Performance of a Compression Joint Seal

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•FREQUENT EARLY failure of common dowel load transfer devices and jointing systems due primarily to corrosion and the entry of free water into joint openings in concrete pavements led a producer of these devices into the research which resulted in the development of a preformed compartmented polychloroprene compression joint seal.

Wide variations in pavement and bridge deck design, joint forming practice, climatic behavior, materials and methods of construction, and what appears to be a general lack of understanding of the forces at work in a typical road or bridge joint environment have given rise to a wide variety of ineffective sealing materials, most of which are of a stress reversing type. Most of these sealants have been effective for only relatively short periods of time, depending on the service conditions imposed.

The idea of a compression joint seal utilizing a material with a demonstrated long outdoor service capability will come to anyone who has examined the sealing problem at length. Recent comprehensive field tests in a number of states incorporating a wide range of liquid and preformed sealers have tended to indicate a good performance capability for compression joint seals (1, 2, 3).

CRITERIA FOR A COMPRESSION JOINT SEAL

An unsealed, jointed pavement has a built-in potential to destroy itself early in its design life. Any attempt to identify a typical kind of pavement distress as being related in part at least to a sealant failure and any discussion of sealing practices would be incomplete without first attempting to define the purpose of a joint seal. Photographs taken at random from recently completed portions of the Interstate Highway System seem to lay down criteria for the performance of any seal, preformed compression or otherwise (Figs. 1-6).

An examination of typical pavement distress indicates the following design criteria for a compression joint seal:

1. It must have a movement capability consistent with volume and temperature changes peculiar to a specific pavement design and environment.
2. It must seal out the entry of free water and, if possible, channel it off the pavement as quickly as possible.
3. It must seal out the entry of incompressibles from the top and sides of the pavement.
4. It must exert a compressive force against and maintain contact with the inner faces of the joint during extremes of slab movement.
5. It must absorb the expansion movement within itself without being extruded above, or expelled from, the joint opening.
6. It must be rugged enough under any condition of slab movement to withstand forces inherent to repetitive traffic loadings, as well as the downward forces exerted through snow, slush, maintenance materials and incompressibles.
7. It must be capable of performance in extremes of hot and cold weather.
8. Because of the difficulty of getting joints "surgery room clean" in the field, its performance should not be entirely dependent on ability to maintain bond to concrete.
9. It must have a long outdoor service capability and be relatively unaffected by sunlight, ozone, petroleum products, chlorides, soil bacteria, maintenance chemicals,

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Figure 1. Complete structural failure on a 7-yr-old turnpike.

Figure 2. Dowels locked in corrosion with movement coming midslab on a 6-yr-old turnpike.

Figure 3. Off-center longitudinal breaking on a 3-yr-old Interstate highway.

Figure 4. Crushing tends to come first at juncture of transverse and longitudinal joints.

Figure 5. **Repeated resealing.**

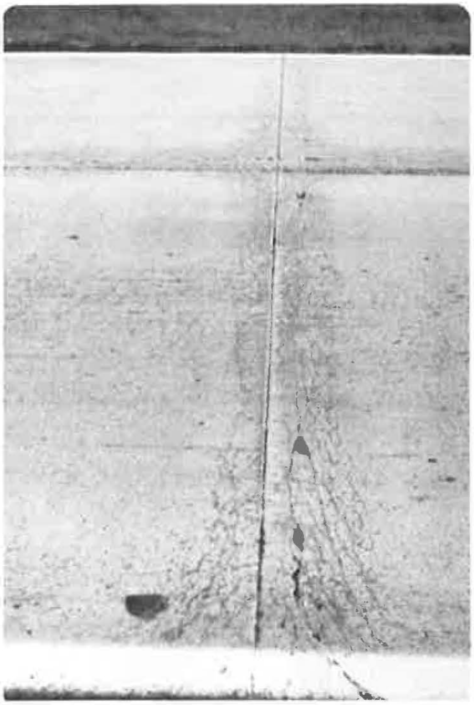


Figure 6. Premature crushing on 6-yr-old turnpike.

cement alkalis, extremes of hot and cold temperatures, forces of abrasion and compressive strains of long-term duration.

COMPRESSION SEAL THEORY

The compression seal discussed in this paper is a preformed tubular compartmented elastomeric device of a given width. It is inserted between two slabs and must constantly maintain a compressive force against the joint interfaces. For all practical purposes, the width of the seal to be used in a given joint opening is computed by adding the anticipated change in joint width to the as-constructed joint width plus a small width safety factor.

SHAPE OF SEAL

Experiments with numerous differing internal web configurations in an attempt to obtain the maximum residual compressive forces against the inner jointfaces under all stages of joint movement have resulted in a general standardization on the cross-braced webs shown in Figures 7 and 8.

The requirement for the seal to deform within itself partly dictates the angle of the web bracing; however, the necessity for a maximum amount of compressive push is best achieved by diagonal bracing rather than round webs, chevron webs or other similar variations. Figures 7 and 8 illustrate our best efforts to date for sealants ranging from ¼ to 1 in. in width for contraction joints, 1¼ to 2 in. for expansion joints, and 1¾ to 6 in. heavy duty bridge seal configurations. Although these seal shapes can probably still be improved, they represent a great deal of trial and error in the field and numerous shape changes as dictated from field usage. A set of working tolerances had to be arrived at due to the continual variances in outer dimension and web thickness natural to the extrusion process. Again, these have been decided on after millions of feet of production (Fig. 9).

