

(i) Better shape factor to reduce strains to those sealant can withstand
(ii) Use of bond breaker and/or backup materials
(iii) Closer joint spacings to reduce individual movements
(iv) Select better sealant
(v) Clean faces and prime
(vi) Saw rather than form armor edges
(vii) Improvements (i) to (vi) will greatly extend life of sealant. Eventual failure must be expected due to combinations of (B) (C) (D) (E), viscous flow, stress relaxation, permanent set etc., with repetitive cycles of stress reversals (See below)

Defects
Mainly
Associated with Non Elastic Behavior

Debris inclusion can lead to spalling, loss of sealant material, change in properties

Unsightly elephant ears run down vertical joints. Tracked by traffic
Also staining and damage due to exudation of volatiles

(i) Select sealant that will resist intrusion
(ii) Routine cleanup of debris
(iii) Indentation by spiked heels, etc. requires (i)

(i) Use better shape factor
(ii) Closer joint spacings
(iii) Avoid mixed expansion contraction joint pavement designs so as to equalize movement
(iv) Avoid trapping air and moisture at installation
(v) Select better sealant and more compressible filler and do not overfill joints or set filler too high

Defects
Mainly
Associated with Flow and Stress Relaxation

(i) Sags or (ii) humps after extension or (iii) necks after compression as direction of movement reverses

Little improvement possible if 'best' sealant is being used. Support may help somewhat.

Fig. 4 - Defects in field-molded sealants
Hypothetical cases showing the effect of installation temperatures in relation to the range of service temperatures, assuming the joint width at mean temperature equals the total joint movement between fully open and fully closed positions. (for simplicity of analysis only temperature effects shown)

**1. SEALANT INSTALLED AT MEAN TEMPERATURE**

(A) INSTALLATION AT MEAN TEMPERATURES 55°F (13°C)  
(B) JOINT OPEN AT -20°F (-29°C)  
(C) JOINT CLOSED AT 130°F (54°C)

Sealant must extend or compress by 50 percent in service.

**2. SEALANT INSTALLED AT LOW TEMPERATURE**

(A) INSTALLATION AT MINIMUM TEMPERATURES -20°F (-29°C)  
(B) JOINT HALF CLOSED AT 55°F (13°C)  
(C) JOINT CLOSED AT 130°F (54°C)

Sealant must compress by 66.66 percent in service.  
Probability of Permanent Deformation or Extrusion. 50 percent more sealant needed.

**3. SEALANT INSTALLED AT HIGH TEMPERATURE**

(A) INSTALLATION AT MAXIMUM TEMPERATURE 130°F (54°C)  
(B) JOINT HALF OPEN AT 55°F (13°C)  
(C) JOINT OPEN AT -20°F (-29°C)

Sealant must extend by 200 percent in service.  
Adhesion, cohesion, or peeling failure certain.

**CONCLUSION:** The closer the installation temperature is to the mean annual temperature the less will be the strain in the sealant in service and the better it will perform in butt joints. Taking into account practical considerations (see Chapter 4 and 6) an installation temperature range of from 40 to 90°F (4 to 32°C) is acceptable for most applications.

**Note:**

(i) Though not illustrated similar considerations govern the selection of the size of compression seals (see Section 4.5). Failure in case (3) above would however be by loss of contact with joint faces when seal passes out of compression.

(ii) Maximum deformation of a sealant in lap joints is also governed by installation temperature. Sealant thickness not less than joint movement acceptable for all temperatures (see Fig. 2.2) may be reduced to ½ provided installation temperature is between 40 and 90°F (4 and 32°C) (movement approximately ½ each way).

**Fig. 5-Effect of temperature on field-molded sealants**
Cases showing the effect of shape on the maximum strains ‘S’ which occur on the parabolic exposed surface of elastomeric sealants. Sealant assumed to be installed at mean joint width so that ½ change of width of sealant will be extension and ½ compression.

**BUTT JOINTS**

1. **JOINT DEPTH TO WIDTH RATIO 2: 1**

   **(A) AS INSTALLED MEAN WIDTH**

   Units of Sealant Required: 4

   ![Diagram](image1)

   **(B) JOINT OPEN**

   

   ![Diagram](image2)

   **(C) JOINT CLOSED**

   

   ![Diagram](image3)

   **CONCLUSION:** Increasing the width and reducing the depth generally reduces strains and hence improves performance of field molded sealants. At the same time less sealant is required. Shape Factor is less important in mastic sealants since plastic not elastic behavior dominates.

2. **JOINT DEPTH TO WIDTH RATIO 1: 1**

   Units of Sealant Required: 2

   ![Diagram](image4)

   ![Diagram](image5)

   ![Diagram](image6)

3. **JOINT DEPTH TO WIDTH RATIO 1: 2**

   Units of Sealant Required: 1

   ![Diagram](image7)

   ![Diagram](image8)

   ![Diagram](image9)

**PURPOSE OF BOND BREAKER AND BACK UP:** In joints open on one face only the back face of the sealant must not adhere to the bottom of the sealant reservoir so that the sealant is free to assume the desired shape. See (A) below. Control of depth of sealant is achieved as shown in (B) where the joint is formed or sawn initially deeper than the required depth to width ratio. (Bi) and (Bii) present cases as to desirable shape of backup.

4. (A) **FUNCTION OF BOND BREAKER**

   ![Diagram](image10)

   **(B) FUNCTION OF BACKUP MATERIAL**

   ![Diagram](image11)

   **(Bi) CURRENT PRACTICE**

   ![Diagram](image12)

   **(Bii) While Detail (Bi) is widely accepted and used, some recent research suggests (B) may be better since, if backup material presents flat face to sealant, peeling stresses at corners are reduced.**

**Fig. 6—Shape factor and strains in field-molded sealants**
extensibility is a function of the shape of the mold in which it was installed as well as the physical properties of the material. A mathematical analysis of sealant deformation was made by Tons, whose laboratory measurements showed that the exposed surfaces of an elastically deformed sealant assume a parabolic shape until close to rupture. Tons concluded that total extensibility is increased directly with width and inversely with the depth of the sealant in the joint. From Tons’s data and that of Schutz, Fig. 6 (1A, B, C, 2A, B, C, 3A, B, C) has been prepared to illustrate the critical importance (and economy) of using a good shape factor especially with thermosetting, chemically curing field-molded sealants. Shape factor pertains to the ratio between the width of a sealant and its thickness (depth) determined by experience and lab tests.

It must be remembered that while selections of shape factor are essentially based on accommodating cohesive stresses in the sealant, at the time of placement an adequate area must be provided at the joint face to accommodate adhesive (bond) stresses. For this reason, experience has indicated a preference in certain applications, such as in concrete pavements, for a minimum 3:2 (depth to width) shape factor rather than the theoretically more desirable ratio (shown in Fig. 6) of 1:1 or 1:2 in order to achieve a better service performance.

2.8-Function of bond breakers and backup materials
Bond breakers and backup materials are used, as illustrated in Fig. 6 (4A, B), to achieve the desired shape factor in field-molded sealants. The principal material requirement for a bond breaker is that it should not adhere to the sealant. Important secondary benefits of a backup material are that it supports the sealant and helps resist indentation, sag and allows a sealant to take advantage of maximum extension. These may often be important considerations when selecting the appropriate type and shape of preformed backup material. The backup material must also be compressible without extruding the sealant and must recover to maintain contact with the joint faces when the joint is open.

2.9-Function of fillers in expansion joints
Fillers are used in expansion joints to assist in making the joint and to provide room for the inward movement of the abutting concrete units as they expand. Additionally they may be required to provide support for the sealant or limit its depth in the same manner that backup materials do. These requirements are usually met by preformed materials that can be compressed without significant extrusion and preferably recover their original width when compression ceases. Stiffness to maintain alignment during concrete placement and resistance to deterioration due to moisture and other service conditions are also usually required.

2.10-Function of primers
Laboratory and field experience indicates that priming joint faces is essential for certain field-molded sealants and can generally improve their bond strength and hence extensibility, especially at low temperatures. Depending on the sealant and condition of the sealant-to-joint interface, the improvement in adhesion may result from one or more of the following: sealing and penetration of the concrete pores, precoating of the concrete pores, precoating of the dust particules, reduction in bubble formation, and reduction in the absorption of oils by the concrete.

CHAPTER 3-SEALANT MATERIALS

3.1-General
This chapter deals with the functional properties of sealing and accessory materials. Because of their physical limitations many materials only perform well in joints of small initial width and subsequent movement. The configuration of the joint, the process by which it is constructed (formed) and access for installation of the sealant also impose restrictions on the types of material that may be suitable for a particular application.

In service, environmental conditions often dictate additional performance requirements beyond those needed to accommodate movements alone.

Selection of the most appropriate materials for a particular application is not a simple matter in view of all the variables involved. Once an understanding is gained of the basic properties of materials required, then available materials can be classified and related to their suitability in various types of joints. This information is conveniently displayed in a series of tables and is cross referenced in later figures which illustrate the details of various joint applications in concrete structures.

This chapter discusses field molded sealing materials used where one surface of the finished joint is open to permit the sealing operation. Sealants used for these applications are listed in Table 1. The joint design for an expansion (isolation) joint may consist of a filler strip below the area where the sealant will be placed, bond breaker material to separate the sealant from an adhering substrate, and backup materials to support the material from sagging. These appurtenant materials are listed in Table 2. Preformed materials used in joints open on at least one surface, materials used as water stops and gaskets are listed in Table 3.

Table 4 shows some of the current uses to which the various sealants are put, and consideration of storage and handling for installation. In cross-referencing types of materials the Roman numeral system is used in Tables 1 and 4 and in Fig. 7 to 12. Individual field-molded sealant materials are lettered A, B, C, and so on, as in Table 1. Individual preformed sealant materials are identified by numbers given in Table 3.

Appendix C lists various specifications and sources of current specifications.

3.2-Required properties of joint sealants
For satisfactory performance a sealant must:
1. Be an impermeable material.
2. Deform to accommodate the movement and rate of movement occurring at the joint.
3. Sufficiently retain its original properties and shape if subjected to cyclical deformations.
4. Adhere to concrete. This means that for all sealants; except those preformed sealants that exert a force against the concrete surfaces or are mechanically interlocked with an anchorage, the sealant must bond to the concrete surfaces and not fail in adhesion (lose its bond to the concrete) nor peel at corners or other local areas of high stress (see Fig. 4).
5. Not internally rupture or pull apart within itself (that is, fail in cohesion) (see Fig. 4).

6. Resist flow due to gravity (or fluid pressure) or unacceptable softening at higher service temperatures.

7. Not harden or become unacceptably brittle at lower service temperatures.

8. Not be adversely affected by aging, weathering or other service factors for a reasonable service life under the range of temperatures and other environmental conditions that occur (see Fig. 7 to 12).

In addition, depending on the specific service conditions, the sealant may be required to resist one or more of the following:

### TABLE 1-MATERIALS USED FOR JOINT SEALING

<table>
<thead>
<tr>
<th>GROUP</th>
<th>I MASTIC</th>
<th>FIELD-MOLDED</th>
<th>PREFORMED</th>
</tr>
</thead>
<tbody>
<tr>
<td>TYPE</td>
<td>VI</td>
<td></td>
<td>VI</td>
</tr>
<tr>
<td></td>
<td>II HOT APPLIED</td>
<td>III COLD APPLIED</td>
<td>VI CHEMICALLY CURING</td>
</tr>
<tr>
<td>Composition</td>
<td>(A) Drying Oils</td>
<td>(F) Asphalts</td>
<td>(N) Polyurethane</td>
</tr>
<tr>
<td></td>
<td>(B) Non-drying Oils</td>
<td>(G) Rubber Asphalts</td>
<td>(L) Polyurethane Coal Tar</td>
</tr>
<tr>
<td></td>
<td>(C) Low Melt, Point</td>
<td>(H) Pitch</td>
<td>(P) Polyurethane</td>
</tr>
<tr>
<td></td>
<td>Asphalt</td>
<td>(I) Coal Tars</td>
<td>(Q) Polyurethane Coal Tar</td>
</tr>
<tr>
<td></td>
<td>(D) Polybutadienes</td>
<td>(J) Rubber Coal Tars</td>
<td>(R) Silicones</td>
</tr>
<tr>
<td></td>
<td>(E) Polysolubilites</td>
<td>(K) All contain 100% solids</td>
<td>(K) Epoxy</td>
</tr>
<tr>
<td></td>
<td>or combination of D &amp; E</td>
<td>(L) (K) Contain 75%</td>
<td>(N) (R) contain 95-100% solids</td>
</tr>
<tr>
<td></td>
<td>All used with fillers,</td>
<td>All contain 90% solids</td>
<td>(O) (Q) contain 96-100% solids</td>
</tr>
<tr>
<td></td>
<td>all contain 100% solids,</td>
<td>All contain 100% solids</td>
<td></td>
</tr>
<tr>
<td></td>
<td>except D &amp; E which may</td>
<td>(O) May be an emulsion</td>
<td></td>
</tr>
<tr>
<td></td>
<td>contain solvent.</td>
<td>(P) May be either one</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>or two component system.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Q) (S) two component system.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colours</td>
<td>(A) (B) Varied</td>
<td>(K) Black only</td>
<td>(N) (R) (S)</td>
</tr>
<tr>
<td></td>
<td>(C) Black only</td>
<td>(L) (M) Varied</td>
<td>(O) (P)</td>
</tr>
<tr>
<td></td>
<td>(D) (E) Limited</td>
<td></td>
<td>(Q)</td>
</tr>
<tr>
<td>Setting Of Curing</td>
<td>Non-curing, remains</td>
<td>Non-curing, sets</td>
<td>Two component system-</td>
</tr>
<tr>
<td></td>
<td>viscous, A and B</td>
<td>upon cooling,</td>
<td>catalyst.</td>
</tr>
<tr>
<td></td>
<td>form skin on exposed</td>
<td>softened, sets</td>
<td>One component moisture</td>
</tr>
<tr>
<td></td>
<td>surface.</td>
<td>upon release</td>
<td>pickup from the air</td>
</tr>
<tr>
<td></td>
<td></td>
<td>of solvent or</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>evaporation of water.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(W) Resilient</td>
<td></td>
</tr>
<tr>
<td>Aging and Weathering Resistance</td>
<td>Low</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>(W) High resistance to weather</td>
<td>(W)</td>
<td>(W)</td>
</tr>
<tr>
<td>Increase in Hardness in Relation to (1) Age</td>
<td>High</td>
<td>High to Moderate</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>(W) No hardness</td>
<td></td>
<td>(W)</td>
</tr>
<tr>
<td></td>
<td>or (2) Low temp</td>
<td></td>
<td>(W)</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>High to Moderate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(W) No hardness</td>
<td></td>
<td>(W)</td>
</tr>
<tr>
<td>Recovery</td>
<td>Low</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>(W) High</td>
<td>(W)</td>
<td>Moderate</td>
</tr>
<tr>
<td>Resistance to Wear</td>
<td>Low</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>(W) High</td>
<td>(W)</td>
<td>Moderate</td>
</tr>
<tr>
<td>Resistance to Wear</td>
<td>Low</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>(W) High</td>
<td>(W)</td>
<td>Moderate</td>
</tr>
<tr>
<td>Shrinkage after installation</td>
<td>High</td>
<td>Varies</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>(W) None</td>
<td>(W)</td>
<td>Low</td>
</tr>
<tr>
<td>Resistance to Chemicals</td>
<td>High except to solvents and fuels</td>
<td>(F) (G) High except to solvents and fuels</td>
<td>Low to solvents, fuels and oxidizing acids</td>
</tr>
<tr>
<td></td>
<td>(H) (I) High and fuel resistant</td>
<td>(H) (I) High and fuel resistant</td>
<td>but moderate fuel resistance</td>
</tr>
<tr>
<td></td>
<td>(W) High</td>
<td>(H)</td>
<td>Low to alkalis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(I) High</td>
<td>(I) High</td>
</tr>
<tr>
<td>Modulus at 100% Elongation</td>
<td>Not applicable</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>(R) (O) (Q) Low</td>
<td>(R) High and Low</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>(R) (O) (Q) Low</td>
<td>(R) Net applicable</td>
</tr>
<tr>
<td>Allowable Extension and Compression</td>
<td>±3%</td>
<td>±5%</td>
<td>±7%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(W) ±25% extension</td>
<td></td>
</tr>
<tr>
<td>Other Properties</td>
<td>(A) (B) (D) (E) (O)</td>
<td>Due to softening in hot weather usable only in horizontal joints</td>
<td>(K) Usable in inclined joints</td>
</tr>
<tr>
<td></td>
<td>(D) (E) Pick up dirt, use in concealed location only.</td>
<td>(W) No flow at elevated temperatures</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(W)</td>
<td>(O)</td>
</tr>
<tr>
<td>Unit first cost</td>
<td>(A) (B) (C) very low</td>
<td>(F) (G) (H) (I)</td>
<td>(K) Very low</td>
</tr>
<tr>
<td></td>
<td>(D) (E) Low</td>
<td>(I)</td>
<td>(L) Low</td>
</tr>
<tr>
<td></td>
<td>(W) Medium</td>
<td>(M)</td>
<td>(M) High</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(W)</td>
<td>(O)</td>
</tr>
</tbody>
</table>

