Joints in Precast Parking Structures

Prepared by the Parking Structures Committee Fast Team

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This paper provides essential information to all stakeholders involved in the design, construction, and maintenance of a parking structure so that the investment involved in the facility will be optimized. Specifically, guidelines and recommendations concerning design, installation, and maintenance of sealant joints in precast concrete parking structures are presented and discussed.

For many years, precast concrete has been a mainstay in the construction of aboveground parking structures. Precast concrete structures are economical, can be constructed relatively quickly, and make use of in-plant quality control processes to ensure consistency in the concrete material properties, curing procedures, and dimensions of the final product.

In order to maximize the life of the structure and affirm the value of precast concrete as a construction material for parking structures, it is critical that all potentially vulnerable points be engineered and installed properly. This is especially true at the joints between precast concrete members. Joint failure is perhaps the most significant repair and maintenance issue in precast concrete parking structures. Without properly designed and installed joint sealants, the inherent durability of precast concrete will not be realized.

A properly sealed joint is the result of successful execution by many individuals, including the designer, the precaster, the precast concrete erector, the welder, the concrete finisher, and the sealant contractor. With so many individuals involved in this important detail, it is easy to see that coordination of their efforts is vital to achieving a leak-free final product.

The intent of this paper is to provide essential information to all stakeholders involved in the design, construction, and maintenance of a parking structure so that the investment involved in the facility will be optimized. Specifically, guidelines and recommendations concerning design, installation, and maintenance of sealant joints in precast concrete parking structures are presented and discussed.

What This Paper Is Not Designed to Do

This paper should not be considered an authoritative design handbook or specification, though it contains elements of both. Design and specification documents contain many more facets than are addressed in this space and are activities typically reserved to licensed design professionals with appropriate field experience. Our hope is that the readers will take away an appreciation for the critical activities that go into delivering on the precast concrete industry's promise to the owners and designers of parking structures and concentrate on ensuring from the outset that those activities are performed to the highest possible standard. Only in this way can the confidence of our clients be secured and the value proposition of precast concrete in this important market segment be reinforced.

This paper also is not designed to address designed, building-expansion joints in the parking structure. These highly engineered assemblies, while equally important in controlling water infiltration, are not subject to the same considerations that affect the performance of the more numerous control joints in the structure.

Who Should Read This Paper

This paper is intended to provide critical information to many different audiences. For the owner/developer/operator, the information on maintenance and repair is important. In order to reap the maximum benefit from the investment in a precast concrete parking structure, or any other structure, regular inspections are a must. Early diagnosis of problems, whether major or minor, can significantly reduce the cost and inconvenience of repairs and upkeep. Regular maintenance is key to prolonging the life of the structure.

Precasters can glean valuable information from the sections on joint configurations, connections, and surface preparation. The work of the precaster has a major impact on the conditions presented to the sealant installer, and thus a significant bearing on the success and longevity of the sealed joints.

Design professionals will find useful information in the sections on material selection and joint design.

The section on installation is primarily intended for the sealant contractor. However, anyone whose work precedes the sealant contractor should also review this section in order to more fully appreciate how the successful installation of sealant depends on the proper completion of the work of prior trades.

Committee Recommendation

The best way to ensure that all activities related to the successful completion of durable, leak-free sealant joints are properly performed is to incorporate all of those activities into the contract of one design team member. That member is the precaster. The precaster is in a unique position of being able to control all the actions that go into a successful joint installation. The precaster casts the concrete and has the opportunity to provide the proper radius to the joint edge. The precaster can prepare the surfaces of the joints prior to shipping the double tees to the jobsite under controlled conditions when the edges are easily accessible. By having responsibility for installation, the precaster can further ensure that erection results in properly spaced joints and connection details, which facilitate sealant installation. And if the precaster is also responsible for the placement of any required toppings, it can make sure the formed joints are properly configured to provide the best chance for the sealant to do its job. Finally, if the precaster must provide the sealed joint, it will be much more attentive to all the preceding details so as to provide the best possible installation.

It is certainly possible that the precaster will subcontract some of this work. But in that event, it will be the precaster's responsibility to coordinate the work of all field trades whose work falls under its contract. The result will be a smoother process and a better joint, without many of the difficulties that result when one tries to coordinate the work of contractors and suppliers working under separate contracts.

CONTRIBUTORS TO QUALITY SEALANT JOINTS

The Owner/Developer

The owners and/or developers of a parking structure, while not responsible for design or installation of sealant joints, need to be well-informed as to their contribution to the overall value of the structure and the need for regular inspection and maintenance of the joints once the structure has been completed and placed in service. A conscientious inspection and maintenance program will go a long way toward ensuring that the owner receives the full benefit of its investment in a precast concrete parking structure.

The Precaster

As stated in "Committee Recomendations," the precaster is in a unique position of being able to control all of the actions that go into a successful joint installation in a parking structure. Because the precaster provides the basic building blocks for the structure, the attention it gives to edge configurations, surface conditions, and other factors will have a major impact on the abilities of subsequent trades to properly perform their phases of the project.

The Sealant Contractor

The contractor charged with sealing the joints must be intimately familiar with the materials to be used and their proper installation. The sealant contractor must also recognize conditions that will compromise the sealant's ability to perform the function for which it is intended. These conditions may include, but are not limited to, poor-quality concrete, improper joint sizes, out-of-plane joint edges, laitance, improperly consolidated edges, joint edges that have not been mechanically prepared, contaminated bonding surfaces, and many other conditions that can affect the outcome of the project. The workers employed by the sealant contractor must understand the critical importance of their respective job functions, from applying primer or mixing a multi-component sealant to proper gunning and tooling techniques, which will ensure complete wetting of the substrate and good long-term adhesion.

It is strongly recommended that the contractor's personnel have been trained in the use of the products by the sealant manufacturer or have attended training programs that focus on proper use and installation of joint sealants. There are programs presented by a number of trade organizations throughout the country, and some, such as that developed by Fort Scott Community College in Kansas, are widely recognized.