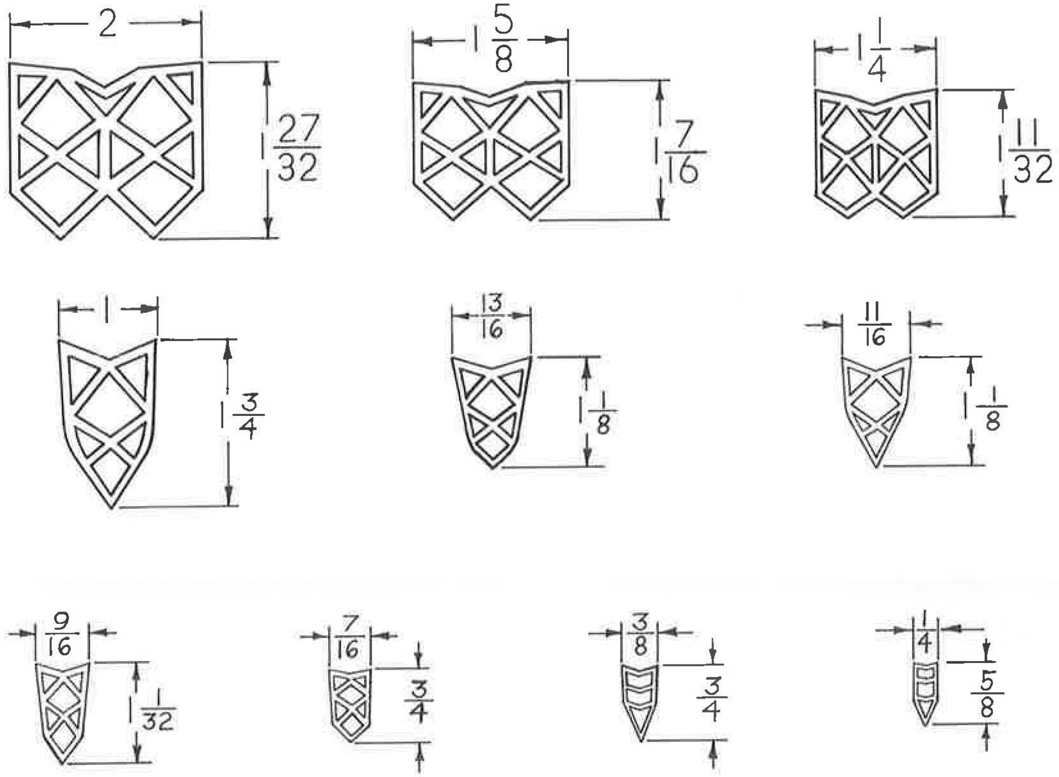
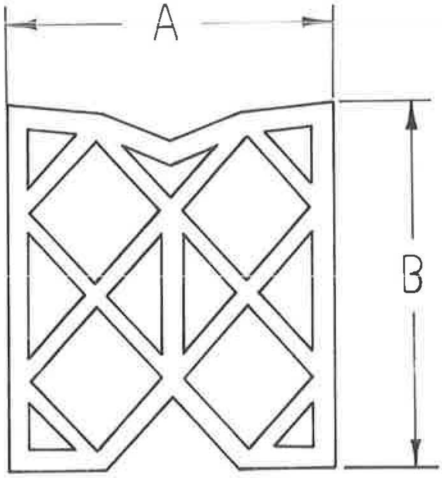
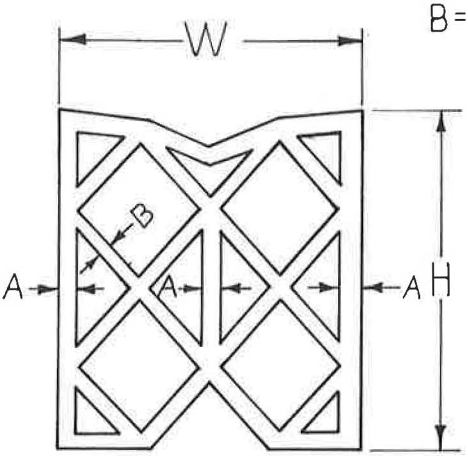


Figure 7. Typical seal designs.



DIM. A	DIM. B
1 3/4	2
2	2 1/16
2 1/2	2 3/4
3	3 13/32
4	4 23/32
5	6
6	7 1/16

Figure 8. Typical bridge seal designs.



A = SHELL
B = INTERNAL WEBS

WIDTH	HEIGHT	THICKNESS	
		A	B
$1\frac{3}{4}{}^{+3/16}_{-0}$	$2\pm\frac{1}{8}$	$\frac{1}{8}{}^{+1/32}_{-1/64}$	$\frac{3}{32}{}^{+1/64}_{-1/32}$
$2{}^{+3/16}_{-0}$	$2\frac{1}{16}\,{}^{+}_{-}\frac{1}{8}$	$\frac{1}{8}{}^{+1/32}_{-1/64}$	$\frac{3}{32}{}^{+1/32}_{-1/64}$
$2\frac{1}{2}{}^{+1/4}_{-0}$	$2\frac{3}{4}\,{}^{+}_{-}\frac{1}{8}$	$\frac{3}{16}{}^{+3/64}_{-1/64}$	$\frac{3}{32}{}^{+1/32}_{-1/64}$
$3{}^{+1/4}_{-0}$	$3\frac{13}{32}\,{}^{+}_{-}\frac{3}{16}$	$\frac{3}{16}{}^{+3/64}_{-1/64}$	$\frac{1}{8}{}^{+3/64}_{-1/64}$
$4{}^{+5/16}_{-0}$	$4\frac{23}{32}\,{}^{+}_{-}\frac{1}{4}$	$\frac{1}{4}{}^{+3/64}_{-1/32}$	$\frac{3}{16}{}^{+3/64}_{-1/64}$

Figure 9. Typical seal tolerances.

The importance of internal web design to seal performance was proven conclusively in the New York State Delmar Bypass tests. Two variations of chevron-type webs were utilized and both failed very quickly because they lacked the necessary compression during cold weather and were driven to the bottom of the joint grooves. Our experiments with a wide variety of internal web designs indicate that there may not be a great deal of latitude in this field. The absolute necessity for 3- to 4-yr field performance tests to prove the feasibility of different web designs has also tended to result in the standardization of webs shown in Figures 7 and 8.

LUBRICANT ADHESIVE

Our design team expended considerable effort in the field to develop a material in liquid form that could be used as a lubricant adhesive for a compression joint seal. It would be difficult, if not impossible to insert a typical compression seal into a groove without some type of lubricant. Some of the earliest installations were made with oil soap. However, it was felt that some liquid that was easily field applied in a single-component system and contained a high degree of lubrication when applied to concrete in extremes of hot and cold weather would give better performance. Many adhesives, both emulsions and solvent based, were experimented with. The resultant adhesive was selected for its long-term compatibility with neoprene, being a neoprene-based adhesive.

A priming agent is absolutely mandatory in any serious attempt to seal a joint with compression seals so that it is completely leakproof. Any existing capillary system in the surface of concrete, porosity, minor spalls, and cavitation inherent to joint sawing and the blasting effects of sawing slush must be primed out with a durable material. A neoprene adhesive compound seems to be ideally suited for this mission. Obviously, neither oils nor soaps would be practical as a priming agent.

The natural notch sensitivity of synthetic rubbers when compressed, or in effect stretched, also presents a problem during installation. The tendency of some aggregates to saw out, leaving sharp edges, and forcing of the neoprene tubes into narrow grooves can produce ragging, cutting and tearing. A thick slippery rubbery lubricant is indicated and the additional ability to seal any tears or minor cuts incurred in the installing process is, of course, highly desirable.

Undoubtedly, it is desirable to bond these neoprene tubes to the surface of the concrete. However, the practical difficulties of field cleaning concrete joints need no further elaboration in this report. Ability to bond to concrete is related to ability to clean properly and maintain cleanliness of joints before application. It may not be practical to expect a typical contractor to observe "surgery room" cleanliness in the field. Our design team felt that we will take whatever bond we get with this neoprene adhesive, regardless of degree, realizing that if the neoprene tubes are always in some degree of compression, the adhesive will never be called on to perform in tension.

Excess adhesive tends to be squeezed downward during insertion of the seal in the grooves. This excess will cure out in a type of "shear shelf" that helps prevent the seals from migrating downward. In colder weather, when the slabs are in a contracted state, residual compression in the seal is somewhat less and the rubber is somewhat less flexible. Hence, anything that will give bottom support to the seal is, of course, desirable.