Note: Table 1-Materials Used for Joint Sealing provides a comprehensive list of materials and their characteristics, including their suitability for various conditions and environments. The table categorizes the materials into groups based on their properties and uses, such as THERMOPLASTICS, THERMOSETTING, and FIELD-MOLDED types. Each material is assessed for its performance in various conditions, including hardness, resistance to weathering, and temperature, ensuring the selection of the most appropriate sealant for the specific application. The table also includes information on solvents and fuels, resistance to alkalis and oxidizing acids, and other environmental factors, providing a detailed guide for selecting the right material for joint sealing.
<table>
<thead>
<tr>
<th>COMPOSITION AND TYPE</th>
<th>USES AND GOVERNING PROPERTIES</th>
<th>INSTALLATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Natural rubber</td>
<td>Expansion joint filler. Readily compressible and good recovery. Closed cell. Non-absorptive. Solid rubber may function as filler but primarily intend as gasket, see Table 3(8).</td>
<td>High pliability may cause installation problems. Weight of plastic concrete may precompress it. In construction joints attach to first placement with adhesive.</td>
</tr>
<tr>
<td>(12) Neoprene or Butyl Sponge tubes</td>
<td>Backup Where resiliency required in large joints. Check for compatibility with sealant as to staining.</td>
<td>Compressed into joint with hand tools.</td>
</tr>
<tr>
<td>(13) Neoprene or Butyl Sponge rods</td>
<td>Backup Used in narrower joints, e.g. contraction joints in canal linings and coverslabs and pavements. Check for compatibility with sealant as to staining.</td>
<td>Compressed into joint with hand tools or roller.</td>
</tr>
<tr>
<td>(14) Expanded polyethylene polyurethane and polyvinyl chloride polypropylene flexible foams</td>
<td>(a) Expansion joint fillers. Readily compressible, good recovery, Non-absorptive. (b) Backup Compatible with most sealants</td>
<td>Must be rigidly supported for full length during concreting. Compressed into joint with hand tools.</td>
</tr>
<tr>
<td>(15) Expanded polyethylene, polyurethane and polystyrene rigid foams</td>
<td>Expansion joint filler. Useful to form a gap but after significant compression will not recover.</td>
<td>Support in place during concreting. In construction joints attach to first placement. Sometimes removed after concreting where no longer needed.</td>
</tr>
<tr>
<td>(16) Bituminous or Resin Impregnated corkboard</td>
<td>Expansion joint filler. Readily compressible and resilient. Not compatible and must be isolated from most non-asphaltic sealants.</td>
<td>Support in place during concreting, or attach to preceding placement. Boards easily damaged by careless handling.</td>
</tr>
<tr>
<td>(17) Bentonite or Dehydrated Cork</td>
<td>Filler with self-sealing properties. Absorption of water after installation causes material to swell. Cork can be compressed. Bentonite incompressible.</td>
<td>Cork available in moisture-proof liners that require removal before installation. Bentonite in powder form, loose or within cardboard liners.</td>
</tr>
<tr>
<td>(18) Wood Cedar, Redwood, Pine, Chipboard, Untreated Fibreboard</td>
<td>Expansion joint filler, has been widely used in the past. Swells when water is absorbed. Not as compressible as other fillers and less recovery. Natural woods should be knot-free.</td>
<td>Rigid and easily held in alignment during concreting.</td>
</tr>
<tr>
<td>(19) Bituminous impregnated fiberboard</td>
<td>Expansion joint filler. Widely used. Resilient cane fibre used. Has moderate recovery after compression. Should not be compressed more than 50 percent or bitumen extruded which may damage sealant.</td>
<td>Reasonably rigid to hold alignment during concreting or placed against preceding placement.</td>
</tr>
<tr>
<td>(20) Metal or Plastic</td>
<td>(a) Expansion joint filler. Hollow compressible thin gauge box. Used only in special applications. (b) Backup, Foil, inert to sealants, but shape irregular.</td>
<td>Installed as for wood or fibreboard materials. Crumple and place in joint.</td>
</tr>
<tr>
<td>(21) Glass Fibre, Mineral wool</td>
<td>(a) Expansion joint filler. Made in board form by impregnating with bitumen or resins. Easily compressed. (b) Backup. Inert without impregnation so as not to damage sealant.</td>
<td>Installed as for wood or fibreboard materials. In mat form or packed loose material or yarn.</td>
</tr>
<tr>
<td>(22) Oakum, Jute, Manila yarn and rope, and Piping Upholstery cord</td>
<td>The traditional material for packing joints before installing sealant. Where used as backup should be untreated with oils, etc.</td>
<td>Packed in joint to required depth</td>
</tr>
<tr>
<td>(23) Portland Cement Grout or Mortar</td>
<td>Used at joints in precast units and pipes to fill the remaining gap when no movement is expected and sometimes behind waterstops.</td>
<td>Bed (mortar) Inject (grout)</td>
</tr>
<tr>
<td>COMPOSITION AND TYPE</td>
<td>PROPERTIES SIGNIFICANT TO APPLICATION</td>
<td>AVAILABLE IN USES</td>
</tr>
<tr>
<td>----------------------</td>
<td>---------------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>(1) Butyl - Conventional Rubber Cured</td>
<td>High resistance to water, vapour and weathering. Low permanent set and modulus of elasticity formulations possible, giving high cohesion and recovery. Tough. Colour - Black, can be painted.</td>
<td>Beads, Rods, tubes, flat sheets, tapes and purpose-made shapes. Waterstops, Combined crack inducer and seal, Pressure sensitive dust and water sealing tapes for glazing and curtain walls.</td>
</tr>
<tr>
<td>(2) Butyl - Raw, Polymer modified with resins and plasticisers</td>
<td>High resistance to water, vapour and weathering. Good adhesion to metals, glass, plastics. Moldable into place but resists displacement, tough and cohesive. Colour - Black, can be painted.</td>
<td>Beads, tapes, gaskets, grommets. Glazing seals, lap seams in metal cladding. Curtain wall panels.</td>
</tr>
<tr>
<td>(3) Neoprene - Conventional Rubber cured</td>
<td>High resistance to oil, water, vapour and weathering. Low permanent set. Colour - basically black but other surface colours can be incorporated.</td>
<td>Beads, rods, tubes, flat sheets, tapes, purpose-made shapes. Waterstops, Glazing seals, Insulation and Isolation of service lines, Tension-Compression seals, Compression Seals, Gaskets, Strip Gland Seals.</td>
</tr>
<tr>
<td>(4) PVC Polyvinylchloride Thermoplastic, Extrusions or Moldings</td>
<td>High water, vapour, but only moderate chemical resistance. Low permanent set and modulus of elasticity formulations possible, giving high cohesion and recovery. Tough. Can be softened by heating for splicing. Colour - Pigmented black, brown, green, etc.</td>
<td>Beads, rods, tubes, flat sheets, tapes, gaskets, purpose-made shapes Waterstops, Gaskets, Combined crack inducer and seal.</td>
</tr>
<tr>
<td>(6a) SBR (Styrene Butadiene Rubber)</td>
<td>High water resistance, NBR has high oil resistance.</td>
<td>Beads, rods, flat sheets tapes, gaskets, grommets, purpose-made shapes. Either solid or cellular sponges. Waterstops, Gaskets for pipes Insulation and Isolation of Service Lines</td>
</tr>
<tr>
<td>(6b) NBR (Nitrile Butadiene Rubber) Polyisoprene - polydiene - Conventional Rubber cure</td>
<td>High water resistance but deteriorates when exposed to air and sun. Low resistance to oils and solvents. Now largely superseded by synthetic materials, Colour black</td>
<td>Purpose-made shapes. Waterstops, Gasket for pipes. Strip-Gland Seals Tension-Compression Compression Seals</td>
</tr>
<tr>
<td>(7a) Polyurethane, Foam impregnated with polybutylene</td>
<td>Low recovery at low temperature, can be installed in damp joints, Colour - Variety</td>
<td>Rods flat sheets (strips) open cell sponges EVA closed cell Gaskets, Compression Seals</td>
</tr>
<tr>
<td>(7b) Ethylene Vinyl Acetate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(8a) Natural Rubber - cured (vulcanized)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(8b) EPDM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(8c) Silicones</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(9) Metals (a) Copper (b) Steel (stainless) (c) Lead (d) Bronze</td>
<td>For waterstops: (a) Ductile and Flexible, but work hardens under flexing and fractures. (b) Rigid must be V or U corrugated to accommodate any movement and anchored. (c) Deforms readily but inelastic to deformation under movement.</td>
<td>Flat and preshaped strips, Lead also melt or yarn. (a) (b) Waterstops (c) Protection for joint edges in floors. (d) Panel dividers in floor toppings</td>
</tr>
<tr>
<td>(10) Rubber Asphalts</td>
<td>Natural Rubber 8, Butyl 1, or Neoprene 3 digested in asphalt. High viscosity, some elasticity. Moldable into place.</td>
<td>Beads, rods, flat sheets (strips) (IIG IIK), Gasket for As alternative to hot or cold applied Rubber asphalts (IIG IIK), Gasket for pipes.</td>
</tr>
</tbody>
</table>
### TABLE 4-USES OF FIELD MOLDED AND PREFORMED SEALANTS

<table>
<thead>
<tr>
<th>TYPE OF APPLICATION</th>
<th>THERMOPLASTIC</th>
<th>FIELD-MOLDED</th>
<th>THERMOSETTING</th>
<th>PREFORMED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
<td>III</td>
<td>IV</td>
</tr>
<tr>
<td>Structures not</td>
<td>A B D E</td>
<td>LM</td>
<td>N P R S</td>
<td>T U V</td>
</tr>
<tr>
<td>under fluid</td>
<td>A B D E</td>
<td>M I N P R S</td>
<td>T V T U V</td>
<td>38</td>
</tr>
<tr>
<td>pressure; e.g.,</td>
<td>A B D E</td>
<td>F G W</td>
<td>N O P Q R</td>
<td>378</td>
</tr>
<tr>
<td>buildings, bridges</td>
<td></td>
<td>G H W</td>
<td>T V T V T V</td>
<td>38</td>
</tr>
<tr>
<td>storage bins,</td>
<td></td>
<td>H J W</td>
<td>T V T V T V</td>
<td>38</td>
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<tr>
<td>retaining walls</td>
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<td>G W</td>
<td>N O P R Q R</td>
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<tr>
<td>Note 3</td>
<td></td>
<td></td>
<td>N P Q R S</td>
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<tr>
<td>Containers</td>
<td>C</td>
<td>G W</td>
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<td>subject to fluid</td>
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<td>134568</td>
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<td>13467</td>
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<tr>
<td>or excluding</td>
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<td></td>
<td></td>
<td>1346</td>
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<tr>
<td>structures</td>
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<td>49.95b</td>
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<tr>
<td>Note 3</td>
<td></td>
<td></td>
<td></td>
<td>13465b</td>
</tr>
<tr>
<td>Pavements</td>
<td>F G W</td>
<td>K</td>
<td>N O P R Q R</td>
<td>38</td>
</tr>
<tr>
<td>Walkways</td>
<td>G W</td>
<td>N O P R Q R</td>
<td>17</td>
<td>1346</td>
</tr>
<tr>
<td>Highway</td>
<td>G W</td>
<td>N O P R Q R</td>
<td>17</td>
<td>1346</td>
</tr>
<tr>
<td>Airport</td>
<td>G W</td>
<td>N O P R Q R</td>
<td>17</td>
<td>1346</td>
</tr>
<tr>
<td>Areas with fuel</td>
<td>H J W</td>
<td>N O P R Q R</td>
<td>17</td>
<td>1346</td>
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<tr>
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<td>Grouting nonworking</td>
<td>K</td>
<td>5</td>
<td></td>
<td>23</td>
</tr>
<tr>
<td>cracks</td>
<td></td>
<td></td>
<td></td>
<td>23</td>
</tr>
<tr>
<td>Storage Life: Limited</td>
<td>F G H I J(o)</td>
<td>K L M(o)</td>
<td>N O P Q R S(I)</td>
<td>38</td>
</tr>
<tr>
<td>(1) Over 1 year (o)</td>
<td></td>
<td></td>
<td>T U V T U V</td>
<td>38</td>
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<tr>
<td>Emulsions are</td>
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<td></td>
<td>7</td>
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<tr>
<td>damaged by freezing</td>
<td></td>
<td></td>
<td></td>
<td>3 Note 2</td>
</tr>
<tr>
<td>Installation: Knife</td>
<td>A B C D E(o)</td>
<td>F G H I J(o)</td>
<td>K L M(o)</td>
<td>38</td>
</tr>
<tr>
<td>or Trowel (k)</td>
<td></td>
<td></td>
<td>N O P Q R S(I)</td>
<td>38</td>
</tr>
<tr>
<td>Mix if two component (m) . Note 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand Gun (g). Pressure Gun (p)</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preposition (pp)</td>
<td>A B C D E</td>
<td>F G H I J</td>
<td>K L M</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>(W) (h)</td>
<td>L (k) (l) (p)</td>
<td></td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>(W) (h)</td>
<td>M (k) (l) (p)</td>
<td></td>
<td>38</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N O P Q R S(I)</td>
<td>T U V (k) (l) (p)</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(h) (i) (j)</td>
<td>1+9(pp)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>i-8(pp)</td>
<td>12 3 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>9d(10) pp</td>
<td>11(p)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>9c(li)</td>
<td>11(p)</td>
</tr>
</tbody>
</table>

**NOTES TO TABLE 4**

Note 1 - Table 4 is only a general guide. Before deciding on a particular material for a specific application, all circumstances, in particular the joint movement to be expected and a suitable joint design (Chapter 4) and joint detail (Chapter 5) must be considered.

