Design of Joints in Precast Concrete Wall Panels

by R. J. Schutz*

The primary purpose of precast concrete wall panels is to weatherproof the building. Fortunately, precast concrete is weatherproof. The problem is weatherproofing the building at the joints between panels, and between panels and other elements. Since building frames move and concrete panels themselves expand and contract due to thermal and moisture changes, the joints must be sealed with a flexible medium. It is not within the scope of this paper to discuss building movements or their causes but how to design weatherproof joints between the elements of the building where differential movement takes place.

Joints in precast panel buildings can be successfully sealed by the use of two basic systems. These two systems are based on either field-molded sealants or premolded sealants. The use of field-molded sealants is generally desirable where joint width and movement is nominal. Premolded sealants should be used and become economical where movement is severe or where the joint is wide due to design or other considerations.

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JOINT DESIGN FOR FIELD-MOLDED SYSTEM

Field-molded systems have worked successfully using elastomeric sealants such as those based on polysulfide polymers. As solids, these elastomers readily change shape during extension or contraction, but not volume. As the joint extends, the material necks down (while maintaining its volume) to accommodate the elongation. In compression the materials bulge out beyond the joint contours.

A definite geometric relationship of changing sealant cross-section exists during extension and compression. The depth-to-width proportion, referred to as the shape factor, determines the joint's efficiency. As the sealant's cross-section adjusts during extension or compression, its internal strains often become severe. The depth-to-width ratio determines the strain with maximum values for the extreme fibers as shown in Fig. 1.

The best and most economical joint is the shallowest. There is less strain on the sealant for a given movement and a minimum amount of material is required.

BEST JOINT IS MOST ECONOMICAL ONE

Some examples illustrate the importance of the shape factor.

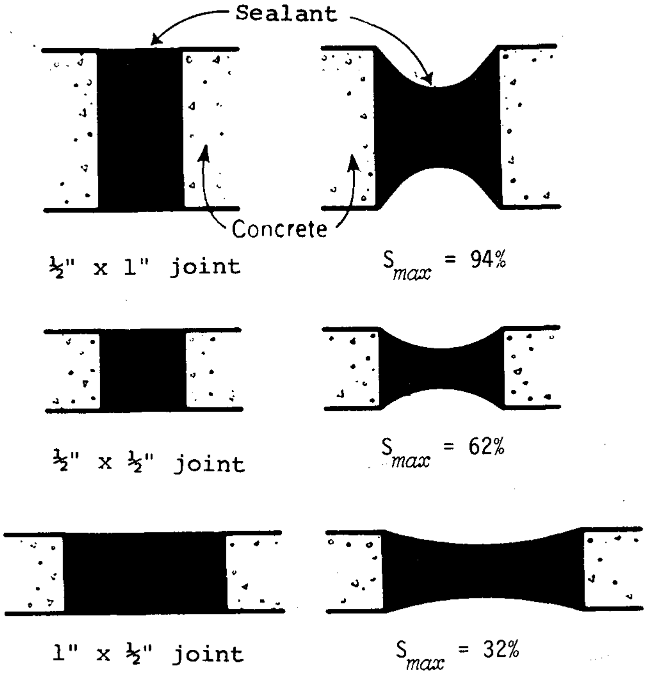

Fig. 1—Strain on the Extreme Fiber of a Sealant for ¼-in. Extension of Different Shape Factors.

Extension. A ½-in. wide by 1-in. deep joint, extended ¼ in., increases the outer fiber's length 94%. By simply reducing the joint's depth to ½ in. (for a ½ x ½-in. cross section), the strain on the outer fiber will be only 62% for the same extension—about a third less, while using half the material. Doubling the joint width to 1 in. (for a 1 x ½-in. cross section) reduces the strain on the outer fiber to 32%—a 68% reduction in strain with the same amount of material, compared to the first section. As a hypothetical case, if the proposed sealant could resist a strain of 75% on the outer fiber, it would fail with ¼-in. movement in a ½ x 1-in. joint, be adequate in a ½ x ½-in. joint, and have a considerable factor of safety for the 1 x ½-in. joint. The economy of proper joint design is illustrated in the above examples.