Some observers have exhibited disappointment with the adhesive properties of the lubricant adhesive because they can in some cases pull out the bonded seals. After considerable experimentation with different types of adhesives, it was realized that the action of pulling on a piece of resilient rubber places these tubes in a very severe test of tear and peal in addition to stretch which reduces the cross-section of the tube. The service requirements of these seals are in no way related to the aforementioned test. Most of the forces in service are in a downward direction and it has been an extreme rarity after observing millions of feet in service to see a seal migrate upwards.

SELECTION OF POLYCHLOROPRENE (NEOPRENE)

An examination of the properties of known low-cost synthetic rubbers with respect to resistance to compression set, ozone, aging, sunlight and weathering, abrasion, chunking or gouging, oils and chemicals and temperature extremes seemed to point in the direction of polychloroprene (neoprene). Most other synthetic rubbers seem to be deficient in one of the important properties. However, the outstanding performance of neoprene in resistance to compression set for long-term exposures was the predominating property which resulted in its use. The attached specification (Appendix A) gives a description of the properties and testing methods that appear to be adequate for performance of a compression joint seal for most environments.

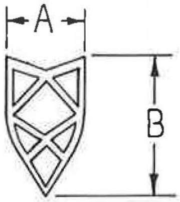
SLAB MOVEMENT

It is readily apparent that the degree of slab movement or joint width change must be known or estimated before the appropriate seal can be selected for a given joint. Although the only true measurement of the overall range of joint width change is that of actual measurement itself, a rule of thumb follows: (a) $^{1}/_{16}$ in. for each 10 ft of slab length on pavement slabs on grade, and (b) $^{1}/_{8}$ in. for each 10 ft of slab length on bridge decks. The difference seems to be related to the presence or lack of subgrade or mechanical restraint.

Short of actual measurement of joint width change, calculations of anticipated changes should be made for bridge decks to avoid exceeding compression limits for specific cross-sections and to use the most economical size of seal. Appendix B shows typical computations for deck lengths of 80, 125 and 150 ft at an as-constructed temperature of 70 F.

The overall movement potential of contraction joints is considerably affected by temperatures prevailing at the time of placement of the concrete. Hot weather poured slabs move a greater distance in contraction than cool weather poured slabs. In the early period of development in New York State, a $^{9}/_{16}$-in. wide seal in a $^{3}/_{8}$-in. wide contraction joint was considered to be adequate for 61-ft long slabs poured in cool weather; however, it later proved that a $^{13}/_{16}$-in. width for the same size joint opening was necessary to handle the increase movement in contraction of the hot poured slabs. It is important to keep this in mind when measuring typical volume changes to determine the appropriate seal size.

Evidence exists that there is a limit to movement of very long pavement slabs or continuously reinforced pavements. It has been observed that the prestressed pavement at Biggs Air Force Base built in 500-ft long panels has an overall change in joint width of



SEAL SIZE		SLAB LENGTH					GROOVE		TYPE OF JOINT
A	B	20	40	60	80	100	WIDTH	HEIGHT	
7/16	3/4	■					1/4	1 1/4	LONG.& TRANSV.
9/16	1 1/32		■				1/4	1 1/2	TRANSVERSE
11/16	1 1/8			■			1/4	1 1/2	" "
13/16	1 1/8			■			3/8	2	" "
13/16	1 3/8			■			3/8	1 3/4	" "
1	1 3/4				■		1/2	2 1/2	" "
1 1/4	1 11/32			■			3/4	2	EXPANSION
1 5/8	1 7/16			■	■		1	2	" "

Figure 10. Seal and groove size recommendations for pavements.

about 1 in. Most of the continuously reinforced pavements, regardless of length, have reported changes in joint width of approximately 1 in., obviously due to a buildup of mechanical or subgrade restraint.

Although it is extremely difficult to predict with accuracy the movement of slabs, the seal sizes given in Figure 10 worked well for the pavement slab lengths indicated when there was no flagrant unloading or movement problem.

It is considered at this time that other factors capable of affecting changes in slab length in pavements, such as drying shrinkage and end rotation attributable to warping, are insufficient to affect seal performance if the recommended seal sizes for given typical slab lengths are observed.

UNLOADING OF JOINT MOVEMENT

The problem of unloading of joint movement is more critical in some areas than in others due to general design and prevalent construction practice. Unloading occurs when there is restraint to slab movement sufficient to overcome the natural desire of a slab to move or change its length. It is a phenomenon wherein two, three, or more slabs move as a single unit, thereby greatly compounding the overall change in width at one particular joint. It is common in pavements of relatively short length (15 to 25 ft) for a short period after placement but normally begins to level off to even movement after the first year, or certainly by the second.

The most serious type of unloading, however, is caused by restraint from the common dowel-type load transfer devices. Crookedness or lack of perfect alignment of dowels is probably the greatest early cause of unloading. Salt brine entering the joints triples the speed of corrosion, as does the typical repeated action of complete stress reversal from repetitive traffic loading. The dowels seize in their sockets and lock as does a corroded nut and bolt. Unloading apparently is inevitable where common dowels are used and complicates the performance not only of liquid sealants with limited movement capability, but also of the compression seal.

On pavement slabs over 50 ft in length, compression seals are dependent for ease of installation on normal and even volume changes. Considerable difficulty has been encountered in some states in inserting compression seals because of this unloading of movement problem and it has usually been traceable to restraint at the doweled joints. In one instance, a quarter of a mile of pavement exhibited extreme seal refusal tendencies because the joint sawing crews had completely missed the load transfer devices with their saw cuts and the movement was coming in the form of midslab cracks. The excellent performance of compression seals recorded in New York State has occurred while utilizing the new "restraint free" load transfer devices.

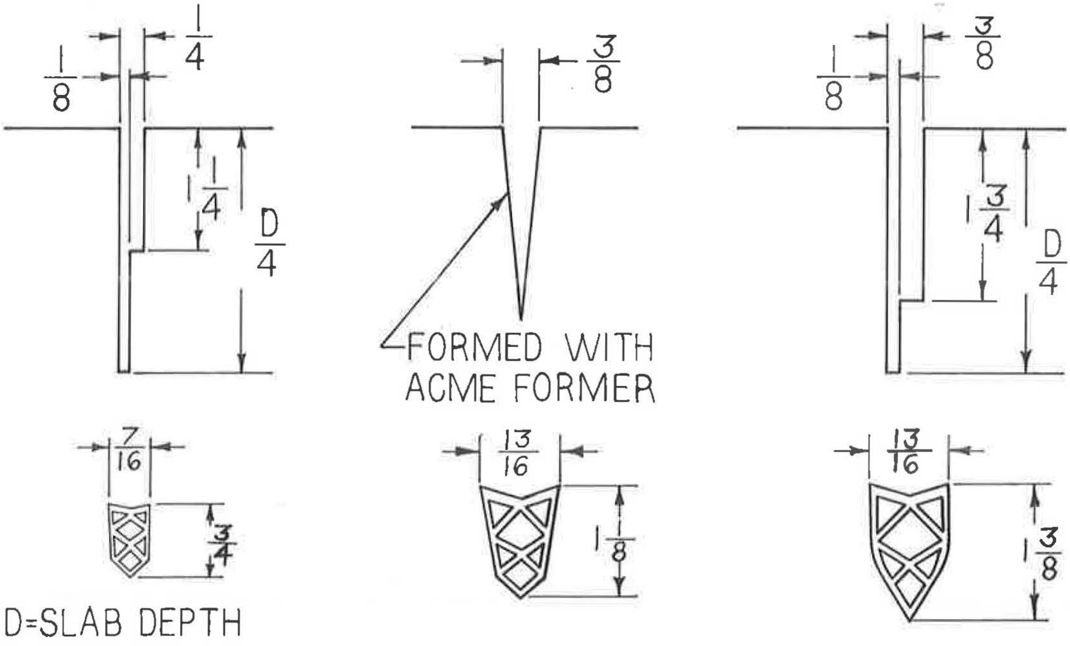


Figure 11. Typical grooves and seal shapes.