Joint preparation and sealant installation are frequent sources of discord on projects where the work of several contractors must be carefully orchestrated, and post-installation difficulties, such as leaking joints, can result in endless disagreements. Many in the precast concrete community would prefer to maintain control of this critical process, as well as the placement of the precast concrete components, to consolidate both responsibility for properly functioning joints and the authority to ensure that the joints are given every chance to succeed. This does not preclude the general contractor or precaster from subcontracting this phase of the work to an experienced sealant contractor, but it does help greatly in the coordination of work if this activity is controlled by the precaster. The best way for the precaster to control sealant installation is for that trade's work to be performed either directly by the precaster or by a sealant installer working as a subcontractor to the precaster.

The Design Professional

The design professional and its sub-consultants traditionally prepare drawings and specifications to describe the project requirements. Carefully prepared contract documents can provide for a fair bid that meets the construction requirements necessary to have successfully performing sealant joints. The following information should be included in the contract documents.

Design—Prior to preparing the documents, the design professional should determine a joint design based on expected joint movement, sealant material, and joint configuration. The design professional can reference the following sections and ASTM C1193[1] and ASTM C1299[2] for more information on joint design.

Specifications—The specification should provide minimum requirements for sealant material, joint preparation, joint tolerances, priming, and installation. The specification should address quality-assurance issues such as initial inspection of joint configuration and surfaces, adhesion tests to verify compatibility of materials and substrates, and material verification. The specification should also indicate requirements for quality-control inspections and testing.

Drawings—The drawings should describe the various joint designs and the location of all the joints. For each joint configuration, the drawings should detail the width, height, and shape. The drawings should indicate any required recess from the driving surface and should show necessary joint fillers, sealant backing, bond breakers, and bonding surfaces.

Pre-Installation Conference—Many specifications require that a pre-installation conference be held among the parties involved in the joint sealant construction, including the general contractor, installation contractor, material supplier, precaster, field topping installer (if applicable), design professional, and owner's representative. Such a conference can be beneficial to verify that all parties understand their roles in the joint construction, to ensure that project requirements are understood by those performing the work, and to ensure that no portion of the work has been left unassigned.

SEVEN STEPS TO QUALITY SEALANT JOINTS

Material Selection

The sealant chosen must be capable of adhering to clean concrete that is free of laitance, grease, oil, or other substances (this may require the use of a primer); accepting the movement experienced by the joint; and withstanding the environment and conditions to which it is subjected.

Historically, polyurethane sealants have exhibited excellent adhesion to clean concrete.

The sealants can be single or multiple component, meeting the requirements of ASTM C920,[3] Types S or M, Grades NS or P, Class 25. As a general rule, the multiple-component products are preferred because they combine excellent adhesion with a relatively quick cure and resistance to gassing or bubbling. Because of the physical demands placed on a sealant in a parking structure, especially across the drive lanes, it is not uncommon to need a primer for best performance (see "Installation"). Even when primer is not specifically required, it can provide a measure of protection against unexpected conditions, such as ponding water or long-term snow cover, chemical exposure, and some forms of surface contamination. In all cases, the sealant manufacturer's printed instructions should be followed with regard to primers, unless the specific conditions on a project dictate otherwise, and the manufacturer has been involved in any discussions related to straying from those instructions. In instances where the manufacturer has taken no exception from deviation from printed instructions, it is often prudent to obtain appropriate written documentation from the manufacturer.

In recent years, greater consideration has been given to the use of low-modulus silicone sealants in parking structures, including horizontal joints subject to traffic. Silicone sealants can be successfully used in these structures, provided that close attention is paid to priming requirements for the individual sealants and especially the need to recess the surface of the sealant to protect it from physical damage from traffic, snow removal equipment, and other vehicles.

Typical parking structure joints are designed for sealants capable of accepting ±25% movement. That is, if a joint is nominally 1 in. (25 mm) wide, a sealant should be capable of performing in 25% extension (joint width extends to 1.25 in. [32 mm]) or in 25% compression (joint compresses to 0.75 in. [19 mm]). There are sealants capable of accepting more movement than this (as much as 100% extension and 50% compression), but it is still prudent to design to the lower movement standard to leave some room for error. Standard tolerances for fabrication and erection can combine to produce a joint smaller than intended.

Sealant used in parking structures will be exposed to mechanical forces associated with direct exposure to rolling loads from passenger cars, light trucks, and sport utility vehicles. These forces include acceleration, deceleration, and turning torques. Consideration should be given to recessing the sealant from the surface of the concrete at drive lanes and ramps. Typical recesses are in the range of $^1/_8$ in. to $^1/_4$ in. (3 mm to 6 mm). A proper width-to-depth ratio should be maintained. Recessed sealant joints are more prevalent when using the lower modulus, softer sealants that offer the higher joint movement capability (+100%, -50% as referenced previously). Finally, depending on the location, the sealant may have to withstand heavy heat and UV (ultraviolet) loads, as in Florida or Texas, or extreme cold and snow, plus the abrasion of sand and salt used on the deck, as in Minnesota or New England states.

A sample sealant specification is contained in the Appendix.

Joint Design

Anticipated Joint Movement—All joints in concrete structures are dynamic, or moving, due to the physical characteristics of concrete. Temperature changes will account for most of the expansion or contraction of a joint, but concrete shrinkage and creep will also contribute to joint expansion in prestressed concrete structures.

Concrete shrinkage is a time-dependent process that occurs with the loss of water during cement hydration and evaporation. The majority of concrete shrinkage occurs within the first few months after casting, but shrinkage continues at a slower rate thereafter. Shrinkage strains that affect joint movement are those occurring after the sealant is installed.