Note 2 - *- 3 refers to Tension-Compression Seals described in Section 3.6.

Note 3 - Certain sealants may contain substances toxic to potable water or foodstuffs. Check local or national restrictions that may govern use in areas exposed to these.

Note 4 - Certain materials are equally suitable for both vertical and horizontal joints. Others are not and while they may stay in place in horizontal joints they would sag or flow out of vertical joints in hot weather. Asphalt and rubber-asphalt materials are examples of these. Some materials are available in two grades. One known as nonsag or gun grade is thixotropic and is suitable for vertical joints. The other known as self-levelling or pour grade is intended for use in horizontal joints.

*Identifying numbers and letters are found in Tables 1 and 3.

† With primer.
### JOINT SEALANTS

#### JOINT TYPE

<table>
<thead>
<tr>
<th>BUTT</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Diagram" /></td>
</tr>
</tbody>
</table>

#### EXPOSURE AND SERVICE ENVIRONMENT

Exterior Walls and Roof: rain, sun, wind, low and high temperatures
Interior Walls, Columns and Floors: dry, room temperature; traffic-light or spiked heels

**Appearance** of sealant and colour often important

**Direction of exposure in sketches**

#### SEALS: TABLE 4; FIELD-MOLDED TYPE IV COMPRESSION SEALS TYPE VI

**GASKETS VIII:** 1 3 4 5 6 7

#### Expansion Construction Combined

- **A** May be horizontal or vertical
- **B** As far as sealant is concerned this is a butt not a lap joint
- **C** Where units abut at right angles
- **D** Cases **A, B, C** can be sealed on both sides if required

#### Expansion Construction Combined

(i) Do not carry waterproofing over joint unless it is extensible
(ii) Insulate roof to reduce joint movement

- **D** Floor to Wall
- **E** Roofs
- **F** Isolation joint for columns from floor

#### Contraction Construction Combined

- **A** May be horizontal or vertical
- **B** In floors and roofs may be bonded and tied
- **C** Between precast units—preformed gasket (i) buried or (ii) may be at surface

(i) For large movements improve shape factor and use bond breaker

**Extra Tips for Better Performance**

(ii) Where seepage may occur due to slight back pressure, steel plates and angles or mortar plugs are sometimes used on top of seal to hold it in the joint.

Or better still:

(iii) Use waterstops across joint as shown in Figure 11.

#### Contraction Monolith

- **A** Horizontal
- **B** Vertical as 2A but omit bond breaker and preferably include waterstop

- **D** Cases **1, 2, 3, 4, 5** above used as Contraction Joints with filler omitted.

Mortar bedding or grout often, used between precast units as rigid filler

**Fig. 7-Joints for structures; concrete to concrete**
EXPOSURE AND SERVICE CONDITIONS

Exterior: Rain, sun, wind, low and high temperatures. Nonconcrete materials may be at higher or lower temperatures than concrete and move differentially.

Interior: Dry moderate temperature

Appearance and color of sealant important

Direction of exposure in sketches:

SEALANTS: TABLE 4 FIELD-MOLDED GENERAL CAULKING NO MOVEMENT TYPE I A-H-D-E. SOME MOVEMENT TYPE II LM; TYPE V T-U-V. CAULKING AND SEALING LARGER MOVEMENTS: TYPE IV N-P-R-S COMPRESSION SEALS VI 3 GASKETS VIII 1 34567 MISCELLANEOUS IX TAPFS ALL AS APPROPRIATE

Fig. 8 - Joints for buildings; special purposes
JOINT SEALANTS

EXPOSURE AND SERVICE ENVIRONMENT

Exterior: rain, sun, wind, low and high temperatures salt traffic, rubber tires, sand and debris, and possible fuel and oil droppings.

Direction of exposure in sketches:

Sealants: TABLE 4, FIELD-MOLDED TYPE II (VERY SMALL MOVEMENTS ONLY), TYPE IV N O Q COMPRESSION SEALS VI 3-8 (SMALL TO VERY LARGE MOVEMENTS IX 3 TENSION COMPRESSION SEAL . STRIP SEALS VI 5-8.

Field molded sealant for small spans, and movements generally less than 3/4 in. (19 mm).

Preformed single unit compression seals for small spans, and movements less than 2 in. (50 mm).

Preformed strip (gland) seals for small to medium spans, and movements up to 4 in. (100 mm).

Preformed tension-compression seals for small to large spans and movements up to 13 in. (330 mm).

Preformed compression or strip (gland) seals, used in as many modules as needed in series to accommodate total movement. Mechanical devices of various designs are used in conjunction with the supports to equalize movement between units and reduce impact and friction forces.

Note: (i) Traffic impact can cause serious damage unless joint faces are armoured and assemblies and devices securely anchored and embedded (see 2 B and 3 B iv).

(ii) Any leakage can lead to serious deterioration of substructure, carry seals through curblines.

(iii) Longitudinal joints and skewed transverse joints induce extra strain in sealant from out-of-plane movements.

Fig. 9-Joints for bridge decks
## Exposition and Service Environment

**Below Water:** wet, small temperature range, various hydrostatic pressures flow.

**Above Water and Dewatering:** rain, sun, wind, low and high temperatures.

**Exterior Below Grade:** ground water sulfates, organic matter, soil infiltration:

Contents usually water, but may be other fluids or gases.

*Direction of exposure in sketches = ⬇️ unless otherwise shown*

### Sealants: Table 4, Field Molded Type IC, IIK (Small Movements) IVN, VI 3, (Larger Movements) VII 1 3 4 5 6 and 8.

<table>
<thead>
<tr>
<th>Joint Type Usually Butt</th>
<th>Water forces sealant back into tapered groove</th>
<th>Ground Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Lining and wall joints for low heads</td>
<td><img src="#" alt="Diagram A" /> For heads up to 15 ft.</td>
<td><img src="#" alt="Diagram D" /> Swelling Bentonite cuts off water flow</td>
</tr>
<tr>
<td>Contraction or construction, combined transverse or longitudinal</td>
<td><img src="#" alt="Diagram B" /> A improved for heads over 15 ft.</td>
<td></td>
</tr>
<tr>
<td><img src="#" alt="Diagram C" /> Insert (Crack inducer) sealant</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**Fig. 10- Joints for containers; canal linings, walls, dams, pipes, culverts, syphons**
JOINT SEALANTS

EXPOSURE AND SERVICE ENVIRONMENT

Below Water: wet small temperature range, hydrostatic pressure, no flow.
Above Water and During Dewatering: rain, sun, wind, low and high temperatures.
Exterior Below Grade: ground water, sulfates, organic matter, soil infiltration.
Contents usually water but may be other fluids or gases.
Appearance and color of sealant important in swimming pools.
Direction of exposure in sketches = unless otherwise shown.

SEALANTS: TABLE 4
WATERSTOPS: 1 3 4 6 8 9A 9B AND OTHER SECONDARY SEALANTS

1. Joints in Walls

   A. Walls: Contraction as Fig. 10, 2B, without grouting but with sealing groove on internal face.

   B. Walls: Monolithic Construction as Fig. 7, 3A, Horizontal 3B, Vertical but with waterstop and often keyway.

   C. Expansion as Fig. 10, 2A, or this detail which has greater resistance to pressures.

2. Joints between walls, floors and roofs

   Wall free to move

   Wall fixed, floor can move

   A. Wall to floor

   B. Wall to floor

   A and B will also work the other way to keep water out. They are then used in building basement retaining walls, tunnels, secondary sealant on outside where possible.

   C. Wall to roof for A above

   D. Wall to roof for B above

   Fillers and backup materials used in the applications in Fig. 10 and 11 should be water resistant and additionally they should support the sealant against the fluid pressure.

3. Joints in floors

   Treat as for slabs on grade Fig. 12 but include waterstop at middepth or bottom (where base plate shown).

4. How to install waterstops

   Depending on type, three methods used in vertical joints

   For horizontal joints embed 1/2 way vertically in lower lift.

   A. Split forms

   B. Nail-on unfold

   C. Nail-on labyrinth

Fig. 11-Joints for containers; tanks, reservoirs, swimming pools; waterstops
EXPOSURE AND SERVICE ENVIRONMENT

Rain, sun, low and high temperatures (except inside floors); salt (highways, walkways); oil, fuel, organic deicers (airports, etc.); solvents, acid, oil (industrial floors); curling (outside exposure); traffic, rubber tires, steel wheels (industrial floors); spiked heels (floors and walkways); sand and debris.

Direction of exposure in sketches =

SEALANTS: TABLE 4: FIELD-MOLDED TYPES II AND IV (FUEL RESISTANT IF NEEDED). COMPRESSION SEALS VI 3 ONLY

Construction steps:

1. Expansion

(1) Preposition filler
(2) Place concrete
(3) Form or saw sealant reservoir
(4) Seal

(1) Preposition filler
(2) Place concrete
(3) Form or saw sealant reservoir
(4) Seal

B Better

Step improves shape factor.

A or B

Bond breaker also used

A Better

With addition of back-up.

Less sealant used

Step improves shape factor.

A or B

Suitable for compression seal

A Better

Construction steps:

(1) Form, tool or saw 1/4 depth to induce crack
(2) Enlarge sealant reservoir if needed
(3) Seal

Transverse

CRACK INDUCER STRIP OR TAPE

B Longitudinal with keyway

A Transverse

or B Longitudinal with crack inducer

A or B is also suitable for compression seals no back-up

Construction steps:

(1) Bulkhead for transverse joints (A)
(2) Form keyway (B) or induce crack (Bi) for longitudinal joint
(3) Form or saw sealant reservoir
(4) Seal

Longitudinal or keyway

Construction steps:

(1) Preposition filler
(2) Place concrete
(3) Form or saw sealant reservoir
(4) Seal

Better shape factor. Base plate prevents subgrade infiltration

Better shape factor due to use of back-up. Less sealant needed

Even better, shape factor due to use of back-up. Less sealant needed

(i) Base plate (or stabilized base) will prevent infiltration of solids from beneath, return base plate up, or sealant down, outside slab edges to keep out shoulder material.

(ii) Seal between pavement and paved shoulder or drainage gutter.

(iii) For industrial floors armor faces, protect sealant with steel plate (similar to Fig. 9 A or B)

(iv) Sealant usually installed slightly below level of pavement surface to avoid contact with traffic. In airports flush installation may be required as an operational safety requirement.

Extra Tips for Good Performance

Fig. 12-Joints for slabs on grade; highways, airports, walkways, floors
lowering: intrusion of foreign material, wear, indentation, pickup by traffic, fire or attack by chemicals present. Further requirements may be that the sealant has a specific color, resists change of color or is nonstaining to the substrate.

Finally, the sealant must not deteriorate when stored for a reasonable time prior to use, it must be relatively easy to handle and install, and be free of substances harmful to the user and concrete or other material that it may abut (see Section 6.14). In certain locations regulations may restrict the use of sealants which contain solvents deemed to be pollutants.

3.3-Available materials

No one material has the perfect properties necessary to fully meet each and every application. It therefore is a matter of selecting a material that is economically and physically acceptable for each application.

For many years oil based mastics or bituminous compounds and metallic materials were the only sealants available. For many applications these traditional materials did not perform well and in recent years there has been active development of many types of “elastomeric” sealants whose behavior is largely elastic rather than plastic and which are flexible rather than rigid at normal service temperatures. Elastomeric materials are available as field molded and pre-formed sealants. Though initially more expensive, pre-formed sealants may be cheaper in the long run because they usually have a longer service life.

Furthermore, as will be seen, they can seal joints at which considerable movements occur that otherwise could not possibly be sealed by the traditional field-molded materials. This has opened up new engineering and architectural possibilities to the designer of concrete structures.

No attempt has been made in this guide to list or discuss every attribute of every sealant. Discussion is limited to those features considered important to the designer, specifier and user so that he can make a suitable choice.

3.4-Field-molded sealants

3.4.1 Mastics-Mastics are composed of a viscous liquid rendered immobile by the addition of fibers and fillers. They do not usually harden, set or cure after application, but instead form a skin on the surface exposed to the atmosphere. Mastics listed in Table 1, Type I, are (A) or (B) drying or non-drying oils (including oleoresinous compounds), (C) low-melting point asphalts, (D) Polybutenes, (E) Polysisobutylene or combinations of these materials. With any of these, a wide variety of fillers is used, including fibrous talc or finely divided calcareous or siliceous materials. The functional extension-compression range for these materials is approximately + 3 percent.

They may be used where only very small joint movements are anticipated and economy of first cost outweighs that of maintenance or replacement. With aging, most mastics tend to harden in increasing depth as oxidation and loss of volatiles proceeds, thus reducing their serviceability. Polybutene and polysisobutylene mastics have a somewhat longer service life than do the other mastics. The main use of mastics is in caulking and glazing in buildings.

3.4.2 Thermoplastics, hot applied-These are materials which become soft on heating and stiff to hard on cooling usually without chemical change. They are generally black, are listed in Table 1, Type II, and include: (F) asphalts, (G) rubber asphalts, (H) pitches, (I) coal tars, and (J) rubber coal tars. They are useable over an extension-compression range of + 5 percent. This limit is directly influenced by service temperatures and aging characteristics of specific materials. Though initially cheaper than some of the other sealants, their effective life is, in practice, shorter. They tend to lose elasticity and plasticity with age, to accept rather than reject foreign materials, and extrude from joints that close tightly or that have been overfilled. Physical properties may be adversely affected by overheating during installation (see Section 6.6).

Those with an asphaltic base are softened by hydrocarbons, such as oil, gasoline, or jet fuel spillage. Tar-based materials are fuel and oil resistant and are preferred for service stations, refueling and vehicle parking areas, airfield aprons and holding pads.

The use of sealant types F, G, H, I and J are restricted to horizontal joints because they would run out of vertical joints during installation or subsequently in warm weather. They have been widely used in pavement joints, but they are tending to be superseded by chemically curing thermosetting field-molded sealants or compression seals. They are also used in building roof decks and containers.

Polyvinylchloride coal tar sealants are being used in pavement and canal liner joints as illustrated in Fig. 12 and 10, respectively.

3.4.3 Thermoplastics -Cold-applied solvent or emulsion type-These materials are set either by the release of solvents or the breaking of emulsions on exposure to air. Sometimes they are heated to a temperature not exceeding 120°F (49°C) to facilitate application but usually they are handled at ambient temperature. Release of solvent or water can cause shrinkage and increased hardness with a resulting reduction in permissible joint movement and in serviceability. Products listed in Table 1, Type III: (K) rubber asphalts, (L) vinyl, (M) acrylcs and (X) modified butyl rubbers are available in a variety of colors. Their maximum extension-compression range is ± 7 percent. Heat softening and cold hardening may, however, reduce this figure.