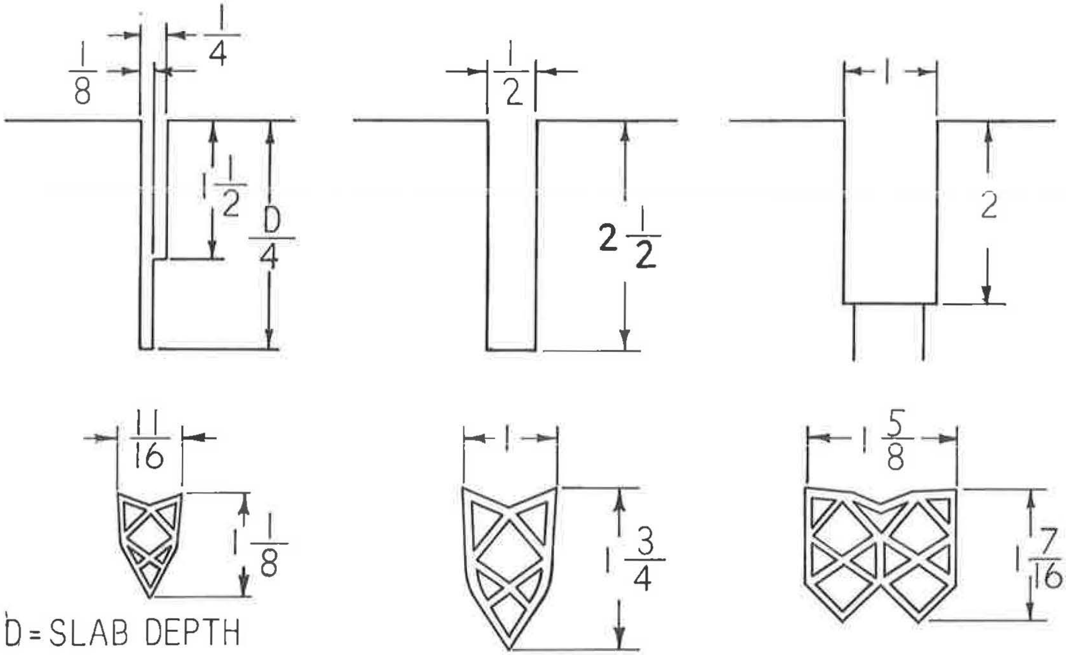
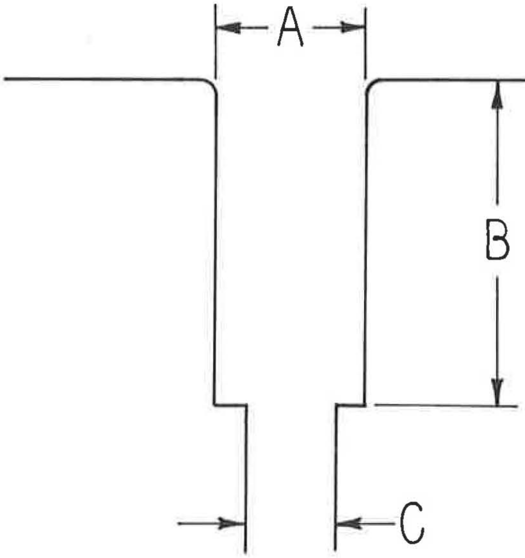


Figure 12. Typical grooves and seal shapes.

Load transfer devices must be initially and potentially free of restraint to obtain full efficiency of preformed compression joint seals. Wherever they have been used, compression seals have tended to indicate if the slabs were having normal movement.

JOINT SHAPE CRITICAL FOR OPTIMUM SEAL PERFORMANCE

A definite and uniform shape for a given joint is not only critical for sealants installed in liquid form but also for a compression seal, although for completely different reasons. The preformed seal is essentially a resilient compartmented synthetic rubber tube, always under compression. At the point of maximum joint opening, the compressive forces exerted against the joint faces are considerably less than when the joints are in a state of closure. A noticeable tendency exists for traffic to drive the seals downward, particularly on slabs over 60 ft in length and where unloading is present. The seals can migrate downward to the bottom of the joint groove and although there is little likelihood of serious crushing damage to slab ends from incompressibles, this is an undesirable position for the seal. It became readily apparent that a seal seat or stop should be a mandatory requirement for all seals in all types of joints, regardless of slab length or joint width. Either a wedge-shaped groove as indicated in Fig-



GROOVE SIZE			SEAL SIZE		SLAB LENGTH-MAX.						
A	B	C	WIDTH	HEIGHT	60	80	100	125	150		
1	2 3/8	5/8	1 3/4	2	■						
1 1/4	2 3/4	3/4	2	2 1/16		■					
1 5/8	3 3/8	1	2 1/2	2 3/4			■				
1 7/8	4 1/8	1 1/4	3	3 13/32				■			
2 1/2	5 3/4	1 1/2	4	4 23/32					■		
			5	6							
			6	7 1/16							

Figure 13. Seal and groove size recommendations for bridges.

ure 11 or a step saw cut is the recommended shape. The depth of the seat or stop is varied to fit the compressed vertical height of the seal (Figs. 11, 12, and 13).

GOOD JOINTS NECESSARY FOR COMPRESSION SEALING

Wherever compression joint seals are in use, there has been a marked tendency on the part of constructors to clean up or improve their jointing practices. All spalls must be patched before inserting compression seals and the end result has been a self-inspection service at the joints for a state highway department.

SELECT FIT OF SEAL AND JOINT SHAPES NECESSARY

For optimum performance, seal shapes should reflect or properly mate with the joint shape (Figs. 11, 12, and 13). Side pressure of the seal against the inner joint faces should be maintained at all times over substantial areas. It is also highly desirable to have good, straight, smooth joint faces, as well as smooth surfaced seals free of lines, depressions and die streaks.

PROPER SETTING HEIGHT

In the early installation of these seals, setting height was specified at from $^1/_{16}$ to $^1/_8$ in. below the riding surface of the pavement. Because of a tendency of joint edges to wear down under repetitive traffic loadings and from the abrasive action of maintenance grits, it is now felt after observing evidence of wear and snow plow damage, it is better to set the seals at least $^1/_4$ in. below the riding surface. Snow plows traveling at high speeds and small stones caught beneath the plow blade edge can rag out the top compartments. Since neoprene has a long life expectancy, the seals should be set lower in the joint grooves to anticipate the minor edge raveling that inevitably comes to nonradius edge joints.