Concrete creep is also time-dependent and produces a shortening in members subjected to a sustained load, such as a prestressing or post-tensioning force. The magnitude of creep strain is dependent on the magnitude of compressive force, the release strength of the concrete, the volume-to-surface ratio of the member, and the relative humidity.

The Appendix of this paper contains **Tables 1** through **4**, which are taken from the *PCI Design Handbook,* Figures 3.10.13 through 3.10.16.[4] These tables provide creep and shrinkage strain values along with the correction factors, which can be used to determine joint movement.

The amount of joint movement from temperature effects is dependent on the coefficient of thermal expansion for the concrete and many other factors. For concrete, the coefficient of thermal expansion will vary depending on the type of aggregate used and mixture proportions. For joint movement determination, a coefficient of thermal expansion value of 6×10^{-6} in./in./°F (11×10^{-6} mm/mm/°C) for normalweight concrete and 5×10^{-6} in./in./°F (9×10^{-6} mm/mm/°C) for lightweight concrete can be used with sufficient accuracy.

Substrate temperature at the time of sealant installation is the basis for determining thermal joint movements. Joints will open as temperatures decrease and close as temperatures increase. Joints sealed in the heat of summer will open more than joints sealed in winter or fall because the magnitude of temperature decrease will be larger than temperature increase. Similarly, joints will experience more closure when installation occurs in winter months.

Recent monitoring of existing precast concrete parking structures has verified that a thermal lag exists between ambient air temperature and concrete temperature. This lag is beneficial because it keeps the concrete from experiencing short-term temperature extremes that often occur with ambient temperatures. Roof members exposed to solar heating will experience a different thermal lag than lower level members.

Monitoring of structures has also shown that standard parking-deck connections have sufficient flexibility to relieve joint restraint from volume-change strains. Thus, joint movement can be calculated based on the distance between individual joints instead of between expansion joints.

Examples of joint movement determination can be found in the Appendix.

Initial Joint Width and Erection Tolerance—Joint widths between precast concrete members are specified and detailed by the design engineer to conform to the structural system design. Variations from the detailed width occur due to production and erection tolerances. These tolerances should be clearly specified by the design engineer and carefully monitored for field conformance. All trades, especially the precaster and erector, should review and accept the specified tolerances before construction begins. Standard PCI erection tolerance for variation in joint width is specified by member length as:

- 0 to 40-ft-long (12 m) members, ±½ in. (13 mm)
- 41-ft- to 60-ft-long (18 m) members, ±¾ in. (19 mm)
- 61 ft and longer members, ±1 in. (25 mm)

These tolerances will have a significant effect on sealant performance and for most sealants additional limitations are required.

For example, a ½ in. (13 mm) detailed joint with an expected joint movement of 0.1 in. (3 mm) would produce 20% sealant movement. If the joint is reduced to $^1/_8$ in. (4 mm), which is acceptable according to PCI tolerance, the same 0.1 in. movement would now produce 80% movement in the sealant. If a sealant with a ±25% movement rating is specified for the project, the reduction in initial joint width would eventually overstress the sealant.

Installers of sealants should not be expected to anticipate joint movement, as the determination of joint movement is generally performed by the design professional. Therefore, specified joint width tolerances must be compatible with the sealant specified for the project and the design movements.

The guidelines in **Table 5** give an example of recommended joint tolerance for a pretopped parking structure deck. Sealants compatible with these tolerances, under anticipated joint movements, must also be specified to ensure proper joint performance.

Reference information concerning seasonal temperature

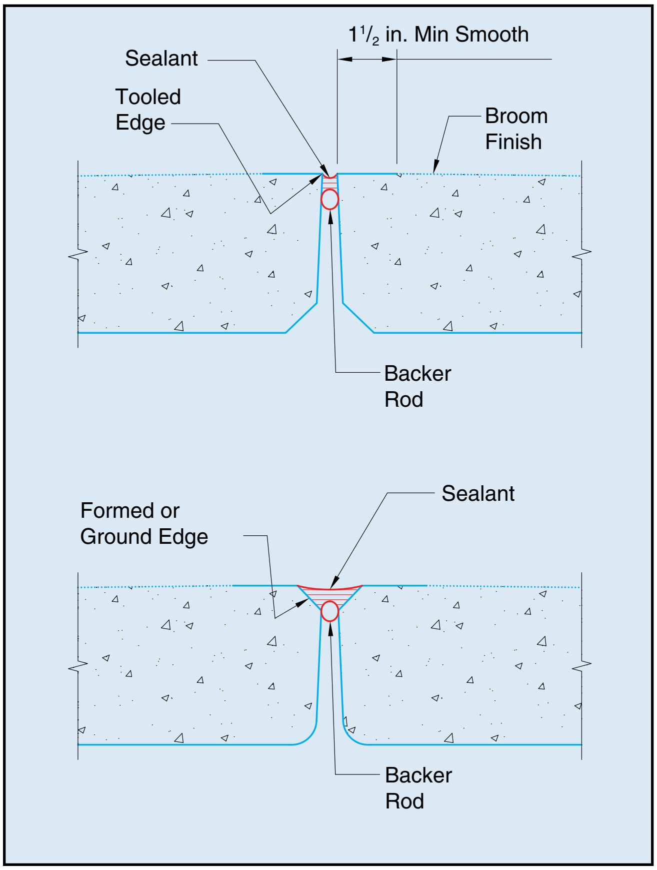

Fig. 1. Typical pretopped double-tee edge shapes.
Note: 1 in. = 25.4 mm

change, average relative humidity, creep, shrinkage, and correction factors for prestress and concrete strength, relative humidity, and volume-to-surface ratio can be found in the Appendix.

Joint Shape—The design of the joint shape between two double-tee flanges is the starting point of a waterproof system. The joint is developed from the forming of the edges of the double-tee flanges during the manufacture of the double tees.