These materials are restricted in use to joints with small movements. Rubber asphalts listed in Table 1, Type III (K) are used in canal linings, tanks, and fillers for cracks. Type III (L) vinyl, (M) acrylcs and (X) modified butyl rubbers are mainly used in buildings for caulking and glazing.

3.4.4 Thermosetting, chemically curing-Sealants in this class are either one or two component systems which cure by chemical reaction to a solid state from the liquid form in which they are applied. Listed in Table 1. Type IV are (N)
polysulfide, (O) polysulfide coal tar, (P) polyurethane, (Q) epoxy-based materials. The properties that make them suitable for a wide range of uses are their resistance to weathering and ozone, flexibility and resilience at both high and low temperatures, and inertness to a wide range of chemicals, including, for some, solvents and fuels. In addition, the abrasion and indentation resistance of urethane sealants is above average. Thermosetting, chemically curing sealants have an expansion-compression range of up to: silicones +100/-50 percent; polyurethanes 25 percent; polysulfides 25 percent; epoxy-based materials less than 25 percent.

Silicone sealants remain more flexible over a wider temperature range than other field-molded liquid sealants.

If substrate conditions are clean and otherwise suitable, then thermosetting, chemically curing sealants can stand greater movements than other field-molded sealants and generally have a much greater service life.

3.4.5 Thermosetting solvent release—Another class of thermosetting sealants are those which cure by the release of solvent. Listed in Table 1, Type V are (V) chlorosulfonated polyethylene, (U) butadiene styrene and (R) silicone materials. Their performance characteristics generally resemble those of thermoplastic cold applied solvent release materials (see KSection 3.4.3). They are, however, less sensitive to variations in temperature once they have “setup” on exposure to the atmosphere. They are mainly used as sealants for joints in buildings, where both horizontal and vertical joints have small movements. Their cost is somewhat less than that of other elastomeric sealants and their service life is considered adequate.

3.4.6 Accessory materials

3.4.6.1 Primers—Where primers are required, a suitable priming material compatible with the sealant is usually supplied along with it. In the case of hot-poured field-molded sealants, these are usually high viscosity bitumens or tars cut back with solvent. To overcome damp surfaces, wetting agents may be included in primer formulations, or materials may be used that preferentially wet such surfaces, such as polyamide-cured coal tar-epoxies.

3.4.6.2 Bond breakers—Many backup materials do not adhere to sealants and thus, where these are used, no separate bond breaker is needed. Polyethylene tape, coated papers and metal foils are often used where a separate bond breaker is needed.

3.4.6.3 Backup materials—These materials serve to limit the depth of the sealant; displacement by traffic and fluid pressure; facilitate tooling and shaping; and may serve as a bond breaker to prevent the sealant from bonding to the back of the joint. Suitable preformed materials are listed in Table 2. In selecting a backup material, it is advisable to follow the recommendations of the sealant manufacturer to ensure compatibility.

The backup material should preferably be compressible within itself so that the sealant is not forced out as the joint closes and it should recover as the joint opens. Care must be taken to select the correct width and shape of material so that after installation it is compressed approximately 50 percent. Stretching, twisting or braiding of tube or rod stock should be avoided. Backup materials and fillers containing bitumen or volatile materials should not be used with thermosetting chemical curing field-molded sealants, since they may migrate to, and/or be absorbed at, joint interfaces, impairing adhesion.

3.5 Preformed seals

Tables 3 and 4 cover preformed sealants for two applications, distinguished by how they are installed in the work and their subsequent accessibility.

Traditionally, preformed sealants have been subdivided into two classes; rigid and flexible. Most rigid preformed sealants are metallic; examples are metal waterstops and flashing. Flexible preformed sealants are usually made from natural or synthetic rubbers, polyvinyl chloride and like materials, and are used for waterstops, gaskets and miscellaneous sealing purposes. Preformed equivalents of certain materials, e.g., rubber asphalts, usually categorized as field molded, are available as a convenience to handling and installation.

In recent times, however, a new and very important use of preformed sealants has been in the form of strip (gland) seals (see Section 3.5.4). Flexible seals which can be installed in joints open on at least one surface after the main concreting operations are complete and may be replaced in service, if necessary.

3.5.1 Rigid waterstops and miscellaneous seals—Rigid waterstops are made of steel, copper and occasionally of lead. The stiffness of steel waterstops may lead to cracking in the adjacent concrete. Steel waterstops are primarily used in dams and other heavy construction projects. Stainless steels may be desirable in particularly corrosive environments. Annealing of steel, after welding, is sometimes required for improving its flexibility at the weldment.

Copper waterstops are used in dams and general construction; they are highly resistant to corrosion, but must be handled with care to avoid damage. For this reason and cost, flexible waterstops are often used instead.

3.5.2 Flexible waterstops—The types of materials suitable and in use as flexible waterstops are shown in Table 3. Butyl, neoprene and natural rubbers have good extensibility and resistance to water or chemicals and may be formulated to give good recovery and fatigue resistance. Polyvinyl chloride (often called PVC) compounds are, however, probably now the most widely used. While it is not quite as elastic as the rubbers, and it recovers more slowly from deformation and is susceptible to oils, grades with sufficient flexibility (especially important at low temperatures) can be formulated. PVC has the great advantage of being thermoplastic and hence it can easily be spliced on the job or special configurations made for joint intersections.

Flexible waterstops, as shown in Table 4, are widely used as the primary sealing system in dams, tanks, monolithic pipe lines, flood walls, swimming pools, etc., to keep the water in, and in buildings below the grade or in earth-retaining walls to keep the water out.

3.5.3 Gaskets and miscellaneous seals—Gaskets and material in the form of a thick ribbon (tape) are sealants widely used with glazing and for precast concrete panels in curtain walls. Gaskets are also extensively used at joints between precast pipes and where mechanical joints are needed in serv-
ice lines. Suitable materials are listed in Table 3 and uses in Table 4. The sealing action is obtained either because the sealant is compressed between the joint faces (gaskets) or because the surface of the sealant, as in the case of polyisobutylene, is pressure sensitive and thus adheres.

3.5.4 Strip (gland) seals—These sealing systems are essentially exposed flexible waterstops and are finding wide use in bridge expansion joints, either in single units [see Fig. 9 (3)] or in series in modular systems [see Fig. 9 (5)].

Neoprene, natural rubber and EPDM (ethylene propylene diene monomer) natural rubber are the main materials currently being used and, as illustrated in Fig. 9 (3), the seals are anchored at the ends and configured so that they are permitted to fold or flex as the joint opens and closes.

3.5.5 Compression seals—Preformed compression seals are compartmentalized and extruded, to the required configuration, from elastomeric compounds, most commonly neoprene and EPDM. For effective sealing, sufficient contact pressure must be maintained at the joint face. This requires that the seal is always in some degree of compression. This is accomplished by internal webs, which fold and flex to accommodate movement, yet keep the side faces of the seal in contact with the joint faces. To obtain these characteristics, good resistance to compression set (that is, the material must recover to its original size and shape sufficiently when released) is required.

To facilitate installation of compression seals, lubricants are used. For machine installation, additives to make the lubricant thixotropic (increased fluidity during agitation) have been found necessary. Special lubricant adhesives, which both prime and bond, have been formulated for use where improved seal to joint face contact is required.

Compression seals are effective joint sealants over a wide range of temperatures in almost all applications. Seals may be used individually, or as components for modular systems [see Fig. 9 (5)].

3.5.6 Flexible foam (impregnated)—Another type of preformed compression seal is polybutylene-impregnated foam (usually a flexible open cell polyurethane). This material has found limited application in structures such as buildings and bridges, but its recovery at low temperature is too slow to follow joint movements, and when highly compressed the impregnant exudes and stains the concrete. This generally limits its applications to joints where less than + 10 percent extension-compression occurs at low temperature or + 20 percent where the temperature is above 50°F (10°C). The material often must be bonded to the joint faces.

3.5.7 Flexible foam (nonimpregnated)—One type of sealant which is in this category is a crosslinked, closed cell ethylene vinyl acetate expanded foam material which exhibits good chemical resistance properties to most mild nonoxidizing acids and alkalines. It is usually custom cut to fit any shape or size joint required. The material is heat-welded in sheets and cut to lengths desired. Heat welding may be accomplished on the job site, to either fabricate lengths or make alterations, with a PTFE-coated iron.

An adhesive compatible with ethylene vinyl acetate is used to bond the sealant to the joint face. Based upon manufacturer’s literature, the allowable movement should be less than 50 percent of the nominal width. Although it has some tension capability, it is preferable that it not be used in tension.

3.5.8 Tension-compression seal systems—Compared to other preformed sealant materials, tension-compression seal systems are composed of relatively massive, molded, block style elastomeric material, commonly neoprene or EPDM, in which a metal bridging plate may be incorporated, either at its surface or embedded within.

The elastomeric element is anchored to both joint faces and movement is accommodated by a combination of grooves and shear deformation of the elastomeric component as illustrated in Fig. 9(4). When this system is used in bridge deck expansion joints, the elastomeric element must be tough and abrasion resistant against direct traffic loads or wear.

CHAPTER 4-JOINT MOVEMENT AND DESIGN

4.1 Discussion

The location and width of joints that require sealing can only be specified with the following consideration in mind: “Is there a sealant available which will take the anticipated movement, and what shape factor (or in the case of preformed sealants - size) is required?” If the first answer is no, then the joint system for the structure must be designed to reduce the movement at the joints. Sealing systems currently available can accommodate (at increasing costs) movements to about 48 in. (1220 mm). With due forethought it should therefore be possible to design and specify a suitable sealed joint for almost any type of concrete structure.

4.2 Determination of joint movements and locations

The anticipated length changes within the structure must be determined and translated into joint locations and movements that not only fit the structural design and maintain the integrity between the individual structural units, but which also take into account the fact that each type of sealant currently available imposes specific limitations on both the shape of joint that can be sealed and the movement that can be accommodated. It should be remembered that the sources and nature of the movement, both long and short term, can be very complex in other than simple structures (see Section 2.4) and that experience and judgement play a big part in designing joints that function satisfactorily. A more complete discussion of this is beyond the scope of this guide except to draw attention to the following simple facts, which if overlooked result in poor joint sealant performance.

1. The movement of the end of a unit depends on its effective length, that is, on the length of the part of the unit that is free to move in the direction of the joint.

2. Except where a positive anchor is a feature of the design, experience shows that the preferred safe assumption is that a joint between two units may be called upon to take the total movement of both units.

3. The temperatures of the materials being joined may vary from the ambient condition, affecting joint movements.

4. Where units to be joined are of dissimilar materials they may not be at the same surface temperature (see Section 2.4) and the appropriate coefficient for each material must be used in calculating its contribution to the joint movement.
It is based on the maximum strain allowable in the sealant. This is less than the movement that can occur at the joint. The part of the total movement which extends the sealant is extended (see Sections 2.2, 2.4, and 2.5) though in some cases occurs in the outer fibers, usually when the sealant is extended, tend to stand out. It is therefore desirable to locate the maximum strain may occur while the sealant is compressed.

5. Where knowledge exists of actual movements that have occurred in similar situations, these should be considered in the design to supplement those indicated by theory alone.

6. Allowance must be made for the practical tolerances that can be achieved in constructing joint openings or in casting and positioning precast units.

7. In butt joints the movement to which the sealant can be achieved in constructing joint openings or in casting and positioning precast units.

8. The width of the joint sealant reservoir must always be greater than the movement that can occur at the joint.

9. When viewing a structure the joint, either sealed or unsealed, tend to stand out. It is therefore desirable to locate and construct them as a purposeful feature of the architectural design or to hide them by structural or architectural details.

4.3-Selection of butt joint widths for field-molded sealants

The selection of the width (and depth) for field-molded sealants to accommodate the computed movement in a joint is based on the maximum strain allowable in the sealant. This occurs in the outer fibers, usually the sealant is extended (see Sections 2.2, 2.4, and 2.5) though in some cases maximum strain may occur while the sealant is compressed. The part of the total movement which extends the sealant is the difference between the width of the joint at the time the sealant is installed and the width of the joint at its maximum opening. The temperature difference between that at installation and that at maximum opening is the main contribution to the extension of the sealant; but any residual drying shrinkage or creep of the concrete that has yet to occur, and shrinkage in the sealant as it sets or cures, will also impose additional extension on the sealant.

When the suitability of a new joint sealant is first being considered and a precise determination of the dimensions of the sealant reservoir are required, the approach using Fig. 13 from Schutz may be followed. This figure relates the maximum allowable strain in a sealant to an assumed joint width and various shape factors. First, the maximum allowable strain for the sealant under consideration must be determined by testing at a specified temperature. Next, a likely approximation to the joint width is assumed and the computed linear extension that the sealant would undergo between the as-installed width and the width at maximum opening of the joint is calculated.

The various curves then permit the computed extension and shape factor to be interrelated so that the maximum allowable strain will not be exceeded. More than one solution is usually possible and where the upper limits of the curves are approached, a wider assumed joint width should be tried. In practice, to allow for unforeseen circumstances, a safety factor of four should be applied in using this chart.

This detailed procedure is simplified for practical use by the aid of the percentage extension-compression shown in Table 1 for each type of field-molded sealant. This figure has been derived by considering the maximum allowable strains for materials of each type and then applying the suggested safety factor. The percentage extension-compression of the sealant is the percentage increase or decrease in the as-installed width of the sealant that can be safely accommodated as the joint subsequently opens and closes. The width of the joint to be formed, which becomes the sealant mold and thus determines the as-installed sealant width, can then be obtained by simple calculation so that in service the permissible extension-compression range is not exceeded. This calculation should, of course, take into account (a) the anticipated temperature at the time of forming the joint, (b) the temperature at sealant installation, (c) any additional joint opening which will be caused by initial drying shrinkage of the abutting concrete units, and (d) the extremes of service temperature.

When the joint width is designed, a precise installation temperature cannot usually be known or specified; otherwise, an intolerable restriction would be placed on the installation operation. All that can be done is to specify installation within a general temperature range. This can be done easily by insuring that for the worst installation temperatures the seal will still function as anticipated (for extension the top of the range is used, and for compression the bottom of the range). A practical range of installation temperatures taking into account this and other factors, such as moisture condensation at low temperatures and reduced working life at high temperatures, has been determined to be from 40 to 90°F (4 to 32°C). This is generally because the tension case as the joint opens with fall of temperature is the more critical to sealant behavior (see Fig. 2 and 5). Joint sealants installed at the low
end of this range may be expected to perform best. A warning note should be included on the plans that, if sealing must take place, for any reason, at temperatures above or below the specified range, then a wider than specified joint may have to be formed, or changes in the type of sealant or shape factor to secure greater extensibility may be needed.

Detailed calculations for selection of the joint width for sealants with an expansion-compression range of +25 percent (which is the most common range for the widely used class of thermosetting-chemical curing sealants) can be dispensed with by the use of Fig. 14. This has been prepared using the previous procedures to cover the range of service temperatures of -20 to +130 F (-29 to +54 F) and other conditions specified in this guide.

Similar charts can be prepared for other sealants and conditions. In addition, most sealant manufacturers publish aids in the form of charts or tables for the proper selection of joint widths to suit their products.

Where a reasonable joint width (see Section 4.6) cannot be determined by the previous considerations, nor those that follow in Section 4.4 as to sealant depth, the proposed joint layout for the structure must be redesigned to accommodate movements tolerable to the sealant.