Compression. Strains on sealants during compression for the same three sections, Fig. 2, show outer fiber compression values as much greater for the same movements than for extension. In addition, all elastomers are subject to the phenomenon of compression set. (When maintained in a compressed condition for prolonged periods of time, they may not fully recover their original characteristics). In designing elastomeric joints for compression, their movement should be limited to 25% or less to ensure that the elastomer will recover as the joint slot expands.

These data apply to free-moving joints on two sides. The side opposite the exposed face should not bond to the inside of the joint slot as this increases strains by more than 100%, as shown in Fig. 3. The use of a bond-breaker prevents bonding

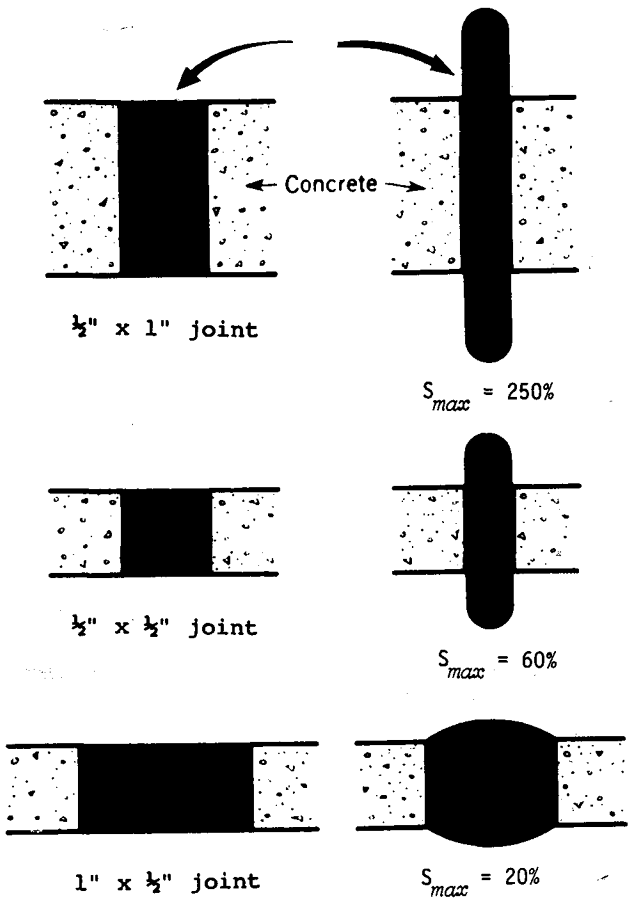

Fig. 2—*Strain, Assuming a Parabolic Shape* for ¼ in. Compression of Different Shape Factors.

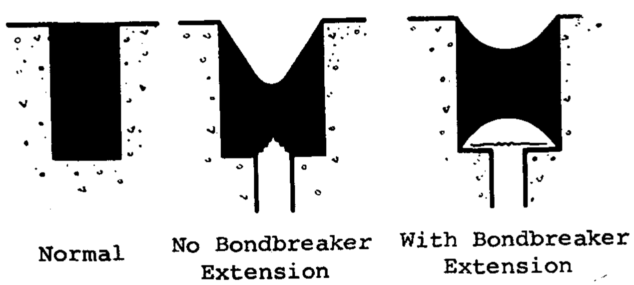

Fig. 3—Effect of a Bond-Breaker on Sealant Performance.

against the inside of a joint slot. Good bond-breakers include polyethylene, silicone treated paper and wax paper.

LIMITING DEPTH OF JOINT

Deep joint slots require back-up material or filler behind the field-molded sealant to limit the depth of elastomer. Such fillers, of necessity, consist of easily-compressible materials, limited to foams. Polyethylene or polyurethane foam have proven the best back-up materials since these foams are compressible, economical and do not absorb water.

POSITION OF JOINTS

All horizontal and vertical joints should align. Non-aligned joints force panels to slide on one another, inducing high tensile forces great enough to crack them. In effect, cracks relieve internal stresses, forming aligned joints. Non-aligned joints subject field-molded or premolded sealants to shear in addition to elongation or compression.

Fig. 4—Concrete Torn by High-Modulus Sealant.