The edge-shape design should consider ease of manufacturing, installation, product removal from the form, and in-place conditions, such as wheel, snow plow, and maintenance equipment loads. Top edges should be rounded ¼ in. (6 mm) to prevent sharp corners, which tend to fracture under service loads. Typical joint shapes for pretopped double tees are shown in **Figure 1**.

Joint Configuration—Establishing the proper sealant shape is critical in developing long term sealant performance. Specifying improper widths or depths may result in cohesion or adhesion failures.

The following criteria are generally recommended for most sealants:

- Sealant width should be at least four times the anticipated joint movement or ¼ in. (6 mm) minimum.
- Contact area on edges and center depth of sealant should be a minimum of ¼ in. (6 mm). It is critical to continue this minimum depth across intruding elements, such as weld flanges and other connections.
- Ratio of width:minimum depth should be 2:1. Where the width of the joint exceeds 1 in. (25 mm), consult the sealant manufacturer for the proper depth recommendation.
- Top surface of sealant should be concave and recessed below the top of the deck.
- For field-topped double-tee joints, topping depth should be 2 in. to 3 in. (50 mm to 75 mm). Joints in the topping need to be located at every joint between precast concrete members. The joint width and depth should be formed with a V-shaped groover, in accordance with the American Concrete Institute's ACI 362.5. Joints are typically grooved to ½ in. (13 mm) in depth. Some designers have expressed a preference for a 1-in.-deep (25 mm) joint, and this is acceptable. The tool must provide a radius of ¼ in. (6 mm) to both edges of the joint. This will serve to eliminate ragged edges to the joint and also to prevent edge spalling. It is essential that the groove be created when the concrete topping is still plastic. Saw cutting of topping joints is not recommended because shrinkage cracks usually form before the sawing operation.

Figure 2 illustrates the installed configuration for a pretopped double-tee joint. A pretopped double tee is also referred to as a factory-topped double tee or an untopped

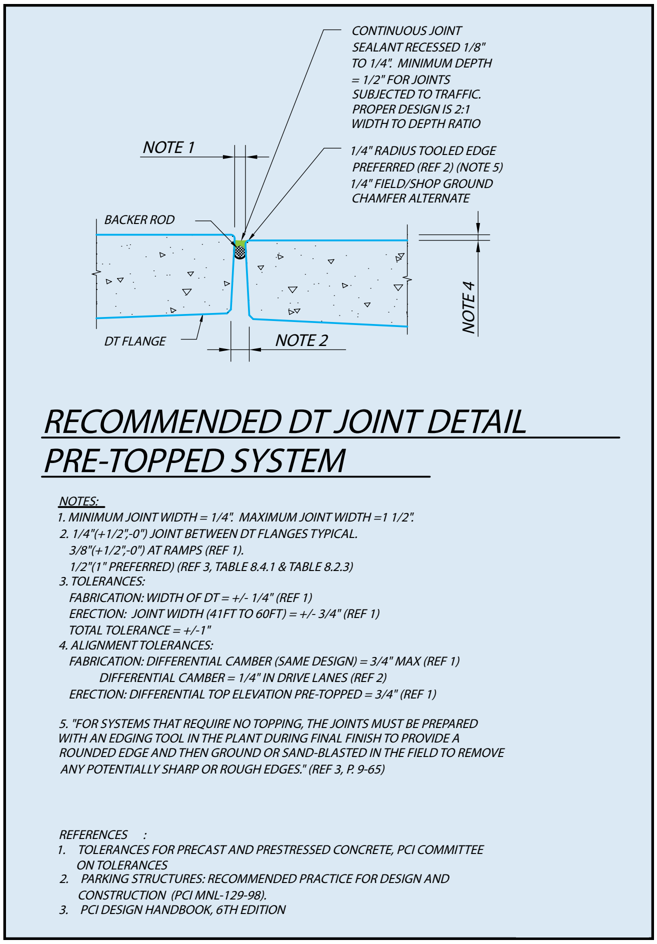

Fig. 2. Recommended double-tee joint detail pre-topped system. Note: " = in.; 1 in. = 25.4 mm.

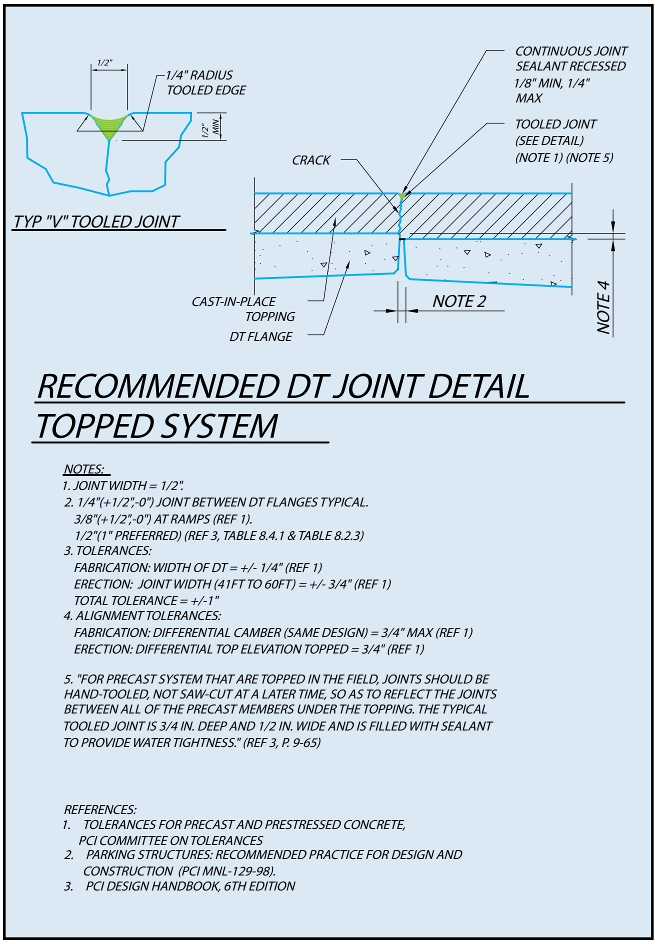

Fig. 3. Recommended double-tee joint detail topped system. Note: " = in.; 1 in. = 25.4 mm.

double tee. The instructions contained within the drawing call out the appropriate edge conditions, typical joint width, and fabrication, erection, and alignment tolerances. **Figure 3** shows a field-topped double-tee joint.