4.4-Selection of butt joint shape for field-molded sealants

When a suitable joint width has been established (see Section 4.3), the appropriate depth for the sealant reservoir must be determined so that the sealant has a good shape (see Section 2.7). Fig. 13 can be used for this purpose. Curves for depth-to-width ratios of 1:1, 1:2 and 1:3 are shown on this chart. Any depth-to-width ratio may be used provided that at the computed extension or compression expected in the sealant the maximum allowable strain is not exceeded. The benefits in both better performance and economy of material by using the smallest possible depth-to-width ratio have already been pointed out (see Section 2.7 and Fig. 6). The chosen depth should generally not, however, be less than 1/2 in. (12.7 mm); otherwise, with aging sealant performance may be adversely affected. The depth of sealant is controlled by using a suitable backup material as described in Sections 2.8, 3.4, 6.3 and 6.5. To obtain full benefit of a well-designed shape factor a bond breaker must be used behind the sealant (see Section 2.8, 3.4, 6.2 and 6.5).

4.5-Selection of size of compression seals for butt joints

A positive contact pressure must be exerted against the joint faces at all times for compression seals to function properly. The development of suitable seal configurations to achieve this, while following the principles explained by Dreher,6 has largely been based on the results of trial and error, laboratory and field experiments in both America and Europe. Compartmentalized compression seals (see Section 3.5.5) must remain compressed approximately 15 percent (at 85 percent of nominal width) at maximum joint opening to maintain sufficient contact pressure for sealing and to resist displacement, and generally not compressed more than 50 percent (50 percent of nominal width) at maximum closing to prevent overcompression. This limit of compressibility has been established by the producers and users to be at a point when the pressure on the seal reaches 35 psi. Higher pressures tend to accelerate pressure decay. Pressure decay is the failure of the elastomeric seal to regain its original shape thus losing its sealing pressure when the joint opens.

The allowable movement of compartmentalized compression seals is thus approximately 35 to 40 percent of the uncompressed seal width. The allowable movement for impregnated foams (see Sections 3.5.6 and 3.5.7) is less, being of the order of 10 percent.

The critical condition for maintaining a positive contact pressure is when the joint is fully open at low temperature since compression set or lack of low temperature recovery may adversely affect sealant performance. The principle of size selection is similar to that for field-molded sealants in that original uncompressed width of seal is that required to maintain the seal within the specified compression range, taking into account the installation temperature, width of normal opening and the expected movement. A detailed method for doing this has been described by Kozlov.7 A simplified chart applicable to the conditions specified in this guide is shown in Fig. 15, and for specific products, charts of seal sizes for various applications are available from the suppliers.

4.6-Limitations on butt joint widths and movements for various types of sealants

The applicability of various sealants to joints of different movements in different types of structures is summarized in general terms in Table 4 and illustrated in Fig. 7 to 12.

Field-molded sealants generally require a minimum joint width of 3/4 in. (6 mm) to provide an adequate reserve against loss of material due to extrusion (see Fig. 4) or to accommodate unexpected service conditions.

The upper limit of joint width and permissible movement varies with the type of material used. Mastic, thermoplastic and solvent-release thermosetting sealants may be used in joints up to 1/2 in. (40 mm) wide with a permissible movement not exceeding 3/4 in. (6 mm). Chemically curing thermosetting materials have been used in joints up to 4 in. (100 mm) wide with movements in the order of 2 in. (50 mm), though it is more usual to confine them to joints of half that size to insure good performance and economy in materials. In wide joints increasing care with sealant installation is necessary and where subject to traffic, protection of the upper surface against damage with a steel plate or other means is required.

Turning to preformed seals, single unit compression seals are available in widths up to 6 in. (150 mm) permitting joints with movements of about 2½ in. (63 mm) to be sealed. The smallest compression seal available can be installed in a ½ in. (3.2 mm) wide joint, where the movement will be negligible. By placing compression seals or strip (gland) seals in modular series [Fig. 9(5)], movements of up to 48 in. (1220 mm), as in the longest suspension bridges, have been accommodated. Tension-compression seal systems have been used to accommodate movements of 13 in. (330 mm).

4.7-Lap joint sealant thickness

As mentioned in Section 2.5, shear governs sealant behavior in lap joints and its magnitude is related to both the movement that occurs and the thickness of the sealant between the
Fig. 14—Chart for determining joint movements and width; field-molded sealants
two faces. It is usually considered that for installations made at normal temperatures of 40 to 90 °F (4 to 32 °C) the thickness of the sealant should be at least one half the anticipated movement and where higher or lower temperatures prevail at installation, the thickness of the sealant should be equal to the anticipated movement. Where there will be no movement, the sealant thickness can be as little as \( \frac{1}{8} \) in. (3.2 mm). However, in assembling concrete units a minimum thickness of \( \frac{3}{16} \) in. (6.4 mm) is desirable to compensate for casting tolerances or any irregularities in the faces.

4.8-Shape and size of rigid waterstops

Metal waterstops may be either flat stock or folded in Z or M cross-sectional shapes. The choice depends on the movement at the joint. End anchored flat shapes permit little or no movement without inducing excessive stresses in the embedded portion of the waterstop. Coating one end with asphalt to permit sliding yet maintain some sealing compatibility may not be entirely satisfactory because leaks may eventually occur. The Z cross section can accommodate slight movements and the M cross section greater movements.

4.9-Shape and size of flexible waterstops

For certain applications, flat shapes may be used but the traditional shape for flexible waterstops has a dumbbell configuration at each end intended to serve both as an anchor and, by pulling it inwards towards the joint as it opens, it acts as a “cork in a bottle” type of seal. This seal is not too effective at small openings and the material is in considerable tension at wider joint openings. To overcome these problems, quite elaborate shapes have been developed in recent years. Numerous ribs at the end now provide better anchoring and sealing, and O or U bulbs at the joint gap permit considerable joint movements to be accommodated without unduly stretching the material. Manufacturers may be helpful with recommendations.

For easier installation, both rubber and PVC waterstops are often specified in thicknesses greater than that required for their function as sealants.

4.10-Shape and size of gaskets and miscellaneous seals

Seals used for concrete pipes or building components are usually sized and shaped to suit the joint configuration including the irregularity of the surfaces being joined. Since the movement is small, the width of the sealant may not be the primary consideration. Square, rectangular, trapezoidal, O-ring and H, U and W purposely made shapes, some with ribs, flanges and serrations, are used depending on the application and how they can be installed. Pressure sensitive tapes of suitable widths are used as auxiliary materials to make window and door frames or panels weathertight.

4.11-Measurement of joint movements

A better understanding of in-service joint movements in all types of concrete structures is needed in order to confirm the theories and laboratory experiments upon which the design prediction of joint widths and sealant performance are based. The factors which influence the movement of joints and the functional performance of sealants are discussed in Chapters 1 and 2 and the preceding part of Chapter 4.

In view of the many variables involved, it is impossible to specify a standard procedure for the observation and assembly of data on joint movements, the causative factors and sealant behavior. However, it is important that both the short term rates of movement over a matter of hours or days and the long term extremes of movements over the annual environmental cycle together with any permanent changes in interfacial joint distance are established.

4.11.1 Means of measuring joint movements-Hand gages, either a simple vernier caliper or reference bar with a dial gage, may be used to measure the distance between reference plugs set on each side of the joint. While this system is simple it only provides a discontinuous record and requires an operator to make each reading. To overcome these disadvantages a scratch gage may be employed. These gages have a scratch probe fixed to one side of the joint opening and a plate or a hand or power rotated disc attached to the other side. The trace of the movement over the movement cycle is then measured. The next stage of sophistication is to use an electronic gage. Usually this is a transducer (or LVDT for greater precision at a greater cost) to measure the movement which is then recorded continuously or intermittently on a strip chart or digitally for later analysis.

In most structures the measured movement of concern to sealant performance is horizontal (across the plane of the joint). In skewed joints, lateral movement (along the plane of the joint) may also need to be measured or calculated since a skew introduces shear in the sealant. Vertical movements (at right angles to the plane of the joint) can be measured by fast response transducers where, as in pavements, moving loads cross the joint. Measurement of other dynamic effects such as vehicle braking, impact and noise generation require specialized instruments.

Absolute measurements of the relative positions of structural members can be made using standard survey practice techniques against a reference datum clear of the structure.

4.11.2 Corresponding measurements of temperature and moisture content-Corresponding data on the thermal and moisture dependent behavior of abutting structural units are needed to fully interpret joint movement measurements. Response to ambient temperature change and solar radiation is much greater and faster than that due to seasonal changes in moisture content in the concrete. Since moisture content is difficult to measure and is unlikely to significantly affect the overall findings, it is often ignored.

Where a continuous record is needed, ambient, surface or internal temperatures are easy to measure by thermocouples and record on a strip chart or digitally for analysis. It must be remembered that, while surface temperature changes induce warping and curling fairly rapidly in thin sections, the internal temperatures of a structural unit control its overall dimensions and hence the end movements at joints. Especially in massive concrete sections there is a considerable time lag between change in external and internal temperatures. This must be taken into account in determining any correspondence between temperature and movement measurements. In massive sections or where the structural configuration is complex or where differential heating because of sun and shade is significant it may be prudent also to measure heat flow and solar radiation. Notwithstanding all these cautions, as a minimum observation, a thermometer reading of
ambient shade temperature should accompany any single measurement of joint width.

4.11.3 Survey of joint sealant performance - In addition to the measurement of movements and the factors that cause these movements, it is important to note the condition of the installed sealant, joint hardware and abutting concrete as part of any overall appraisal of joint performance.

CHAPTER 5-JOINT DETAILS

5.1-Introduction

Fig. 7 through 12 illustrate the application of joint sealants to a wide variety of design configurations which occur in concrete construction (for a key to symbols see Appendix A). The details shown are representative of current practice and cover most standard variations, although other variations in use may not be shown. These details are presented in outline form, omitting for the sake of clarity structural details such as reinforcing steel, dowels, etc., not directly relevant to the sealing of the joint. The location of a joint is indicated only where this is significant to delineate the type of joint and sealant that may be suitable. As stated in Sections 1.5 and 4.2, the location and spacing of joints for particular applications is beyond the scope of this guide. Similarly, sealant reservoirs (grooves) and expansion or contraction gaps are not dimensioned as to width or depth because differing sealants have a wide range of performance capabilities. The required configuration should be determined as outlined in Chapter 4 and/or may be obtained from supplier’s literature.

Exposure and environmental service conditions are shown for each group of applications, since this is an important consideration in selecting a suitable sealant.

Often, alternatives exist for a particular application. Therefore no endorsement is intended for selecting one detail over another, or choosing one sealant rather than another. The guide does endorse and promote those standard design features documented throughout the guide (e.g., improving the shape factor of field-molded sealants) that will insure the best possible performance of any given seal or sealant.

5.2-Structures

Fig. 7 and 8 cover applications to structures in general and buildings in particular, where sealing against significant fluid pressure is not a consideration. Where ground water must be excluded, as for example in basements or earth-retaining walls, reference should also be made to Fig. 11 since additional sealing using waterstops may be indicated. Since the appearance of sealed joints in many buildings is important, additional architectural treatment not shown in the figures, for example, V-ing of joint edges may be required.

Bridge deck joints are treated separately in Fig. 9, since large movements and special sealing problems are often involved. Joint details suitable for bridge substructures generally follow those in Fig. 7, or where water pressure is involved those shown in Fig. 11.

Containers of all types are covered in Fig. 10 and 11. Except where the head is small, the use of waterstops in “in place construction” or gaskets under compression for precast pipes is almost essential if the contents are to be kept in. In certain uses, for example dams, a second waterstop may be used some distance behind the first as an additional line of insurance against premature failure.

Many of the details shown in Fig. 10 and 11 also serve equally well for keeping water which is outside the structure from passing through the joint to the inside face. The exclusion of water from basements, subways and tunnels are examples of this application. Tunnel applications are discussed in greater detail in ACI 504.1R.

5.3-Slabs on grade, highway, and airports

Slabs on grade are shown in Fig. 12. These may be outside as on highways, parking garages and airports, or they may be within a building or container with the modifications indicated in the figures specific to these applications.

Many highway authorities are specifying short contraction joint spacings in both plain and reinforced concrete pavements; some are using a random spacing averaging between 15 and 20 ft (4.57 and 6.10 m) in plain pavements for which the repeating series 13, 18, 19, 12 ft (4.0, 5.5, 5.8, 3.7 m) is popular; some are also skewing joints at 2 ft in 12 ft (0.61 m in 3.66 m). While the objectives are reducing intermediate slab cracking and improving ride and load transfer, such designs place less demand on the sealant because of the smaller movement that occurs at each joint. Fuller information on the design and construction of joints in concrete pavements will be found in the reports of ACI Committee 325.

5.4-Construction and installation considerations

The practical aspects of constructing the joint and sealing it must be kept in mind when its details are being designed. The general construction steps for any expansion, contraction and construction joints are stated in Fig. 12. The method of making monolithic construction joints is outlined in Fig. 7(3). Fig. 9 (2B) shows the breakout required where later installation of expansion joint devices is planned. The positioning of waterstops is shown in Fig. 11 (4) and further discussion on their installation and that of sealants in general follows in Chapter 6. It must be remembered that a joint detail that makes it unnecessarily difficult to install the sealant is a poor one likely to lead to premature failure.

CHAPTER 6-INSTALLATION OF SEALANTS

6.1-Introduction

The most appropriate technique for installing (applying) a joint sealant depends on the material, the width, shape, inclination, and accessibility of the joint and on whether it is a small or large project. Each step in the construction and preparation of the joint to receive the sealant and for its installation requires careful workmanship and thorough inspection to avoid initial defects that may be costly and time consuming to correct.

The specification for the work should state how the selected sealant is to be installed and any special features required in the construction or preparation of the joint to receive it. Before the containers of sealant are opened, their labels should be checked to make sure that the right sealant has been supplied and that there is no conflict between the
specification and the manufacturer’s instructions for installation. Any discrepancy should be referred to the architect or engineer before work commences.

The most auspicious time for installing field-molded sealants, if the construction schedule permits, is on dry days when the temperature is close to the annual mean. Compression seals, especially the large ones, are easiest to install on cold days. However, a satisfactory job can and usually must be done in less than ideal conditions, provided the effects of this are compensated for in the design of the joint.

Sealant storage and installation requirements are summarized for each material in Table 4. These operations are discussed in greater detail as follows.

6.2-Joint construction with sealing in mind

Some of the defects resulting from improper concrete joint construction are shown in Fig. 16. These and others can be avoided by the following:

1. Saw or form the joint to the required (and uniform) depth, width and location shown on the plans. Manufacture precast units to close tolerances and position them carefully.

2. Align the joint with any connecting joints to avoid blockage to free movement.

3. Judge the time of sawing to avoid edge spalling or plucked aggregate (too early) or random cracks (too late).

4. Correctly position dowels and other joint hardware, fillers, waterstops and bulkheads, and rigidly support them to avoid displacement during concreting.

5. Remove any temporary material or filler used to form the sealant reservoir by raking out or rotary cutting to the specified depth.

6. Keep curing compound and other materials from contaminating joint faces. Apply supplemental curing where the original curing is broken by construction operations before the joint edges and faces have fully cured.