SEAL "POP"

The typical compression seal configuration is a difficult extrusion at best. Some of the earlier extruded shapes had a noticeable tendency to tuck into themselves rather than into the joint grooves. Side friction and excess cavitation from joint faces may cause certain shapes of seals to tuck partially into themselves rather than fully into the joint groove. Subsequently, the first sizeable movement of the slabs in contraction tends to release the seal and it "pops" up to its full height, giving the impression that the seal is popping out of the joint where, in fact, it actually never was fully inserted. Consequently, all original cross-sections were redesigned to eliminate as far as possible the tendency to pop. Bent rather than straight webs, round edges and an outside shape lacking basic insertability have serious pop potential.

The seal shapes shown in Figures 7 and 18 have all been relieved of pop tendency. A slight taper on smaller seal sizes seems to be important to insertability.

GROWTH-STRETCH PHENOMENON

The tendency of construction or installing personnel to stretch the smaller sizes of compression seals (under 1 in. wide) during installation has given rise to some concern. One incident was reported wherein a contractor requested information on the tensile strength of the cross-section. It developed that he intended to hook a D8 tractor to the material to stretch it 300 percent and cut his material costs accordingly.

A typical compression seal when being compressed for insertion elongates. The percentage of elongation is directly proportional to the amount of squeezing or compression required for insertion into the joint opening. Constant unavoidable variations in the web thickness of the extruded seals within allowable tolerances can result in more severe squeezing or elongating and, therefore, attempts to arrive at a maximum allowable growth or stretch have been unsuccessful. As an example, a $^1/_4$-in. saw cut as constructed in a 60-ft slab can vary in width as much as $^5/_{16}$ in., depending on temperature at the time of installation. Saw blade wear, differences in joint width due to other variables in construction practice, as-constructed temperature differences, and excessive drying shrinkage are of sufficient magnitude to vary the amount of growth in installation. In one large paving project in 1963, incorporating some 206,000 lin ft of joint, only 170,000 lin ft of seal were used; growth accounted for the difference. Constant close supervision was in effect on this project so that no visible stretching of the seal was involved.

DURABILITY OF JOINT INTERFACES

The durability of joint interfaces is critical to seal performance. If a joint spalls after sealing with any known sealant, the seal can no longer be effective. Spalls have to be patched before a seal can work. Conventional spall patching methods have tended generally to be troublesome and somewhat unreliable. As a companion material, a low-cost energy-absorbing spall patch material was developed in conjunction with this seal. The principle was used that a force or wheel load applied to a stone laying on a hard epoxy-type patch will normally take out the patch at or near the juncture of the patch and the base concrete. Energy-absorbing isopox polymer patches do not fully transmit a wheel load force to the bond between the patch and the concrete and, in fact, tend to absorb the force within itself. Polyethylene plastic dams were developed to fit into the joints to restore the original joint shape when spall patching.

SAWED JOINTS IN ASPHALT

In a recent report to the Highway Research Board (4), the Connecticut State Highway Department reported favorably on their work with relieving asphalt overlays with saw cuts to control reflection cracking. Our early experimentation with sealing of asphalt sawed joints has been largely unsuccessful; however, it is now believed that a proper sealing technique utilizing compression seals can be worked out. The principal difficulties occur during warm days when the asphalt becomes at least partly mobile.

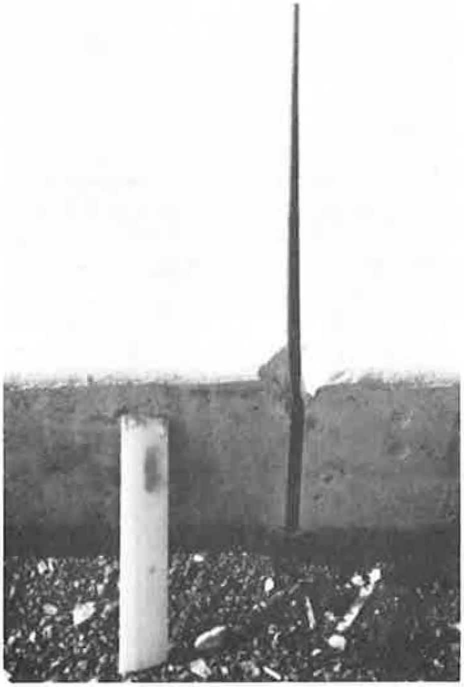


Figure 14. Pavement edge groove forming.

Figure 15. Pavement edge sealing.

The compressive forces tend to mount up the asphalt at the joints. Further experimentation is planned using deeper saw cuts and setting the seals deeper with improved lubricant-adhesive techniques.

PAVEMENT EDGE SEALING

The earliest and most noticeable evidence of crushing effects on pavements can be found at the outside edges, probably due to the presence of shoulder materials which tend to migrate into the joint openings from the sides. A number of areas now using compression seals have incorporated edge sealing into their specifications to check this area of distress.

Edge grooves are formed with short sections of plastic scale inserts placed inside the paving forms. These can be then used as saw point indicators so that a continuous groove is sawed or formed through to the bottoms of the outside edges of the pavement. Michigan and the Ontario Department of Highways have incorporated baseplates under their load transfer devices which, with the compression seals, prevent entry of materials into the joint spaces from all four sides of the pavement (Figs. 14 and 15).

PAVEMENT THRUST AND COMPRESSION SEALING

Cement concrete pavements have historically thrust themselves in the direction of bridges, probably because of incompressibles finding their way into joint openings of pavements during the contraction cycle of movement. As the pavements grow in length during the expansion cycle, they creep or shove towards the bridges or any direction in which they can find relief. The recent predominating use of contraction joints and occasional expansion joints, together with ineffective sealants, will certainly contribute to making the pavement thrust problem a monumental one for maintenance forces (Figs. 16 and 17).

Blowups, bridges pushed off their bearings, split back walls and other evidences of stress relief are common across the country on relatively new pavements of contraction joint design. At one large metropolitan airport, a $1\frac{1}{2}$-mi long runway after 5 yr of life is 2 ft longer, probably due to incompressibles entering the joint openings. Illinois uses four pieces of expansion joint on the last joint before a bridge; Virginia utilizes a special 3-ft wide asphalt-filled trough adjacent to bridges; Maryland build its last panel of pavement adjacent to bridges out of asphalt to delay the effects of pavement thrust.

Figure 16. Split back wall on 10-yr-old bridge.

Figure 17. Crushed bearing seat on a 6-yr-old structure.

It has been the considered opinion of the design group that developed this compression seal that the costly effects of pavement thrust would be greatly minimized, if not eliminated, by its use. Pavements constructed with "grower aggregates" which actually permanently increase their length with time could then be dealt with in initial design and the pavement thrust problem would probably be virtually eliminated.