Surface Preparation—For sealants to adhere properly, they must have a suitable surface to which to bond. Surface preparation is distinct from priming and involves providing a suitable profile for adhesion and also a surface that is free of contaminants, which can interfere with the bonding of either the primer or the sealant to the concrete.

Pretopped or untopped systems: If the double tees are to be topped in the plant prior to shipping to the site, or if the double tees are to be installed and left untopped, then the bulk of the preparation is done in the plant, where the edges of the double tees are readily accessible and work can be performed under controlled conditions. This consists of grinding the edges to which the sealant will bond. Grinding is preferred to power wire brushing because it removes the top layer of material and exposes fresh, sound concrete below, which is devoid of loose matter, laitance, form release compounds, and other contaminants. It is also preferred to sandblasting, which is more random and requires containment procedures for safety and health reasons. If grinding is properly completed prior to shipping the precast concrete elements, then a light wire brushing followed by vacuuming or solvent cleaning will suffice in the field to remove any contaminants that have been deposited during shipping and installation or while other trades have been working on the deck prior to sealing of the joints.

Field-topped systems: If the double tees are to receive an additional topping in the field, then no surface preparation will be required in the plant. However, once the topping has cured sufficiently, the previously tooled joints will require preparation. As in the plant, grinding is the preferred method to remove unconsolidated material, laitance, or any other contaminants prior to priming. A V-shaped grinding wheel will facilitate the proper preparation of the joint. Once the joint has been ground, loose material should be vacuumed out of the gap or blown out using dry, oil-free compressed air. Priming and sealant installation can then proceed. When preparing to place topping in the field, it is important to make sure that concrete cannot pass through the gap between the double tees. The material used to block the gap must not impede the bond between the field topping and the precast concrete member, in order to prevent delamination of the concrete at the double-tee edges.

Joint Connections—Connections between precast concrete elements are provided to create a structurally stable system that transfers horizontal and vertical loads while providing displacement compatibility between members. A variety of connection types and configurations are available for precast concrete construction with load capacities well established by several resources, such as the *PCI Design Handbook* and the *PCI Connections Manual*.[4,6] However, in addition to having adequate strength, connections must be properly detailed to ensure long-term performance.

In parking structures, deck connections are required between double-tee flanges and from the flanges to walls, beams, spandrels, and columns. Deck connections must resist vertical forces from superimposed dead loads and live loads created by automobile wheels, pedestrian traffic, and snow. In addition, horizontal stresses are created by diaphragm action and volume change strains from creep, shrinkage, and temperature changes. Heat created by welding the connections will also create localized stresses. Detailing connections that resist those various strains without forming cracks through or adjacent to the joint seal is the key to developing a properly sealed joint.

Typically, each connection between double-tee flanges is made up of two metal components, each cast in their respective flange and then welded together in the field by a small bar across the joint. Historically, the spacing between connections for pretopped double tees has been 4 ft to 6 ft (1.2 to 1.8 m) and 8 ft (2.4 m) between connections for a field-topped double tees.

Many different types of metal connectors cast into the double-tee flanges have been used and are available. Some have been one piece, either a thin plate or a piece of concrete reinforcing steel. The majority have been a thin steel plate with two steel anchors welded to the plate for pretopped double tees. Field-topped double tees used a single piece of concrete reinforcement or small plate or angle with two anchor bars welded to the plate or angle.

Problems have occurred when connectors lack the ability to deform and separate from the concrete during welding or from service strains. Without proper detailing, cracks may form in the adjacent concrete or at the edges of the joint sealant.

Figure 4 shows two types of standard pretopped flange-to-flange connections used to align the flanges and transfer

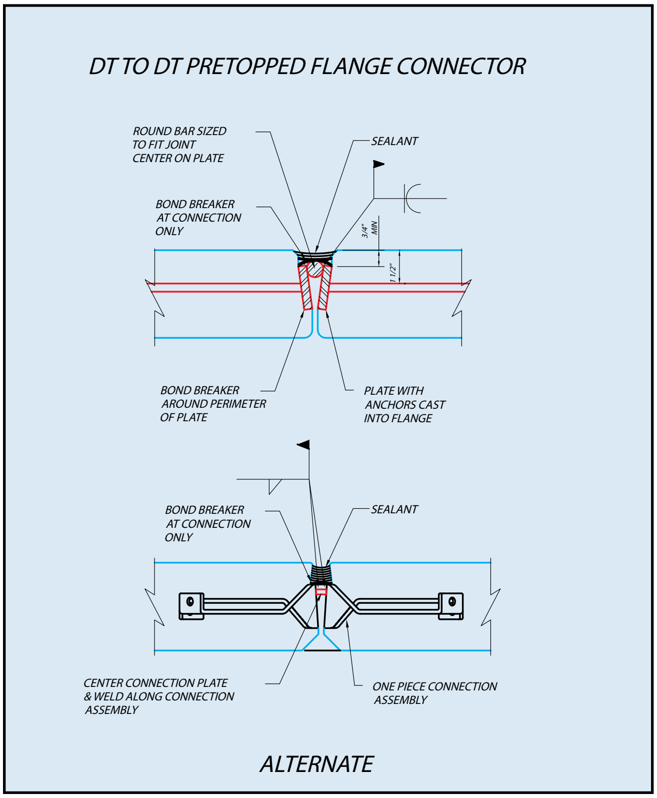

Fig. 4. Double tee to double tee pretopped flange connector. Note: “ = 1 in.; 1 in. = 25.4 mm.

vertical loads and horizontal diaphragm shear. These connections have a history of successful performance due to the following characteristics, which are essential for proper joint performance.