6.3-Preparation of joint surfaces

Joint faces must be clean and free of defects that would impair bond with field-molded sealants or prevent uniform contact of preformed sealants. Removal of contaminants may require washing out of debris left by sawing and wire brushing or routing and sand blasting. Though sand blasting is more expensive, it is more likely to succeed and therefore is warranted where relatively expensive thermosetting, chemical curing field-molded sealants are used.

Solvents intended to remove oil, etc., usually have the opposite effect and carry the contaminants further into the pores of the concrete. Solvents are, however, distinctly useful in cleaning nonporous surfaces such as glass or metal frames. Defects in the joint faces such as loose aggregate, embedded foreign material and spalls in the case of compression seals or blockages to free movement require repair (see Section 7.2.1). Final cleanup to remove dust is usually required. This is essential where a good bond must be developed with chemically curing thermosetting field-molded sealants. Final cleanup can be done by a brush, but the use of oil-free compressed air or vacuum cleaner is more likely to be successful.

As a general rule, joint faces must also be dry since the sealant has to bond with the concrete. Exceptions are claimed by sealant manufacturers. They include neoprene compression seals and emulsion and certain elastomeric sealants formulated to displace water from contact faces. Notwithstanding, better results will be achieved if sealant installation is done in the dry.

6.4-Inspection of readiness to seal

Inspection of each joint to insure it is sufficiently clean and dry is essential prior to placing backup materials, priming or sealant installation. It is also wise to check the joint width and temperature (preferably that of the concrete rather than the ambient) against assumptions made in the joint design. Restrictions on joint width and temperature at the time of sealant installation should be shown on the plans. In the absence of these, installations at above 90°F (32°C) or below 40°F (4°C) should generally be avoided. Installation at temperatures above or below these values may lead to various difficulties. Extra strains may be induced on field-molded sealants (see Section 4.3). Problems may arise due to shortened working life at higher temperatures or moisture condensation and frost at lower ones. In the case of compression seals, it is harder to properly install them in tight joints or the lubricant may be too fluid or viscous.

6.5-Priming, installation of backup materials and bond breakers

Where priming is required with the selected field-molded sealant the necessary primer is usually supplied with the sealant and can be applied by brush or spray. (As a general rule priming is required for all porous surfaces such as concrete, wood, and possibly plastics if thermosetting, chemical curing field-molded sealants are to adhere satisfactorily). Brushing can be tedious and unless excess material is properly brushed out to insure a uniform film over the whole joint face, adhesion failures may result. For horizontal joints on larger projects, spray applicators may be more appropriate. Most primers require time to dry out before the sealant is installed. Failure to permit this action may lead to adhesion failure or exudation of the primer.

Backup materials and/or bond breakers require positioning, usually by hand method, before the sealant is installed. They must be set at the correct depth avoiding twisting or contamination of the cleaned joint faces.

6.6-Installation of field-molded sealants, hot applied

As noted in Table 4, certain joint sealants are melted and applied hot in the field. These hot-poured compounds are usually comprised of bituminous materials (either asphalt or tar) and may or may not contain rubber or other elastomeric substances. Each has a manufacturer’s recommended pour point as well as a safe heating temperature which should not be exceeded. The safe heating temperature usually is 20°F (11°C) above the recommended pour temperature. Subjecting sealants to temperatures above the safe heating limit results in a breakdown or setting up of the compound which precludes good field performance as well as longevity.

These materials are usually heated in double-boiler type melting kettles equipped with a suitable agitation system in the sealant melting chamber, a positive, pressure delivery and recirculation system and a recording thermometer. The inner tank should be oil-jacketed and the temperature of the high flash point heat transfer oil should be thermostatically
JOINT SEALANTS

Note in examples A B C D E F G movement will occur at the crack and not at the 'intended' joint. Therefore, the crack rather than the joint should be sealed if repairs (which would be desirable) are not undertaken to correct the underlying cause.

Random cracks associated with expansion joint -possible causes

A Sealant reservoir (groove) not formed or sawn deep enough
B Filler displaced during concreting
C Sealant reservoir narrower than filler (or off center)

And also for short cracks and spalls Fig. 3 ⑪ and Fig. 4 ⑫

Random cracks in plan-possible causes

D Crack follows and/or crosses joint. May be due to A B C or sawing joint late after crack had already formed
E (i) Crack ran ahead of sawing to slab edge due to late cutting
(ii) Infiltration of incompressible material from shoulder
F Sealant reservoir (groove) or crack inducer not deep enough to form plane of weakness at desired joint location
G Joints at intersection were not lined up. Crack occurs to complete omitted continuity

Other Defects

H Joint opening not formed (or sawn) with uniform width (or depth). While movement is the same sealant has varying shape
I Edge spalled when groove former was removed or during sawing. Inadequate bearing for compression seal or poor shape factor for field molded sealants

Fig. 16-Defects in joint construction
controlled. Earlier models of melters were of the gravity-feed type and some required the use of separate pouring devices. These are preferably oil-jacketed also, but all suitable units were insulated. The newer melting kettles equipped with pressure discharge through hoses, wands and nozzles should have the application lines insulated.

Hot-poured materials are normally suitable for installation in horizontal joints only. They can be placed in vertical joints but adequate dams are necessary to prevent the sealant from flowing to the bottom before it cools and sets. Horizontal joints should be underfilled to slightly below the pavement surface.

6.7-Installation of field-molded sealants, cold applied

Except for extremely short joints or in touch up work, cold applied sealants are usually extruded under pressure from a nozzle whose orifice may be sized and shaped to mold the required bead of sealant to suit the joint opening. The simplest piece of equipment for this purpose is the familiar hand operated caulking gun. The sealant is either supplied pre-packaged in cartridges to suit the gun, or the chamber or cartridges are loaded on the job from bulk containers as required, or in the case of two-component sealants, they are filled with the compound after mixing. Depending on the size of the project, more sophisticated pressure application equipment is available including models where two-component materials are brought by individual lines to the nozzle where they are intimately and continuously mixed in a small chamber immediately prior to extrusion. Pumps, compressed air or gas may be used to supply the necessary pressure for extrusion.

With two-component sealing, full and intimate mixing is essential if the material is to cure out with uniform properties. Little can be done with patches of sealant that do not harden except to remove and replace them with properly mixed material. Small quantities of two component sealants can be mixed with a broad bladed putty knife. However, for any significant quantity of material, mechanical mixing is required. For small batches hand held electric drills with paddle blades can be used. Large batches need purposely made mixing machines.

Frequently, it is convenient to premix sealants at a location remote from the job site. To prevent curing until it is time to use them, sealants may be frozen at -40°F (-40°C) or below and held in storage. In some urban areas frozen premixed cartridges are available from sealant suppliers. On the job, cartridges are thawed out for about 30 min at a temperature of 70 F (21°C) (additional heating to hasten thawing may be detrimental and should not be used).

Application of a sealant to fill a joint reservoir requires a skilled operator. The gun nozzle must be controlled at an angle (about 45 deg) and moved steadily along the joint so that a uniform bead is applied without dragging, tearing or leaving unfilled spaces. A skilled applicator will be seen to push the bead rather than draw it with the gun leading. In large joints, several runs may be needed, building up the sealants in roughly triangular wedges at each run.

For nonsag sealants, when the joint has been filled with the required amount of material it is tooled to insure intimate contact with the joint faces, to remove any trapped air or voids, to consolidate the material, and to provide a neat, uniform appearance. At the joint faces the exposed face of the sealant should usually match the level of the edge of the concrete. An exception is in areas subject to traffic where self-leveling sealants are used. In this case the surface should be left slightly low.

It must be remembered that two-component sealants in particular have a limited working (pot) life, especially on hot days. Once the accelerator is mixed in, the curing reaction starts, therefore the batch size should be limited to what can be used within the pot life of the material.

6.8-Installation of compression seals

Compression seals require a uniform joint width along the whole length with straight, smooth, spall-free, properly cleaned joint faces to permit proper installation and to provide uniform contact. It is advantageous to remove sharp aris- ses at the joint edge or to form or saw the joint with a slight rounded or V-edge.

A neoprene-based or other lubricant (which may have adhesive properties for most applications) is applied in a bead to the upper edge of each joint face to facilitate installation of the seal. The lubricant is fluid at normal temperatures and is usually applied by a hand-pressure applicator. Where machine installation of the sealant is used for pavement joints, this unit may also be designed to apply the lubricant, which then generally should be a thixotropic formulation. The lubricant must be applied immediately ahead of inserting the seal so that it does not prematurely dry out.

For installation either by hand roller or with the machine, the seal is positioned vertically over the joint opening and then, by pressing down and forward, it is forced into the opening. The seal must not be twisted, folded over on itself or stretched during this operation. A small permissibly amount of stretching, up to 5 percent, may occur as the seal is forced in. The seal must not be willfully stretched (thus reducing its cross section) to make installation easier and the seal length go further. Near zero stretch can be achieved with both hand and automatic machine installation which may be desirable since the seal will not be under tension along its length nor reduced in effective width.

It is important to install the seal at the specified depth. In highway pavements, this is usually slightly below the surface to keep it out of contact with traffic. The seal should be installed in as long a continuous piece as possible. If field splices cannot be avoided they should be made in the least critical location as far as maintaining a sealed joint is concerned. Usually the seal is spliced simply by butting it against the next length with some lubricant adhesive. However, more sophisticated means are available and may be warranted where it is important that a splice should not part.

Where a compression seal is to be installed between precast units, it may be attached to the face of one and compressed as the adjacent unit is positioned.

The polybutylene impregnated foam type of compression seal is precompressed and inserted in the joint opening. To achieve a good bond, the joint faces may first require priming with an epoxy adhesive. Other cellular foams such as ethylene vinyl acetate are installed in a similar fashion.
6.9-Installation of preassembled devices

Placing large seals 4 in. (100 mm) and over in bridge and other large movement joints presents special problems. Firstly, these seals are not particularly easy to handle and they cannot be bent or formed to suit an abrupt change of direction. Secondly, they require considerable force to compress them as they are pushed and levered into the opening, especially if it is a warm day and the joint is partly closed beyond its mid-range. For this reason (and because the seal must be sized to the joint opening), there is merit in joint devices which are installed as a complete unit prior to concreting with the seal precompressed or preset to the required width. The joint is activated after the concrete has set by releasing the ties connecting the joint faces. Strip (gland) seals and modular systems designed to accommodate large movements are similarly supplied precompressed or preset, ready for installation and subsequent activation.

Tension compression devices as used in bridge decks (see Fig. 9) require setting flush with the pavement surface. Except where a subsequent bituminous surfacing is to be laid, this requires a recess in the concrete surface on each side of the joint. Provision for the holddown bolts required for the mechanical anchoring of the device can be made either by pre-setting inserts using a template when the concrete is placed, or subsequently by drilling and installing the anchors after the concrete is set.

In cases where the anchorage units are preattached to the edge elements (strip seals and armored type systems) the expansion joint is set to line and grade and then the concrete is placed.

6.10-Installation of waterstops

Three methods of positioning waterstops in vertical joints are shown in Fig. 11 (4). Of these, placing between split forms is still the most common, though nail-on types may be more convenient and economical. In horizontal joints, waterstops are usually embedded halfway into the first lift. In all instances, the waterstop should be securely held in position so that it will not be displaced during concreting, and care is required in placing and consolidating the concrete so that no voids or honeycombing occurs adjacent to the waterstops to prejudice its sealing ability. Contamination of the waterstop surfaces, for example, by form coatings, should be avoided. While rubber and polyvinyl chloride waterstops are not susceptible to damage during normal handling or concreting operations, thin metal waterstops are easily bent or torn and therefore require special care.

Waterstops may need splicing at intersections, abrupt changes of direction or to form long continuous lengths. It is often convenient to order prefabricated junction pieces from the manufacturer so that these can be joined to the main run by simple butt splices in the field. Polyvinyl chloride waterstops can be spliced by trimming their ends to the required matching shape and then butt-welding them together by softening under heat and pressing them together until cool. Since excess heat or an open flame would char the material and destroy its resilience, thermostatically controlled electric heating tools should be used. Rubber waterstops can be joined by mitering the ends to mate and, after cleaning and roughening, cementing them together. They must then be held in a mold under heat and pressure until cured (vulcanized). An alternative is to use premolded splicing sleeves into whose opposite sides the cemented ends of the waterstop are inserted.

6.11-Installation of gaskets

Gaskets are either positioned in the joint opening or are prepositioned because they are attached to one of the units to be joined, for example, on the spigot end of the pipe. Positioning the unit in place closes the joint on the gasket which, under pressure, then forms the seal.

6.12-Installation of fillers

Most compressible fillers in expansion joints are installed ahead of the concreting operation in the required location and position, and held either by the bulkhead if it is a construction joint, or by some rigid device at other expansion joint locations until the concrete has been placed and set. Problems of the type illustrated in Fig. 16 have often occurred because due care and attention has not been given to making sure fillers are accurately positioned and/or are not displaced.

6.13-Neatness and cleanup

Nothing esthetically looks worse on a new structure than a sloppy job of joint sealing in which the sealant is uneven or is adhering to everything except the joint faces. Careful workmanship such as uniform depth of installation, proper tooling and lack of spilled or excess material on surfaces adjacent to the joint are all signs of a good, conscientious job.

A very neat joint can be obtained with field-molded sealants if strips of masking tape are first placed on each side of the joint opening. These can be later removed carrying any excess sealant with them. Proper cleaning of equipment and tools immediately after their use ceases, for even a short period, will avoid contamination of the work or delays due to hardened sealant on their surfaces. The instructions on the containers of cold applied sealants usually list suitable solvents for this purpose. Unused hot applied sealants must not be allowed to set up in heating vessels and applicator equipment.

6.14-Safety precautions

There are certain hazards in using joint sealants. They can be minimized, however, by taking simple precautions. Specific warnings are stated on the containers together with action or antidote in case of accident. In addition, material safety data sheets (MSDS) are required by law and should be available for all products. Users of joint materials should expect to receive MSDS with the best information regarding the use of the particular material they will be handling.

1. Hot-applied materials can cause serious burns or a fire may be set if flammable materials are spilled. Excessive breathing of fumes or skin contact with coal tar compounds may cause irritation.

2. Cold-applied materials (other than emulsions) and primers may contain flammable solvents. Containers should be kept closed and away from flames. Working areas must be well ventilated.
3. Toxic chemicals may be present in many elastomeric sealants. Skin, eye or internal contact must be avoided. Protective gloves and sometimes masks and goggles are required. Lunch pails should not be opened until the operator has cleaned up.

4. Sealants containing poisonous chemicals, for example, lead dioxide, may not be appropriate in joints open to potable water or food processing areas.

5. Most liquid sealants are highly sensitive to liquid oxygen (LOX) creating a serious safety problem. The chemicals in sealants are in a state such that they can easily react with oxygen to promote explosion and/or toxic gases. Special materials have been developed for exposure to LOX; however, they are usually not durable and a service life of 12 months duration is as long as the user/owner should anticipate before replacement. Loss of bond may result in a safety hazard by allowing infiltration of LOX where otherwise inert materials will become highly reactive due to contamination.

6. Since many joint sealants are combustible organic materials, attention should be given to their effect on the fire resistance of the structure.