BRIDGE JOINT SEALING

Bridge joints are apparently sealed for somewhat different reasons than concrete pavements:

1. Salt brine corrosion of bridge subdecks and piers under the joints (Figs. 18 and 19);
2. Migration of back slopes (Figs. 20 and 21);
3. Undesirable side effects of free water escaping through joints (Fig. 22);
4. Aesthetics, including staining of the concrete (Fig. 23); and
5. Accumulation of incompressibles, debris, etc. and potential crushing of concrete (Figs. 24 and 25).

Bridge joints and their accompanying width changes are normally of a much greater magnitude than those of pavements. Slab end rotation, skew joint movement peculiarities, compression limitations on each cross-section of compression seal and other complexities of bridges as compared to pavements call for marked differences in sealing practices. Figures 9 and 13 represent an attempt to recommend seal sizes and tolerances for those bridge deck lengths and joint widths shown. To date, we have made no serious attempts to use compression seals on decks in excess of 150 ft.

From evidence in the field, it would appear that some type of armor plating of bridge joints such as shown in Figure 26 is desirable (Fig. 27). This practice tends to eliminate the problem of durability of concrete or asphalt joint edges and when seal seats or

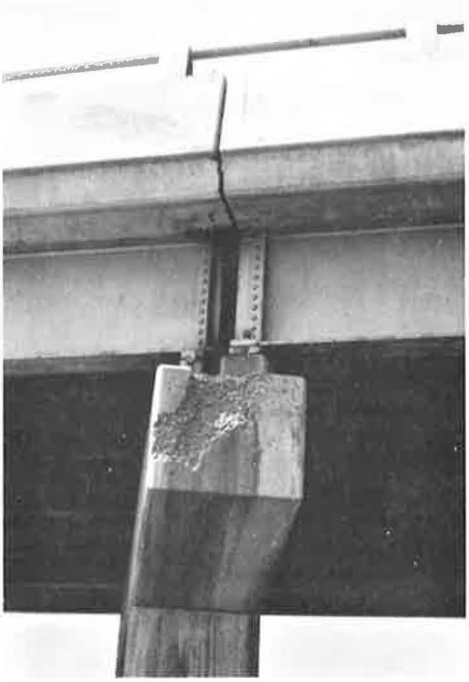


Figure 18. Salt brine corrosion.

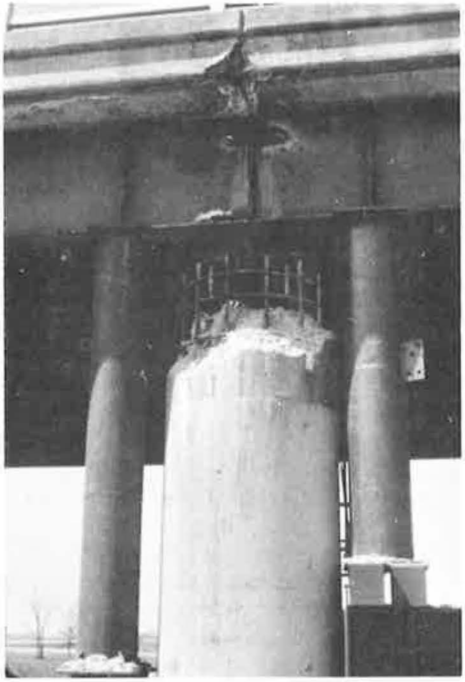


Figure 19. Salt brine corrosion.

Figure 20. Migration of back slope.

Figure 21. Migration of back slope.

Figure 22. Undesirable side effects of free water escaping through joints.

Figure 23. Straining of concrete.

stops are incorporated in the inner joint faces, movement unloading and setting height difficulties are of less concern. Figures 28 and 29 show a practical method of armor plating joints on bridge decks with asphalt wearing courses, heretofore considered to be unsealable.

Bridge compression seals as shown in Figure 8 are much more rugged in cross-section than are those of pavements and

Figure 24. Accumulations of incompressibles, "elephant earing."

Figure 25. Sliding plate joint seal failure.

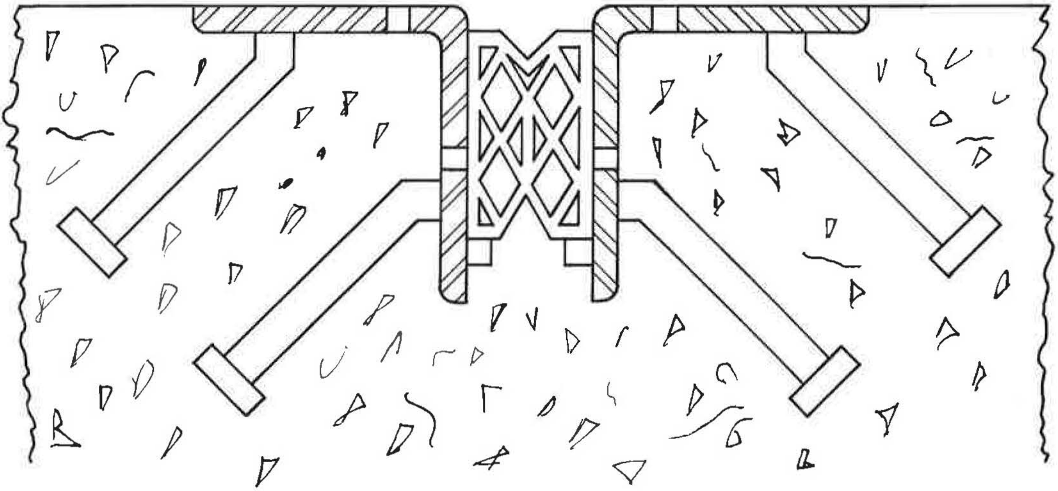


Figure 26. Steel joint faces.

necessarily must be, partly because of the wider joint openings and dynamic movement. One of the reported side effects of the use of these giant-sized bridge seal configurations and the accompanying tremendous compressive force exerted particularly in the expansion cycle of movement is a marked reduction in deck vibration normal to repetitive traffic loadings.

COST OF COMPRESSION SEALING

Over a 3-yr period in New York State, when an alternate of compression seals or two-component polysulfide sealants was permitted, contractors predominately elected to use compression seals. Lack of necessity to purchase expensive complex proportioning and mixing equipment, lack of need for operating engineers, lack of temperature restrictions, no reworking of sealants after the initial installation such as spudding off excess materials in warm weather or filling up joints in cooler weather, no air-entrapment problems, no equipment plug-ups, and the general simplicity of compression sealing became cost factors to contractors in their choice of compression seals. Also, there has not been any reflection in bid prices when compression sealing was subsequently made mandatory in New York State construction.

There are, in fact, other highly desirable cost-reducing potentials resultant from compression sealing. Generally, narrower joints can be sawed at marked reductions in sawing costs per foot. Because of its simplicity, sealing operations can be worked concurrently with other less efficient operations. In some areas, crews who normally removed curing blankets from concrete pavements now install compression seals as well with no additional labor cost to the contractor. The seals are being installed when the joints are at their cleanest with an additional saving in joint-cleaning costs. With no temperature restrictions, sealing crews can work until snow arrives, enabling contractors to finish their project without having to wait over a winter to seal the joints.