- Top of connection is located a minimum of ¾ in. (19 mm) below the top surface and plate anchors have 1½ in. (38 mm) of cover.
- Connection rod is located between the plate anchors with a minimum size weld.
- Plate anchors are sufficiently spaced to allow the body of the plate to deform during welding and under transverse volume strains. Connections should have a deformation capacity greater than the anticipated joint movement without cracking of the adjacent concrete.
- The top edge of the embed plate is free of concrete and the back face is debonded from the concrete. The sealant is debonded from the connection plate.

Generally, pretopped end chord connections and connections for field-topped systems do not need the flexibility of pretopped flange systems due to the confinement and stiffness of the topping. Standard industry connections that are properly anchored are typically sufficient for these conditions.

Installation of Connectors—Connectors should be installed so that they do not move during the casting process. Proper attachment is the key to this operation. Setting the connector into fresh concrete is not desired. If the connectors are askew, the field welding operation cannot be done properly.

The connectors must have relief around all four edges. This relief helps allow for expansion during welding.

Welding of Connectors—Because the connections between double tees are made by welding, the welding process has a major influence on the waterproofing of the joint. Excessive heat from the welding process can create cracking at and around the connection that will violate the integrity of the joint.

A qualified individual proficient in welding procedures for the connection should address the welding procedure for each particular project. Written procedures should be created and conveyed to all responsible personnel including the welder. A jobsite review of the welding procedures is also required.

Welding for flexible connections should be detailed to minimize weld heat. This can be accomplished by specifying the minimum weld size, weld length, arc voltage, and current. Excessive welding is detrimental to connections that need to flex under joint expansion.

The key to welding is to not overheat. This should be conveyed to the welders.

Prewelding planning and meeting: A meeting with the engineer, the project manager, the erector, and the welders prior to any welding should be held to convey welding procedures and details.

Welding procedures: As in all welding operations, the welding equipment should be maintained and checked prior to any welding. A written welding procedure should be created, reviewed, and communicated by a professional engineer familiar with the welding conditions for the particular project. The welder should be certified for the field conditions. Because welding temperature is one of the most important facets of the welding operation, temperatures should be minimized and maintained. Stainless steel welding will be hotter than the standard ASTM A36 carbon steel,[7] but the lowest possible temperature should nevertheless be maintained: **do not overheat.**

The proper electrodes should be used to fit the material and conditions. The welding of dissimilar metal should also be avoided. Ambient temperature should be considered when welding; welding in cold temperature requires special procedures, for example preheating.

Proper weld types and sizes should be designed for the connection detail. The weld types and sizes should be shown clearly on the drawings that are approved and conveyed to the field. Overwelding is not always beneficial for joint performance.

A prewelding meeting between the welder, welding inspector, and engineer prior to any welding is recommended. Welders should be shown the welding procedures, the engineering detail, and specifications for the connection. A sample weld should be executed and approved; this sample is the guide for the welder. Any change in welders requires a new sample and approval.

Proper field connection bars should be ordered for the field conditions. Joint sizes in the field vary. This requires various widths of field connection bars. These various-width bars should be made readily available to the welder. Inventory should be taken prior to the welding operation and any discrepancies should be reported for correction.

The bar should be placed true and level in the center of the connector.

It is recommended to use one bar of the proper joint width, but no more than two bars should be welded together to make a joint connection of the proper width.

Welding equipment: The welding equipment should be in good operating condition. Proper calibration methods should be used to ensure the accuracy of the operating adjustments. The amperage gauge controls the heat; the higher the amperage the higher the heat.

Certifications for type of welding: Welding personnel certifications should be kept on file for review of the welding inspector.

Inspection: Welding inspection is required. The inspector should be part of a prewelding meeting.

Testing: Any welds that are questionable during inspection should be tested for their integrity.

Remedial work: Any welds that are deemed insufficient should be replaced.

Quality Assurance

Quality-assurance measures help to confirm that all of the efforts prior to the installation of the sealant will work together to provide a successful sealant joint.

Material Verification—Product information and data sheets should be submitted to the design professional, demonstrating that the products meet or exceed the project requirements. This information should include the necessary test results demonstrating compliance and performance with design documents. This information should also demonstrate compatibility of the various components, compatibility at locations where different sealants intersect, and adequate adhesion with the intended substrates. The manufacturer's recommendations for joint preparation and installation should be included.

Installer Qualifications—The sealant installer's qualifications should be submitted and verified. Many sealant manufacturers and project specifications require that the installer be certified, trained, or authorized by the sealant manufacturer. Where certification or training programs are available, they should be employed.

Mock-Ups and In-Situ Adhesion Tests—Prior to beginning construction of the sealant joints, a mock-up of each joint type should be constructed. This mock-up should be reviewed for acceptable appearance. An adhesion test such as that described in ASTM C1521[8] should be performed on each of the joint mock-ups. This testing should be done to verify that the joint configuration, preparation, priming, and installation work together to provide adequate adhesion between the substrate and the sealant material.

Project Conditions—The sealant installer should carefully inspect all joints to verify that the width and depth sizes are within the range acceptable to the sealant manufacturer. The joint surfaces should be carefully inspected to verify that the concrete is sound and will provide the proper adhesion. Joints that do not fall within the acceptable tolerance of the sealant material should not be filled. The joints should be modified to meet the project requirements or the joint design should be modified to provide a successful sealant joint. Joint sealants should not be placed until the surface preparations have been satisfactorily completed. Sealant material should be placed only when surfaces are dry and when both ambient and substrate temperatures are within the material requirements.