7. Solvents used in clean up or released during curing may be restricted by some jurisdictions since they are deemed to be atmospheric pollutants even though nonhazardous.

CHAPTER 7-PERFORMANCE, REPAIR, AND MAINTENANCE OF SEALANTS

7.1-Poor performance

Much experience of poor sealant performance and resulting damage to a wide variety of structures exists. Concern with problems arising from the use of low grade asphalts and asphaltic sealants spurred the development and introduction of higher class sealants, both field-molded and preformed. Failures have continued to occur, however, often within days and weeks of installation rather than months or years, for five main reasons:

1. Design of the joint geometry was insufficient to accommodate the movement.

2. Unanticipated service conditions resulted in greater joint movements than those allowed for when the joint design and type of sealant were determined.

3. The wrong type of sealant for the particular conditions was selected, often on the false grounds of economy in first cost.

4. New sealants have sometimes been initially over-promoted and used before their limitations were documented.

5. Poor workmanship occurred during joint construction and preparation to receive the sealant or sealant installation.

Some of the common problems with joints are shown in Fig. 3, 4 and 16, together with advice as to how these defects may be avoided in future work.

7.2-Repairs of concrete defects and replacement of sealants

7.2.1 At joints-Minor touch-up of small gaps and soft or hard spots in field-molded sealants can usually be made with the same sealant. However, where the failure is extensive it is usually necessary to remove the sealant and replace it.

Where the sealant has generally failed but has not come out of the sealing groove it can be removed using hand tools, or on larger projects such as pavements, by routing or plowing with suitable tools. Alternatively, especially where widening is required to improve the shape factor, the sealant reservoir can be enlarged by sawing.

After proper preparation to insure clean joint faces and additional measures designed to improve sealant performance such as the improvement of shape factor, provision of backup material, and possible selection of a better type of sealant, the joint may be resealed as described earlier.

Minor edge spills to concrete joint faces may be repaired with suitable repair materials, an essential operation if a compression seal is being used. Otherwise most repairs to correct defects in the original construction of the joint involve major, exacting and often expensive work. The reason for the failure must be identified and, depending on the cause, continuity must be restored in the joint system either by the removal of whatever is blocking the free working of the joint or by cutting out the whole joint and rebuilding it.

7.2.2 At cracks-Where cracks have occurred because of a nonworking or absent joint, or because of unanticipated deformation of the structure, they can be routed out and sealed with a suitable field-molded sealant to prevent damage to the structure. ACI Committee 224 has done considerable work in this area and their information regarding repairing of cracks would be of significant help. (See ACI 224.1R). An additional problem occurs where water is flowing through the crack and the upstream face cannot be reached for sealing. Before sealing can be successfully undertaken, the water flow must be stopped. If the source of water cannot be cut off by dewatering, then depending on the circumstances one of the many alternatives such as cutting back the crack deeper and plugging with a quick setting or dry-pack mortar or cement, chemical or epoxy resin grouting may be tried. External plates are sometimes bolted to the concrete, or keyed grooves are filled with mortar to hold the sealant in case water pressure redevelops as the joint moves. Successful execution of any of these operations usually requires specialized knowledge, experience and workmanship.

7.3-Normal maintenance

Few exposed sealants have a life as long as that of the structure whose joints they are intended to seal. Fortunately, buried sealants such as waterstops and gaskets have a long life because they are not exposed to weathering and other deteriorating influences.

Most field-molded or preformed sealants will, however, require renewal sooner or later if an effective seal is to be maintained and deterioration of the structure is to be avoided. The time at which this becomes necessary is determined by service conditions, by the type of material used and whether any defects of the kind already enumerated were built in at the time of the original sealing.

The opportunity should be taken when inspections are being made for other purposes, or in the case of buildings when the facade is cleaned, to establish the condition of sealed joints and whether resealing is required immediately or is likely to be required in the near future. Far too often, in the past, resealing has been postponed either because of lack
of knowledge that it was needed or failure to budget ahead, with inevitable costly consequences.

Sealant renewal follows closely the methods listed under the repair of defects (see Section 7.2). When renewal is needed prematurely, consideration must be given to improving the sealing system from that originally used, otherwise money will be wasted since failure may soon recur. Ways of evaluating this have already been described.

CHAPTER 8-SEALING IN THE FUTURE AND CONCLUDING REMARKS

8.1-What is now possible

The cost of providing well-sealed joints by using the best available sealants, carefully installed in joints of the correct type, size and location, is usually only a small fraction of the total cost of a concrete structure. The available sealants and knowledge of the criteria for joint sealing are now adequate to insure success in at least 9 out of 10 situations; there is no justification for poor sealing practices when the very integrity and service life of a structure may be at stake.

8.2-Advancements still needed

8.2.1 Since joint sealing is done in a wide variety of environments with a large array of differing sealant materials under conditions less than optimum their performance is usually less than perfect. The satisfactory working life of sealants still requires improvement in that we can expect as low as one year of performance to generally five years of performance for most sealants. Modern structures are being designed to minimize maintenance and designers are looking for high performance sealants with life cycles of 10 to 20 years.

It takes several years after the time of initial installation to evaluate the performance of a particular sealant. After several years have passed, the long term performance and capabilities of a sealant become evident for a given type of joint or application. Obviously some sealants perform better than others. As a result, manufacturers are constantly improving a particular sealant’s ability to perform. Thus this manual must be constantly updated to provide the latest information.

8.2.2 Research and development work is still required to improve:

1. Knowledge of the movements which actually occur in every type of concrete structure.

2. The materials available for use as joint sealants. The challenge is to achieve good performance in a wide variety of joints that are wet and dirty when the sealant is installed.

3. The methods by which sealants may be installed so that human error is avoided as far as possible.

4. Techniques for resealing leaking joints and cracks.

8.2.3 Spreading the word—Public authorities and sealant manufacturers and suppliers have been the source of copious technical data and advice that has greatly benefitted the art of joint design and sealing. However, many of the current sealant problems will continue unless improvements are made in disseminating and applying available knowledge and upgrading skills. For example, improvements are required in:

1. Making designers more aware of the importance of joint design and the selection of suitable sealants.

2. Providing clear instructions on the plans, in the specifications and on the sealant containers so that the workers on the job can understand and implement what is required.

3. Educating and training at all levels of responsibility so that joint sealing is no longer regarded as a necessary evil to be left to the last moment for the low man of the scaffold.

8.2.4 Future codes, standards, recommended practices and specifications—Appropriate criteria should be included in the contract documents for joints in concrete structures (location, type, movement determination, width, shape, sealant selection and installation criteria).

CHAPTER 9-REFERENCES


2. Joint Sealing & Bearing Systems for Concrete Structures, SP-70, American Concrete Institute, Detroit, 1981. 2006 pp.


APPENDIX A-LAYMAN'S GLOSSARY FOR JOIN SEALANT TERMS

This glossary is based on the terminology used or proposed by ASTM and ISO committees or common trade parlance. The definitions are not definitive and are prepared for the purpose of understanding this guide only.

Accelerator*-A compounding ingredient used in small amounts with a curing agent to increase the speed of vulcanization and/or enhance the physical properties of the vulcanizate.

Adhesion-The state in which two surfaces are held together by interfacial forces.

Adhesive-A substance having the capability of maintaining surface attachment by interfacial forces between two or more surfaces.

Anti-foaming agent-Product which greatly increases the surface tension, thereby reducing the tendency to foam during mixing or application.

Antioxidant-Compounding ingredient used to retard deterioration caused by oxidation.

Applied skin-A thin surface layer of elastomeric material applied to a cellular product.

Backup-A compressible material used in the bottom of sealant reservoirs to reduce the depth of the sealant thus improving its shape factor. Also serves to support the sealant against sag or indentation.

Bleeding*-Exudation with possible absorption by porous surfaces of a component of a sealant.

Blister-A cavity or sac that deforms the surface of a material.

Blowing agent-Compounding ingredient used to produce gas by chemical and/or thermal action in manufacture of hollow or cellular articles.

Bond breaker*-Material used to prevent a sealant bonding undesirably to the bottom of a joint; or to facilitate independent movement between two units that would otherwise behave monolithically.

Bond face-That part of the joint face to which a field-molded sealant is bonded.

Butt joint*-A joint in which the structural units being joined abut each other so that under movement any sealant is in tension or compression between the joint faces.

Catalyst*-Substance added in small quantities to promote reaction between two other substances while itself remaining unchanged.

Cellular material-A generic term for material containing many cells (either open, closed, or both) dispersed throughout the mass.

Chemical cure-Curing (hardening) by chemical reactions usually involving the formation of cross linked polymers.

Closed cell-A cell totally enclosed by its walls and hence not interconnecting with other cells.

Cohesion-The form of attraction by which the body of an adhesive or sealant is held together. The internal strength of an adhesive or a sealant.

Compound-An intimate admixture of a polymer with all the ingredients necessary for the finished article.

Compression seal-A compartmentalized or cellular sealant which by compression between the joint faces provides a seal.

Conventional rubber cure-See vulcanization.

Copolymer-Large molecule resulting from simultaneous polymerization of different monomers; more commonly, the compound consisting of such molecules.

Cross linked-Molecules of a polymer that are joined side by side as well as end to end.

Cure-To set up or harden through change in the physical properties of a plastic, resin or polymer by chemical reaction.

Curing agent-Catalyst or hardener.

Diluent*-Liquid which lowers viscosity and increases the bulk but is not necessarily a solvent for the solid ingredients; a thinner.

Drier*-Chemical which promotes oxidation or drying.

Effective length-The length of that section of a structural unit which is free to move toward or away from a joint.

Elastomer-Macromolecular material that returns rapidly to approximately the initial dimensions and shape after substantial deformation by a weak stress and release of the stress.

Elastomeric-Having the attributes of an elastomer.

Emulsion*-Water system containing dispersed colloidal resin or liquid particles.

Expansion-compression-The percentage increase and decrease in width from the installed width tolerable to a sealant in service.

Extender*-An organic material (usually cheaper) used as a replacement for a portion of the material required in a sealant compound.

Extensibility*-The capacity of a sealant to be stretched in tension.

Field-molded sealant-A liquid or semi-solid material molded into the desired shape in the joint into which it is installed.

Filler*(a) Finely divided material compounded in sealant to give body. (b) Compressible, preformed material used between the faces of an expansion joint to form or maintain the space between them.

Gasket-A deformable material clamped between essentially stationary faces to prevent the passage of matter through an opening or joint.

Hardener*-Substance which enters into chemical combination with other substances to form a new, more solid material.

Hardness-The property of resisting indentation. Note: When hardness is expressed as a number, the number has no quantitative meaning, except in terms of a particular test in which the size and shape of the indenter, the indenting load, and other conditions of the test are specified.

Hump-See sag. Sealant is, however, raised rather than depressed.

Joint-The interstice between component parts or units.

Joint movement (total)-The difference in width of a joint opening between the fully open and fully closed positions.

Lap joint-A joint in which the structural units being joined override each other so that under movement any sealant is in shear between the joint faces.

*Terms designated by asterisk differ in some way from definition given in ACI Committee 116, Cement and Concrete Terminology (ACI Publication SP-19).
Low temperature recovery - Ability of a sealant to recover its original form at low temperature when the deforming load is removed.

Mastic - A sealant with putty-like properties.

Migration - Spreading or creeping of sealant vehicle onto adjacent surfaces usually to the detriment of bond.

Monomer - A composition of single molecules; a basic chemical used to make polymers.

Necking - An irrecoverable reduction in cross section of a sealant under stress.

Non-staining - Unable to stain or discolor adjacent surfaces (see stain).

O-ring - An elastomeric seal of homogeneous composition molded in one piece to the configuration of a torus with circular cross section.

Open cell - A cell not totally enclosed by its walls and hence interconnecting with other cells or with the exterior.

Packing - A deformable material used to prevent or control the passage of matter between surfaces which move in relation to each other.

Peeling* - Local pulling away or curling of the sealant from its substrate at points of stress concentration such as corners, edges or bubbles.

Pick-up - Unwanted adherence of solids in contact with the open surface of a sealant, i.e., adherence of sealant to tires.

Permissible movement - The safe joint movement which can take place without failing the sealant.

Polymer* - A compound formed by the reaction of simple molecules having functional groups which permit their combination to proceed to high molecular weights under suitable conditions.

Positive anchor - Point of intentional restraint against movement.

Pot life* - (Sometimes referred to as “work life”).- Time interval after mixing during which liquid material is usable with no difficulty.

Preformed sealant - Sealant functionally reshaped by the manufacturer so that only a minimum of field fabrication is required prior to installation.

Pressure sensitive - Capable of adhering to a surface when pressed against it.

Primer - A material applied to joint faces to improve the bond (adhesion) of field-molded sealants.

Reinforcing agent - An ingredient used in rubber to increase its resistance to destructive mechanical forces, e.g., resistance to abrasion, rupture, tear, etc.

Retarder* - Compounding ingredient used to reduce the tendency of a mix to vulcanize prematurely.

Reversion - Chemical reaction leading to sealant, back-up or filler deterioration due to moisture trapped behind the sealant.

Rubber - A material that is capable of recovering from large deformations quickly and forcibly.

Rubber latex - Colloidal aqueous emulsion of an elastomer.

Sag - Sealant flow within the joint so that it loses its original shape, usually becoming depressed in horizontal joints or alternately bunched and attenuated in vertical joints.

Seal - A generic term for any material or device that prevents or controls the passage of matter across the separable members of a mechanical assembly.

Sealant - Any material used to seal joints or openings against the passage of solids, liquids or gases.

Set: (compression), (tension) or (permanent)* - The change occurring in a sealant when deformed that prevents full recovery when the deformation ends. More correctly, the strain remaining after complete release of the load producing deformation.

Shape factor* - The relationship between depth and width of a field-molded sealant.

Shelf life* - Maximum length of time a sealant can be stored prior to use without adversely affecting its properties.

Skin - A relatively dense layer that forms at the surface of a sealant on exposure to air.

Solvent - Liquid in which another substance may be dissolved.

Sponge - Cellular version, consisting predominantly of open cells, of a solid material.

Stabilizer - Substance which makes a solution or suspension more stable, usually by keeping particles from precipitating.

Stain - The changed color or appearance of the surface of the substrate adjacent to an applied sealant; the change is usually penetrating and the coloring is transparent and without surface film.

Stock - The shape in which preformed materials are supplied.

Stress relaxation* - Reduction in stress due to creep under sustained strain (deformation).

Structural unit - That part abutting a joint between it and another part which may have a similar or dissimilar structural function.

Substrate - The surface to which a sealant must bond (or remain in contact) usually the joint face.

Swelling* - The increase in volume or linear dimensions of a specimen immersed in a liquid or exposed to a vapor.

Tack-free time - Measure of the period for which a field-molded sealant remains tacky and not yet fully serviceable with respect to pick-up.

Tear strength - The maximum force required to tear apart a specified specimen, acting substantially parallel to the major axis of the test specimen.

Thermoplastic* - Mobile; softening with heat.

Thermosetting - Becoming rigid by chemical reaction and not remeltalbe.

Vehicle* - Liquid carrier; binder (anything dissolved in the liquid portion of the sealant is a part of the vehicle).

Volatile - Evaporating readily.