MATERIAL DESIGN OF FIELD-MOLDED SEALANTS

Elastomeric sealants selected should have a capability of extension with a force less than 45 psi. Use of high moduli of elasticity sealants results in pulling off the surface mortar from the panel rather than in the sealant's elongation. The Shore A Hardness of an elastomer has no relation to its modulus of elasticity. As an example, some sealants with a Shore A Hardness of 25 have moduli which vary from the low extreme, and can be extended with as little force as 15 psi, to a high modulus requiring forces as large as 240 psi for elongation. The latter sealants may be satisfactory on steel or other substrates but cause failure of concrete at points of attachment during extension. Fig. 4 shows a joint in a precast concrete stadium sealed with a sealant with a high modulus of elasticity. Note that the edge of the concrete has been pulled away as the joint moved.

A practical depth of ½-in. is the minimum for field-molded sealants which can be installed with any degree of reliability, because of limitations dealing with workmanship and installation. Field conditions invariably have limitations: bubbles in the sealant, pock marks in the concrete, or dust particles on the joint slot surface. By installing a ½-in. minimum depth of sealant chances of failure are minimized.

MATERIAL DESIGN SHAPE FACTOR FOR FIELD-MOLDED SEALANTS

The strain along the parabolic curve is determined by the shape factor as shown in Fig. 5 for a predetermined joint size. After the proper curve for the joint factor has been determined, the percentage of linear expansion is calculated and a joint sealant selected on the basis of its physical characteristics to withstand the strains.

The maximum strain which a given sealant can withstand can be determined by laboratory tests. Testing at the lowest predicted service temperature yields conservative data since all elastomers become harder and, therefore, resist less movement at lower temperatures. Typical curves obtained by testing two polysulfide-based sealants is illustrated in Fig. 6. This data was determined at a temperature of 0°F using a safety of four to compensate for age hardening and less precise field workmanship than obtained in the laboratory.

At this point of the design stage, the following factors can be established:

a. Joint depth (assumed as ½ in.)

b. Joint spacing (fixed by size specifications)

c. Movement from contraction or expansion (as determined by thermal coefficient of expansion of concrete of 4 to 7×10^{-6}). Temperature variation ranges from the lowest anticipated ambient temperature to the highest temperature anticipated in the panel. The upper limit will exceed the highest ambient temperature because of absorption of the radiant heat of the sun. In the southern U.S., a panel temperature of 145°F in the summer is not uncommon.

The joint width can be chosen, by using Fig. 6, so that the strain on the outer fiber does not exceed the limits of the sealant. By following this design procedure, field-molded sealants in precast panel construction can successfully be used to seal joints.

MATERIAL DESIGN OF PREMOLDED SEALANTS

When joints become larger than 1½ in. in width, premolded sealants are more economical and often perform better. This may be the case 1) where panels are large, 2) where movement is severe, or 3) where required by structural design considerations. Premolded sealants for concrete panels are either sheets or tubes, made from neoprene or butyl rubber. These sheets or tubes are bonded to the sides of the joint slot with a gap-filling epoxy adhesive or a non-sag field-molded sealant.

Premolded sealants should be designed so that the sealant is subject only to bending and flexing but

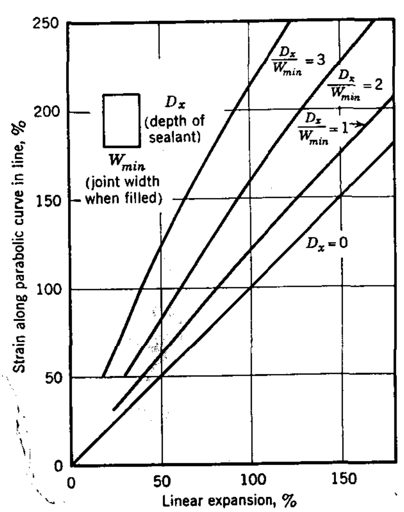

Fig. 5—Maximum Strain on a Joint Plotted Against Percentage of Linear Expansion.