Installation

Ideally, a sealant should be installed in a joint at a time when the concrete substrate temperature is at the midpoint of its expected low-to-high temperature range. When this can be done, the result is a sealed joint that is more or less equally compressed and extended over time. Because joints frequently must be sealed when the substrate is not at its midpoint temperature, good joint design takes into account the possibility that a sealant will have to function almost exclusively in either compression or extension. For example, if a sealant is capable of 25% extension or compression, good design dictates that the nominal joint size be four times the anticipated movement. Thus, if total joint movement is expected to be ¼ in. (6 mm), the nominal joint size should be at least 1 in. (25 mm).

In order for a sealed joint to perform properly, the concrete must have had sufficient time to cure prior to sealant installation. Sufficient concrete cure time ensures that moisture in the concrete will not interfere with proper cure and adhesion of the sealant. In general, it is best to wait until the concrete has cured for 28 days. While it may be possible to install sealant before that time, depending on the concrete mixture proportions, conditions of cure, and the sealant being used, it is best to plan for a 28-day cure and to ensure that adequate time is built into the job schedule up front. Negotiating cure time away near the end of the project is tempting but can produce a false economy, allowing an earlier opening at the expense of premature repairs of the sealed joints and reduced revenue after the opening of the deck.

Primer—Priming is a subject frequently avoided until the last possible moment. In some cases, it is assumed that a sealant will require the use of primer because the joints will be subject to traffic. In other cases, it is assumed that no primer will be required because a sealant generally has good unprimed adhesion to concrete. However, in some cases, it is only discovered that primer will be required after the bid has been submitted and accepted and the contract signed. Then, either the contractor should absorb the cost of this extra step or an extra payment should be approved by the specifier. Any requirement for primer should be identified at the earliest possible stage so that provisions may be made for the time and cost involved. While priming sealant joints is a minor-cost item in the overall budget for a parking structure, it often comes at a stage of construction when unanticipated delays can be frustrating to the contractor and especially to the owner/developer, who usually wants to commence utilization of the facility at the earliest possible date.

Once the bonding surfaces have been properly prepared and profiled, primer is applied. Prime in accordance with the needs and uses as specified by the sealant manufacturer and use only the primer specified. While there are similarities among concrete primers for urethane sealants from different manufacturers, each is carefully formulated to complement the chemistry of the sealant or sealants with which it is used. Never mix primers and sealant types from different suppliers on the same project.

Be careful to apply primer only to the bonding surface to prevent staining of the concrete to either side of the joint.

Primer should ideally be applied prior to the installation of the joint backing. In general, the primer will not damage the backing, nor will it enable the sealant to bond to it. However, priming a joint that already contains joint backing can result in ponding or puddling of any excess primer, which will result in a much longer drying time. If excess primer cannot puddle, and if air is free to flow through the joint while the primer is drying, then the sealant installation can take place more quickly.

Most, if not all, concrete primers for polyurethane sealants have an amber color and may darken considerably if exposed to sunlight. For this reason, it may be desirable to prevent the primer from contacting the exposed surface of the deck by taping the edges of the joint. This will help to maintain a neat, clean appearance. Tape should be kept clear of the bonding surfaces inside the joint. Generally, masking tape or duct tape is used for this application. The tape should be applied on the day the joint is to be caulked and removed as soon as possible after installation of the sealant, but certainly the same day.

Backer Rod—Joint backing, or backer rod, is an important part of the sealant installation. Round joint backing helps to give the final sealant installation the hourglass shape that results in the optimal distribution of stress. It also regulates the depth of the joint to maintain the 2:1 width:depth ratio that is recommended. For non-sag or slope-grade sealants, the backer rod helps push the sealant against the bonding surfaces when it is tooled, ensuring the best possible adhesion. And for self-leveling sealants, a tightly installed backing will help prevent the fresh sealant from leaking through the bottom of the joint. The accepted rule is having the backer rod 25% larger than the width of the joint to ensure the desirable snug fit.

There are different types of joint backing from which to choose, and it is important to be able to distinguish among them in order to specify the type that is best suited to a specific project or application.

Closed-cell backer rod—A closed-cell backer rod is typically an extruded polyethylene rod that is somewhat wider than the joint at installation so that compression will hold it in place during sealant installation. Sealant manufacturers will typically include directions on proper sizing of the rod in their data guides or specifications. Closed-cell rods are impervious to water because their internal cells are not connected, and so water cannot migrate through them. This internal structure also results in a relatively stiff product, which tends to give support to the sealant above and helps it resist extensive deflection from point loads, while reducing the incidence of tearing of the sealant. For these reasons, it is popular in horizontal joints exposed to traffic.

A detriment associated with the use of closed-cell rod is outgassing. This occurs when the cells of the rod are punctured during installation and the pressurized gas within the ruptured cells begins to escape. If the gas is still seeping out when the fresh sealant is installed, then it may result in the appearance of bubbles in the surface of the sealant. This is certainly not pleasing in appearance and may result in premature failure of the joint if the bubbling is serious enough. To prevent this cellular rupture, install the product with a blunt tool or roller rather than a sharp tool, such as a putty knife or spatula. As a precaution, wait a minimum of 20 minutes after installation for any gases to escape.

While exceptions are occasionally made due to irregular joint edges, major sealant manufacturers (both urethane and silicone sealants) recommend closed-cell joint backing as their first choice for backing traffic-bearing sealants.

Open-cell backer rod: Open-cell rods are usually made from polyurethane foam and have a continuous cellular network and no surface skin. This makes them soft and easy to install so that a larger size can be used for a variety of joint sizes. The product is packaged in compressed bales so that a great volume of product can be packaged in a small bundle. This saves on transportation as well as storage of unused product and faster installation at the site.

The downside to the use of open-cell backer rod is its ability to absorb and retain water. This can result in the softening of the sealant above the rod and premature joint failure if water is permitted to get behind the joint. When used in horizontal joints, open-cell rods provide little physical support for the sealant and make it more susceptible to puncture by pointed objects such as umbrella points or high-heeled shoes.