In the past 4 yr, the cost of compression seals has been reduced about 50 percent, primarily because of mass productions. With the rubber industry now gearing up for high-volume usage, it is anticipated that further marked reductions will occur. Certain newer materials are presently under test which, if successful, may offer compression seals at costs per foot comparable to the cheapest asphalt sealants available today.

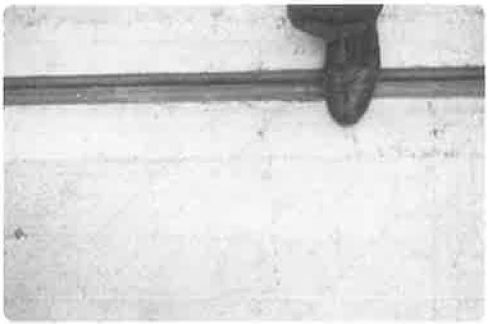


Figure 27. Armor-plated joint with compression seal.

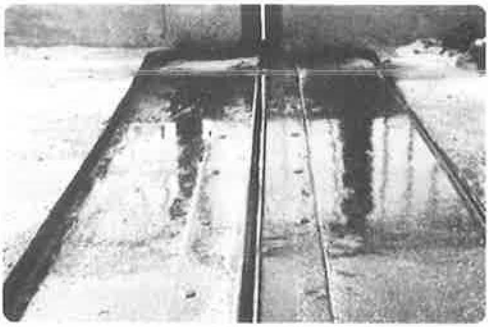


Figure 28. Armor plating of joints in asphalt overlay on a bridge.

Figure 29. Compression seal in armor-plated joint carried through curb.

One cannot view the presently completed portions of the interstate highway system or recently built toll roads without becoming seriously concerned with the frequent evidence of premature pavement self-destruction. There is undoubtedly a definite causal relation between ineffective sealing practice and certain types of premature pavement distress. When the full impact of the real cost of ineffective sealants and the importance of the joint seal as a vital performing component in a pavement is understood and appreciated by design engineers, a realistic appraisal of the cost of sealers that actually seal the joints can be made.

CONCLUSIONS

1. Recent documentation of compression seal performance gives promise of a new device to help extend the maintenance-free life of pavements and bridges.
2. An examination of typical pavement distress has resulted in design criteria for a compression seal.
3. Important considerations in the use of compression seals are the performance capability of the elastomer, outside shape and internal web configuration of the seal, geometry of the joint to be sealed, setting height of the seal with relation to the riding surface, use of a lubricant adhesive, proper sizing technique for each specific pavement design, proper installation, and durability of joint interfaces.
4. A thorough evaluation of the many physical and environmental factors influencing joint width change throughout the overall service life of each particular slab design is necessary for accurate sizing and efficient use of compression seals.

REFERENCES

1. Graham, Malcolm D., Burnett, William C., Hill, J. G. Frederick, Jr., and Lambert, John R. New York State Experience with Concrete Pavement Joint Sealers. Highway Research Record No. 80, 1965.
2. Wright, P. J. F. Full Scale Tests of Materials for Sealing Joints in Concrete Roads. Gt. Brit. Dept. of Sci. and Ind. Res., Road Res. Lab.
3. Skeels, Paul C. Construction of Concrete Pavement—General Motors Proving Ground Circular Test Tract. General Motors Proving Ground, Milford, Mich., May 14, 1964.
4. Wilson, John O. Crack Control Joints in Bituminous Overlays on Rigid Pavements. Highway Research Board Bull. 322, pp. 21-29, 1962.

Appendix A

SPECIFICATION FOR PREFORMED JOINT SEALER

Description

This work includes furnishing and installing preformed elastic joint sealers of the sizes and shapes shown on the plans, or as otherwise permitted by the plans. The sealer shall be installed in the concrete with an approved lubricant adhesive.

Materials

The sealer shall be a preformed, elastic polychloroprene joint sealer, compatible with concrete and resistant to abrasion, oxidation, oils, gasoline, salt, and other materials that may be spilled on or applied to the surface. The sealer shall be so shaped that when installed, at minimum joint opening, it shall be so completely compressed as to be substantially solid and have a minimum of air spaces. It shall also be so shaped that in its compressed condition the top center of the exposed surface shall be depressed below the surface of the installed sealer. The sealer shall be furnished in a sufficient number of widths to accomplish this kind of closure.

The sealer shall conform to the ASTM requirements given in Table 1; it must be compounded using the low crystallizing polychloroprene base. Each lot of the joint seal shall be identified with the manufacturer's name or trademark and shall be accompanied by the manufacturer's affidavit attesting conformance with the specification.

Lubricant Adhesive

The lubricant adhesive shall be a one-component polychloroprene compound containing only soluble phenolic resins blended together with antioxidants and acid acceptors in an aromatic hydrocarbon solvent mixture and shall have the following physical properties:

1. Average net weight per gallon, 7.84 lb ± 5 percent;
2. Solids content, 24 to 26 percent by weight;
3. Brookfield viscosity at 77 F, No. 2 Spindle at 10 rpm, 7,000 to 7,500 cps;
4. The adhesive shall remain fluid from 5 to 120 F; and
5. Film strength (ASTM-D-412), 2,300 minimum tensile strength, 750 percent minimum elongation before breaking.

Test specimens composed of two pieces of 0.064 gage of 6061 aluminum alloy bonded together with the adhesive on a joint 1-in. wide with ½-in. lap and aged 14 days shall show the following minimum strength when tested by the laboratory:

TABLE 1

REQUIREMENTS FOR PREFORMED COMPRESSION SEAL[a]

Property	ASTM Test Procedure	Transverse or Longitudinal Requirement
Tensile strength, min. (psi)	D-412	2,000
Elongation at break, min. (%)	D-412	250
Hardness, Type A durometer	D-676	55 ± 5
Permanent set at break, max. (%)	D-412	10
Compression set, max. (%):	D-395 Method B,	
22 hr/158 F	Paragraph 5 (b)	15
70 hr/212 F		40
Oven aging, 70 hr/212 F:	D-573	
Tensile strength, max. change (%)		-30
Elongation, max. change (%)		-40
Hardness, max. points change		+10
Oil swell, ASTM Oil No. 3, 70 hr/212 F, max. volume change (%)	D-471	80
Ozone resistance, 20% strain, 300 pphm in air, 70 hr/100 F[b]	D-1149	No cracks
Low-temperature stiffening, min. °F to reach 10,000-psi modulus	D-1053	-30

[a] All test sections used in the testing methods shall be cut and buffed from the actual extruded compression joint seal.

[b] Wipe with solvent to remove surface contamination.

1. Dynamic strength, 1,300 psi at 70 and 0 F; and
2. Static (1 min), 700 psi at 70 and 0 F.

Each lot of the adhesive shall be delivered in containers plainly marked with the manufacturer's name or trademark and date of manufacture and shall be accompanied by the manufacturer's affidavit attesting conformance with this specification.