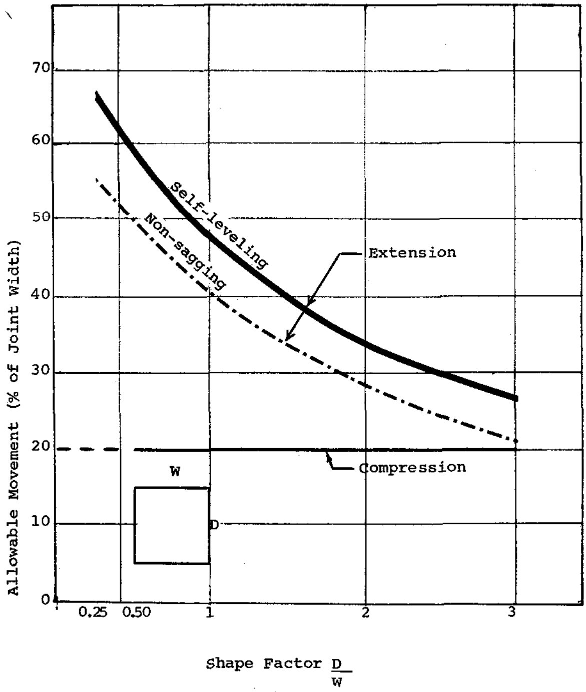

Fig. 6—High Performance Polysulfide Sealants (Shore A Hardness 25 at 0°F)

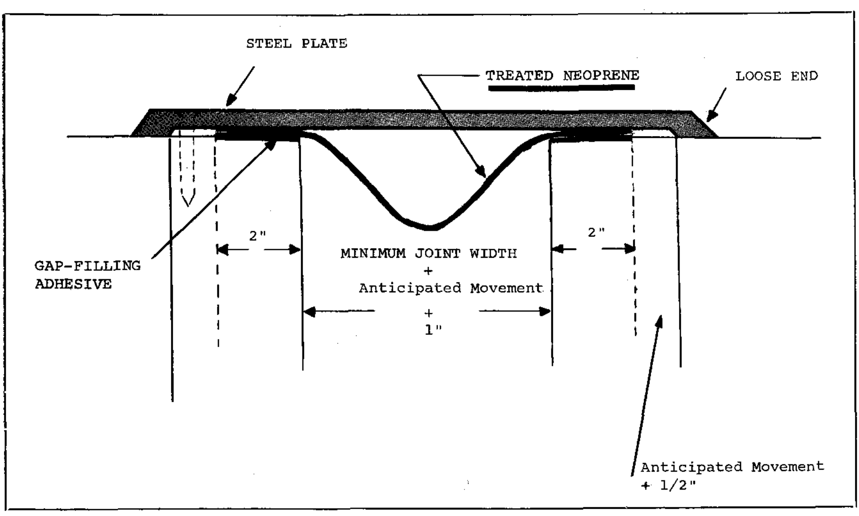

Fig. 7—Typical Premolded Sealant (Sheet)

never to stretching. This is also applicable when elastomeric sheets are installed in a "U"-shape as shown in Fig. 7. For vertical joints the premolded "U"-shape should be placed inward. In horizontal areas subjected to traffic, the premolded joint should be protected with a cover plate fastened to the concrete on only one side. The joint material should be pitched for drainage.

In the case of hollow tubes made from elastomeric materials, the tubes should be compressed during installation, allowing recovery of its original shape during extension. The tube diameter should be large enough so that it does not reach complete recovery at maximum extension of the joint. If the joint slot extends to such an extent that the tube is stretched, the adhesive will be subject to peel and the system may fail.

COMBINATION SYSTEMS

Often the most economical joint system can be designed from a combination of field-molded and premolded sealants. Fig. 8 shows a detail of a combination system used for the vertical joints of a high rise building. Vertical joints between panels were sealed with a premolded neoprene tube bonded in place with a field-molded sealant. Horizontal joints, Fig. 9, were subject to less movement and were relatively narrow joints. A field-molded polysulfide base sealant was used, in combination with a proper shape factor, bond-breaker, and foam backup material.