Vulcanization - A process in which rubber through a change in its chemical structure (e.g., cross-linking) is converted to a condition in which the elastic properties are conferred or improved.

Waterstop* - Diaphragm used across a joint as a sealant, usually to prevent the passage of water.

Working* - See pot life

Wrinkling - Crinkling of the surface skin of sealants affecting appearance, but not usually affecting sealing capability.
APPENDIX B—KEY TO SYMBOLS USED IN FIGURES

- Sealant (general)
- Tie bars across joint

- Specifically a compression seal
- Crack

- Filler-compressible
- Bonded concrete surface
- Exposure from this direction

- Back-up material
- Movement opening joint

- Mortar filler, bedding or grout
- Movement closing joint

- Not compressible

- Waterstop
- Ground line

- Bond breaker (Also intentionally non-bonded concrete surfaces)
- Keyway

1ST
2ND
ETC.

Sequence of placing concrete
Wood or other forms

W  Joint width (general)
Wi  Joint width at installation of sealant
Wmax  Joint width when open (usually at -20°F (-29°C))
Wmin  Joint width when closed (usually at 130°F (54°C))
d  Depth of sealant (general)
dmax  Maximum depth of sealant at installation width Wi to provide required shape factor
### APPENDIX C-SOURCES OF SPECIFICATIONS

#### NUMBER AND TITLE

### DESCRIPTION-USE-REQUIREMENTS

#### AMERICAN SOCIETY FOR TESTING & MATERIALS SPECIFICATIONS

1. **ASTM C 920-87**
   - Specification for Elastomeric Joint Sealants
   - For single or multi-component cold applied materials, used in building construction other than highways, air fields and bridges

2. **ASTM D 1190-80**
   - Concrete Joint Sealer, Hot Poured Elastic Type
   - No specific material; mixture forming a resilient sealant, for use in pavement, bridges, etc. Tests include pour point, penetration, flow, and bond.

3. **ASTM D 1854-74**
   - Jet Fuel-Resistant Hot-Poured Elastic Type
   - No specific material; composed of mixture of materials forming a resilient sealant for use in concrete pavements exposed to jet fuel spillage and jet blasts. Tests include penetration, bond, and safe heating temperature.

4. **ASTM D 3405-78**
   - Joint Sealants, Hot-Poured for Concrete and Asphalt Pavements
   - No specific material. Tests include penetration, flow, bond, and resilience.

5. **ASTM D 3406-85**
   - Specification for Joint Sealant, Hot-Applied, Elastomeric Type for Portland Cement Concrete Pavements
   - PVC-coal tar; for use in PCC pavement, bridges, etc. Tests include penetration, flow, bond, resilience, tensile adhesion, and artificial weathering.

6. **ASTM D 3569-85**
   - Specification for Joint Sealant, Hot-Dained Elastomeric Type, Jet Fuel Resistant for PCC Airfield Pavements
   - PVC-coal tar; for use in PCC airfield pavements subject to jet fuel spillage and jet blast. Tests include penetration flow, bond, resilience, tensile adhesion, artificial weathering, and jet fuel solubility.

7. **ASTM D 3581-80**
   - Specification for Joint Sealant, Hot-Poured, Jet Fuel Resistant Type for Portland Cement Concrete and Tar Concrete Pavements
   - For single or multi-component hot applied materials, checks fuel resistance.

#### FEDERAL SPECIFICATIONS

8. **SS-S-1401 C, 8/15/84**
   - Sealing Compound, Hot-Applied, for Concrete Asphalt Pavements
   - Material shall be two-component elastomeric type consisting of base and activator forming a rubberlike compound after mixing. Rate of curing shall permit traffic within one hour after curing. Material shall be resistant to jet fuel. Tests include tackfree time, ball penetration, resilience, bond, flow, self-leveling, weathering, solubility, volume change, and flame resistance.

9. **SS-S-1614A, 8/15/84**
   - Sealant, Joint, Two-Component, Jet-Blaster Resistant, Hot-Applied, for Portland Cement and Tar Concrete Pavements.
   - Covers multicomponent cold-applied elastomeric joint sealant. Two types: I, Flow, self-leveling; and II, Non-sag. Class A compounds resistant to 50 percent maximum total joint movement, Class B to 25 percent maximum. Tests include compression-extension cycling at 158F (70C) and 15F (-9C) with glass, aluminum, and concrete, peel strength, stain, and others.

10. **SS-S-200E Amended 8/23/88**
    - Sealing Compound, Cold-Applied, Concrete Paving
    - Covers elastomeric polymer type sealant for use without mixing. Types, classes, and requirements essentially the same as in TT-S-00227e. Some formulations require several weeks to reach full cure in the joint.

11. **TT-S-00227E (COM-NBS) 10/8/70**
    - Sealing Compound, Elastomeric Type, Multi-Component (For Caulking, Sealing, and Glazing in Buildings and Other Structures)
    - Covers components cold-applied elastomeric joint sealant. Types: I, Flow, self-leveling; and II, Non-sag. Class A compounds resistant to 50 percent maximum joint movement. Tests include compression-extension cycling at 158F (70C) and 15F (-9C) with glass, aluminum, and concrete, peel strength, stain, and others.

12. **TT-S-00230c (COM-NBS) 2/27/00**
    - Sealing Compound, Elastomeric Type, Single Component (For Caulking, Sealing, and Glazing in Buildings and Other Structures)
    - Covers components cold-applied elastomeric joint sealant. Types: I, Flow, self-leveling; and II, Non-sag. Class A compounds resistant to 50 percent maximum joint movement. Tests include compression-extension cycling at 158F (70C) and 15F (-9C) with glass, aluminum, and concrete, peel strength, stain, and others.

#### AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS SPECIFICATIONS

13. **(8) MI 73-60**
    - Hot Poured Elastic Type
    - Same description, use, and requirements as in ASTM D 1190-74 (1980).

14. **(9) WV**
    - Material shall be two-component elastomeric type consisting of base and activator forming a rubberlike compound after mixing. Rate of curing shall permit traffic within one hour after curing. Material shall be resistant to jet fuel. Tests include tackfree time, ball penetration, resilience, bond, flow, self-leveling, weathering, solubility, volume change, and flame resistance.
<table>
<thead>
<tr>
<th>NUMBER AND TITLE</th>
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<tbody>
<tr>
<td>(14) 60/71</td>
<td>Material is a single component cold-applied silicone rubber compound (joint sealants) for sealing, caulking, and glazing in building construction. Test requirements are essentially the same as (15) except that extrusion at -15°F (9.4°C) is required and no water immersion test is required for porous masonry.</td>
<td>(23) 19-GP-17M</td>
<td>This standard applies to one-component acrylic water emulsion sealing compounds suitable for sealing, caulking, or glazing interior building joints that experience up to ±10%. The substrates may be concrete, glass, wood, or metal. Materials meeting this standard are not intended for use in experience continuous water immersion nor for exterior building joints.</td>
</tr>
<tr>
<td>CANICGSB-19.2-M87</td>
<td>Butyl rubber based, solvent release type (for buildings and other types of construction).</td>
<td>CANICGSB-19.18</td>
<td>This standard applies to one-component silicone rubber based joint sealing compounds that cure primarily by solvent evaporation intended for sealing interior or exterior building joints that have movements up to +20% movement with an application air temperature range of 5 to 30°C (41 to 86°F). Materials meeting this standard are not intended for traffic or continuous water immersion conditions.</td>
</tr>
<tr>
<td>CANICGSB-19.24-M80</td>
<td>Cold-Applied Sealing Compound, Acoustical</td>
<td>CANICGSB-19.2-M87</td>
<td>This standard applies to cold-applied jet fuel-resistant sealing compounds intended for sealing joints in portland cement concrete pavements where the air application temperature is between 4 and 35°C (39 to 95°F).</td>
</tr>
<tr>
<td>CANICGSB-19.24-M90</td>
<td>Sealing Compound, Multi-Component, Chemical Curing</td>
<td>CANICGSB-19.21-M87</td>
<td>This standard applies to acoustical sealing and bedding compounds suitable for sealing interior building joints that experience up to ±5% movement and the application air temperature range is between 5 to 30°C (41 to 86°F). The substrates may be concrete, masonry, metal, gypsum-board, plaster, or wood.</td>
</tr>
<tr>
<td>CANICGSB-19.2-M7</td>
<td>This standard applies to acoustical sealing and bedding compounds suitable for sealing interior building joints that experience up to ±5% movement and the application air temperature range is between 5 to 30°C (41 to 86°F). Tests include tensile strength, elongation, hardness, oil swell, ozone resistance, low and high temperature recoveries.</td>
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<td>CANICGSB-19.18-M7</td>
<td>This standard applies to cold-applied jet fuel-resistant sealing compounds intended for sealing joints in portland cement concrete pavements where the air application temperature is between 4 and 35°C (39 to 95°F). Materials meeting this standard are not intended for traffic or continuous water immersion conditions.</td>
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<tr>
<td>CANICGSB-19.21-M87</td>
<td>Cold-Applied Sealing Compound, Acoustical</td>
<td>CANICGSB-19.24-M90</td>
<td>This standard applies to two types (self-leveling and nonsag) and two classes (glazing and non-glazing) of multi-component joint sealing compounds that cure to a rubber-like solid when properly mixed. Materials meeting this standard are intended for sealing or caulking exterior or interior building joints that have movements up to ±25% and may be used on concrete, masonry, metal, glass (class I only) or wood.</td>
</tr>
<tr>
<td>CANICGSB-19.24-M90</td>
<td>Sealing Compound, Multi-Component, Chemical Curing</td>
<td>ASTM D 2628-81</td>
<td>Material shall be preformed and manufactured from vulcanized elastomeric compound using polyvinylchloride as the only base polymer. Tests include tensile strength, elongation, hardness, oil swell, ozone resistance, low and high temperature recoveries.</td>
</tr>
<tr>
<td>ASTM D 3542-85</td>
<td>Specification for Preformed Polyethylene Elastomeric Joint Seals for Concrete Bridges</td>
<td>ASTM D 994-71 (1982)</td>
<td>Material shall be preformed and manufactured from vulcanized elastomeric compound using polyvinylchloride as the only base polymer. Tests include tensile strength, elongation, hardness, oil swell, ozone resistance, low and high temperature recoveries, and movement calibration.</td>
</tr>
<tr>
<td>ASTM D 1751-83</td>
<td>Expansion Joint Filler for Concrete Paving and Structural Construction (Nonexuding and Resilient Bituminous Types)</td>
<td>ASTM D 1751-83</td>
<td>Material consists of preformed strips formed from cane or other cellular fibers which are bound together and saturated with bituminous binder, or strips formed from granulated cork bound with bituminous material and encased between layers of bituminous felt. Tests include compression, extrusion, recovery, water absorption, weathering, and others.</td>
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<tr>
<td>(32) ASTM D 1752-84</td>
<td>Specification for Preformed Sponge Rubber and Cork Expansion Joint Fillers for Concrete Paving and Structural Construction (Nonextruding and Resilient Nonbituminous Types)</td>
<td>Three types for use in concrete, brick, and stone: Type I, sponge rubber; Type II, cork; Type III, Self-expanding cork. Tests include compression, extrusion, expansion, resistance to acid, density, and weathering.</td>
<td></td>
</tr>
<tr>
<td>(33) ASTM C 509-84</td>
<td>Specification for Cellular Elastic Preformed Gasket and Sealing Material</td>
<td>Material consists of preformed shapes for gaskets and seals in building applications including glazing. Four grades are included depending on degree of firmness. Tests include compression-deflection stress relaxation, dimension stability, and low temperature brittleness.</td>
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</tr>
<tr>
<td>(34) ASTM C 542-82 (1964)</td>
<td>Specification for Lock Strip Gaskets</td>
<td>Consists of elastomeric material resistant to sunlight, weathering, flame, oxidation, permanent deformation and diminution of gripping pressure. Gaskets are generally known as &quot;zipper type.&quot; Tests include tensile strength hardness, compression set, ozone resistance.</td>
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**AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS SPECIFICATIONS**

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<td>Preformed Expansion Joint Filler for Concrete (Bituminous Type)</td>
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<td>(36) M-4870 (1982)</td>
<td>Asphalt Plank</td>
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<tr>
<td>(37) M-53-84</td>
<td>Preformed Sponge Rubber and Cork Fillers for Concrete Paving and Structural Construction</td>
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<tr>
<td>(38) M-220-1 965</td>
<td>Preformed Elasticomeric Compression Joint Seals</td>
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**U.S. FEDERAL SPECIFICATIONS**

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<td>(40) HH-F-341 F, 6/6/77</td>
<td>Fillers. Expansion Joint Bituminous (Asphalt and Tar) and Nonbituminous (Preformed for Concrete)</td>
</tr>
<tr>
<td>(41) HH-F-1 9a, 2/16/67</td>
<td>Packing Material. Sewer Joint, Asphalt Saturated Cellulose Fiber</td>
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**U.S. ARMY CORPS OF ENGINEER SPECIFICATION**

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<tr>
<td>(42) CRD-C 513-74</td>
<td>Specifications for Rubber Waterstops</td>
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<tr>
<td>(43) CRD-C 572-74</td>
<td>Specifications for Polyvinylchloride Waterstops</td>
</tr>
<tr>
<td>(44) CRPC 527-88</td>
<td>Specification for Joint Seals, Cold Applied, Non-Jet-Fuel-Resistant, for Rigid and Flexible Pavements</td>
</tr>
<tr>
<td>(45) CRD-C 548-88</td>
<td>Specification for Jet Fuel and Heat Resistant Preformed Polychloroprene Elasticomeric Joint Seals for Rigid Pavements</td>
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**ONTARIO HYDRO**

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<tbody>
<tr>
<td>(46) M-264-M-83</td>
<td>Polyvinylchloride Waterstop</td>
</tr>
<tr>
<td>(47) L-219-88</td>
<td>Standard Specification for Waterstop Butadiene Rubber</td>
</tr>
</tbody>
</table>
SOURCES OF SPECIFICATIONS

The specifications listed were the latest editions at the time this report was prepared. Since these specifications are revised frequently, generally in minor details only, the user should check directly with the sponsoring society if it is desired to refer to the latest edition.

Information regarding the availability of the specifications listed can be obtained from the agencies below.

ASTM Specifications
American Society for Testing and Materials
1916 Race St.
Philadelphia, Penn. 19103

AASHTO Specifications
American Association of State Highway and Transportation Officials
444 N. Capitol St., N.W. Suite 225
Washington, D.C. 20001

Federal Specifications
Business Service Center
General Services Administration
7th and D Streets SW
Washington, D.C. 20407

Military Specifications
Commanding Officer
Naval Publications and Forms Center
5801 Tabor Avenue
Philadelphia, Pa. 19120

ANSI Specifications
American National Standards Institute, Inc.
1430 Broadway
New York, N.Y. 10018

U.S. Army Corps of Engineers
Chief, Concrete Laboratory, WES
Box 631
Vicksburg, Miss. 39180

Canadian General Standards
Secretary
Canadian General Standards Board
Phase III
9C1 Place du Portage
Hull, Quebec KIA OS5

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800 Kipling Avenue S.
Toronto, Ontario M8Z 5B2
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This report was submitted to letter ballot of the committee and was approved in accordance with ACI balloting procedures.