Construction Details

The sealer shall be installed by suitable hand or machine tools and thoroughly secured in place with an approved lubricant adhesive which shall cover both sides of the sealer over the full area in contact with the sides of the concrete joint. The adhesive may be applied to the concrete or the sealer or both. The sealer shall be installed in a substantially fully compressed condition and shall at all times be below the level of the pavement surface by approximately $\frac{1}{4}$ in. The sealer shall be in one piece for the full width of the transverse joint. In longitudinal joints, the sealer shall be in practical lengths. Any joints in the sealer material shall be adequately sealed with additional adhesive.

The sealer may be installed immediately after the curing period using a lubricant adhesive that is compatible with the sealer and the concrete at that stage. Temperature limitations of the adhesive as guaranteed by the manufacturer shall be observed. Joints shall be cleaned free of foreign material immediately before installation of the sealer.

Inspection of Material

All sealers and adhesives will be furnished to comply with the material as approved as a result of tests. For all such sealer and adhesive furnished and installed on a contract, the contractor shall furnish to the engineer a certification that the materials placed are the same as those approved and shall back this up with a certification by the manufacturer as to the nature and characteristics of the materials purchased by the contractor. The exact details of the certification will be furnished at the time the material under test is approved.

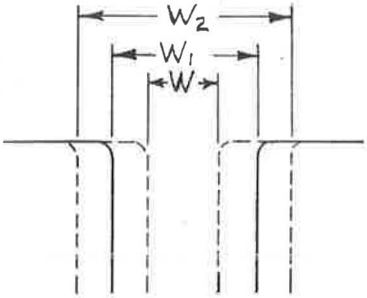
Appendix B

TYPICAL BRIDGE MOVEMENT COMPUTATIONS

SLAB LENGTH = 80 FEET
POURING TEMPERATURE = 70° F.
$\propto$ = COEFFICIENT OF EXPANSION
ΔT = CHANGE IN TEMPERATURE
W_1 = GROOVE WIDTH AT 70°F.
W_2 = MAX. GROOVE WIDTH AT -30 F.
W = MIN. GROOVE WIDTH AT 120 F.

L = SLAB LENGTH
ΔL = CHANGE IN LENGTH
T_1 = POURING TEMP. 70°F.
T_2 = MIN. TEMP. -30°F.
T_3 = MAX. TEMP. 120°F.

$$\begin{aligned}\Delta L/10^\circ\text{F.} &= L \propto \Delta T\\ &= 960'' \times (6 \times 10^{-6}) \times 10^\circ\text{F.}\\ &= .0576''\end{aligned}$$



MAX. JOINT WIDTH - W_2

$$\begin{aligned}W_2 &= W_1 + L \propto \Delta T\\ &= 1.25'' + 960''(6 \times 10^{-6})(T_1 - T_2)\\ &= 1.25'' + 960''(6 \times 10^{-6})(70^\circ + 30)\\ &= 1.25'' + .576''\\ &= \underline{\underline{1.826''}}\end{aligned}$$

MIN. JOINT WIDTH - W

$$\begin{aligned}W &= W_1 - L \propto \Delta T\\ &= 1.25'' - 960''(6 \times 10^{-6})(T_3 - T)\\ &= 1.25'' - 960''(6 \times 10^{-6})(120 - 70)\\ &= 1.25'' - .288''\\ &= \underline{\underline{.962''}}\end{aligned}$$

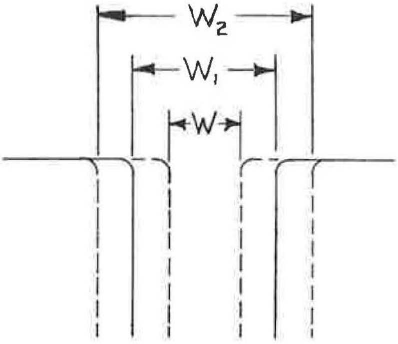
SLAB LENGTH = 125 FEET

POURING TEMPERATURE = 70° F.

α = COEFFICIENT OF EXPANSION
ΔT = CHANGE IN TEMPERATURE
W_1 = GROOVE WIDTH AT 70° F.
W_2 = MAX. GROOVE WIDTH AT -30° F.
W = MIN. GROOVE WIDTH AT 120° F.

L = SLAB LENGTH
ΔL = CHANGE IN LENGTH
T_1 = POURING TEMP. 70° F.
T_2 = MIN. TEMP. -30° F.
T_3 = MAX. TEMP. 120° F.

$$\begin{aligned} \Delta L / 10^\circ F &= L \alpha \Delta T \\ &= 1500''(6\times10^{-6})\times 10^\circ F. \\ &= .09'' \end{aligned}$$



MAX. JOINT WIDTH = W_2

$$\begin{aligned} W_2 &= W_1 + L\alpha\Delta T \\ &= 1.875'' + 1500''(6\times10^{-6})(70+30) \\ &= 1.875'' + .9'' \\ &= \underline{\underline{2.775''}} \end{aligned}$$

MIN. JOINT WIDTH = W

$$\begin{aligned} W &= W_1 - L\alpha\Delta T \\ &= 1.875'' - 1500''(6\times10^{-6})(T_3 - T_1) \\ &= 1.875'' - .45'' \\ &= \underline{\underline{1.425''}} \end{aligned}$$

SLAB LENGTH = 150 FEET

POURING TEMPERATURE = 70°F.

α = COEFFICIENT OF EXPANSION

ΔT = CHANGE IN TEMPERATURE

W_1 = GROOVE WIDTH AT 70°F.

W_2 = MAX. GROOVE WIDTH AT -30°F.

W = MIN. GROOVE WIDTH AT 120°F.

L = SLAB LENGTH

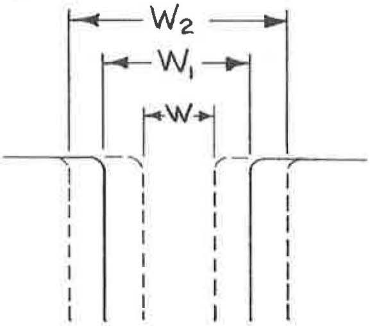
ΔL = CHANGE IN LENGTH

T_1 = POURING TEMP. 70°F.

T_2 = MIN. TEMP. -30°F.

T_3 = MAX. TEMP. 120°F.

$$\begin{aligned}\Delta L/10°\text{F.} &= L\alpha\Delta T\\ &= 1800'' \times (6\times10^{-6})\,10°\text{F.}\\ &= .108''\end{aligned}$$



MAX. JOINT WIDTH = W_2

$$\begin{aligned}W_2 &= W_1 + L\alpha\Delta T\\ &= 2.5'' + 1800''(6\times10^{-6})(T_1 - T_2)\\ &= 2.5'' + 1800''(6\times10^{-6})(70+30)\\ &= 2.5'' + 1.08''\\ &= \underline{\underline{3.58''}}\end{aligned}$$

MIN. JOINT WIDTH = W

$$\begin{aligned}W &= W_1 - L\alpha\Delta T\\ &= 2.5'' - 1800''(6\times10^{-6})(T_3 - T_1)\\ &= 2.5'' - 1800''(6\times10^{-6})(120+70)\\ &= 2.5'' - .640''\\ &= \underline{\underline{1.860''}}\end{aligned}$$