CONCLUSION

Joints between precast panels and precast panels and other elements can be successfully sealed if the following eleven rules are observed:

1. Sealants are solids and change shape, but not volume; therefore, shape factor will determine the efficiency of any given sealant.
2. Determine the anticipated movement at the joint slots. This will be dependent upon joint spacing and anticipated temperature change.
3. Design joint width and then shape factor based on the movement of the joint and the allowable maximum strain which the proposed sealant can withstand. Do not design on the extension

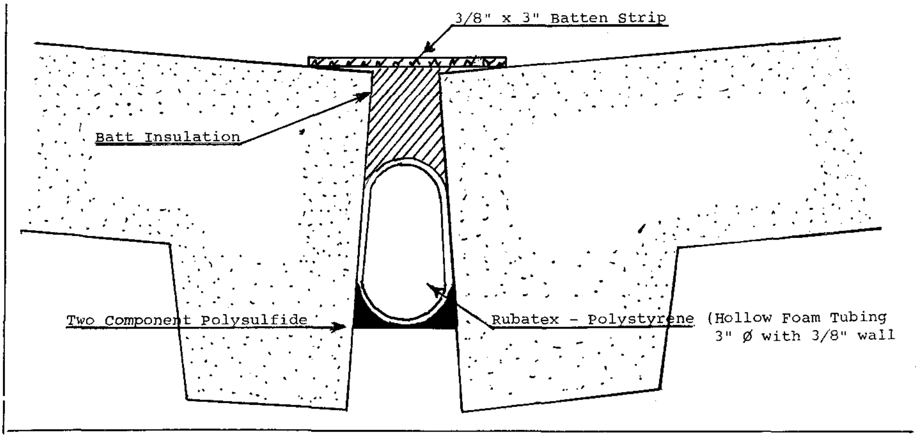

Fig. 8—Typical Premolded Sealant (Tube)

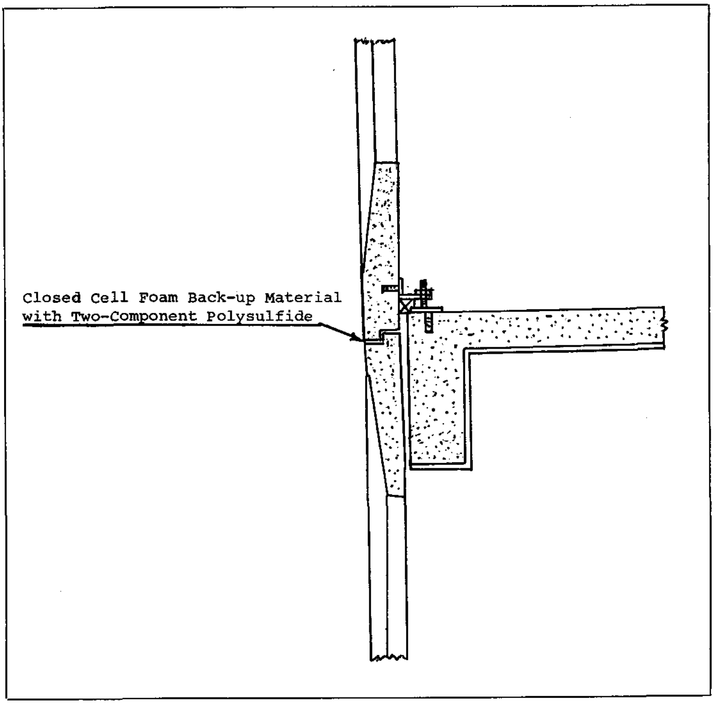

Fig. 9—Typical Detail for Field-Molded Sealant

of the sealant as such.

4. Since the surface tensile strength of concrete panels is relatively low, use sealants with low moduli of elasticity. Remember modulus of elasticity is not indicated by Shore Hardness.
5. Since all sealants are subject to the phenomenon of compression set, limit the compression of the joint slot in design to 20% or use a very flat shape factor less than 2:1.
6. Use bond-breakers and compressible foam backup materials where required.
7. If the joint width required to allow for proper movement exceeds 1½ in. in width, design for premolded sealants.
8. The design of premolded sealants should be such that the sealant is subject to bending not to stretching.
9. Bond the premolded sealant to the concrete with either a gap-filling epoxy adhesive or a low modulus premolded sealant.
10. Keep joints in line.
11. Keep joints accessible for ease of installation and repair.

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Discussion of this paper is invited. Please forward your Discussion to PCI Headquarters before January 1 to permit publication in the April 1967 issue of the PCI JOURNAL.