Open-cell backer rod is not recommended for use in horizontal joints because of its propensity to hold water.

Hybrid or soft-cell backer rod: A compromise product, intended to provide the best of both worlds, is the so-called soft-cell joint backing. This backing has an open-celled interior to allow for easy compression and prevent outgassing. However, its continuous outer skin prevents water from being absorbed into the foam and keeps any water that enters the foam from the open ends from being held in contact with the sealant.

Because soft-cell backing is much easier to compress than traditional closed-cell backing, it is easier to install.

Mixing—For multiple-component sealants, proper mixing is critical to smooth long-term performance. If the components are not properly proportioned and blended, the result will be premature failure, usually due to poor cross-linking, which prevents the sealant from expanding and contracting normally and reduces wear resistance in traffic areas as well as weather resistance.

The laborers mixing the sealant should be well-trained in this technique and should be familiar with the mixing requirements for the specific product with which they are working.

Applying Sealant

Non-Sag Sealants—Multiple component, non-sag (or gun-grade) sealants must be installed with a bulk caulking gun The gun is fitted with a properly sized nozzle and the sealant is dispensed into the joint from the bottom up to prevent entrapment of air. Apply with a steady flow and avoid overlapping to eliminate the entrapment of air. Once the joint is filled, the sealant must be tooled in order to establish proper contact with the bonding edges. A rounded tool is normally used in order to create the proper hourglass profile for optimal performance. Tooling should be done with a dry tool to prevent a tooling solution from contaminating the open joint faces or from chemically reacting with the sealant and preventing it from curing properly. A properly filled joint can be effectively tooled in one pass in the opposite direction from which it was filled.

Self-Leveling Sealants—Self-leveling sealants are sealants that flow into horizontal joints under the influence of gravity. They generally require no tooling and may be poured directly from the mixing container or some suitable dispenser but do present some special challenges. First, it is essential that the bottom of the joint be completely sealed to prevent sealant from dripping through the bottom of the joint. If the backer rod is not capable of providing a sufficient seal, then a small bead of a compatible non-sag sealant at the edges of the backer rod may suffice to seal the bottom of the joint. Second, if the joint is out of alignment or is sloped, the sealant will tend to run downhill. This will result in both performance and housekeeping difficulties. Once the sealant is in position, dragging a nail or a wire through the wet sealant can help to bring trapped air to the surface, where it can escape before forming a bubble in the surface of the curing sealant. Again, avoid overlapping the sealant to eliminate the entrapment of air.

Sealants on a Slope—Some manufacturers supply slope-grade sealants for use in areas where self-leveling sealants will not stay in place. These sealants should be treated as non-sag sealants in the sense that they will require gunning and tooling in order to function properly. However, they are generally easier to handle than their non-sag counterparts. In the absence of a slope-grade sealant, a non-sag sealant may be used in sloped joints.

Quality Control

Quality-control measures help to confirm that the construction of the sealant joints provide successful seals.

Inspections—Inspections during the construction of the joints should confirm that the preparation and installation of the joints meet the project requirements and match the construction of the quality-assurance mock-up. After preparation, the joint surfaces should be carefully inspected to verify that the surfaces are sound and all dirt, oil, grease, paint, waterproofing treatments, frost, ice, and laitance have been removed, as well as the top surface of concrete paste, exposing the properly profiled surface for bonding of the primer or sealant. The installation procedures should be reviewed to verify that the manufacturer's recommendations for joint backing and/or bond breaker installation, component mixing, sealant recess, sealant installation, and tooling are being diligently followed.

Freshly installed sealant can be inspected for the proper depth by using a tooling blade, spatula, or tongue depressor to measure the depth of the sealant in the center of the joint.

Tests—Periodic testing, such as described in ASTM C1521,[8] should be performed to verify that the joint adhesion meets or exceeds the values determined in the quality-assurance mock-up and that the appearance also matches that of the test installation. ASTM C1521[8] contains provisions for both destructive and non-destructive adhesion testing of joints.

Performance Review and Repair

Six-Month (or One-Year) Inspection—Periodic inspections of the condition of the structure can identify small problems before they have the opportunity to become major maintenance issues. This is especially true in the case of sealed joints. A full inspection of the joints every 6 to 12 months, preceded by a thorough washdown of the deck, will help to identify minor performance and durability problems. The washdown will help in two ways. First, it will clean the surfaces of the joints so that any damaged portions can be more easily identified. Second, it will help expose leaks when damaged areas become wet and water passes through them to the level below. It is much easier and less disruptive to ramp operations to repair these areas while they are small and while traffic can be easily routed around them.

Spot Repair—Spot repair of damaged or failed areas of joints is relatively easy. If a routine walk-through or a more detailed inspection reveals the need for small repairs to the joints, the repair areas need to be documented as to location, size, and type of failure (types of failures are listed in "Joint Failures—Types and Causes"). This can be done by the owner or with the help of a qualified engineer, consultant, or contractor. Once this is done, if the joints are covered under warranty, the contractor who issued the warranty can work with the owner to schedule the repairs. If the structure is no longer covered by a warranty, then a contract for repairs will need to be negotiated.

Repair of damaged concrete edges should be performed in accordance with guidelines published by ACI or the International Concrete Repair Institute (ICRI).[9,10] An excellent general reference for concrete repair is *Concrete Repair and Maintenance Illustrated* by Peter Emmons.[11]

Unless the existing sealant has been found to be entirely deficient, it is generally best to replace small sections with the same product, if known. In the case of cohesive failure, where the sealant is still firmly bonded to the concrete, the manufacturer may make a recommendation to cut away the failed sealant, leaving a thin film on the joint edge, and install fresh sealant against freshly cut edges of the previously installed product. In this situation, care must be taken to ensure the proper shape factor and joint design are maintained. In the absence of a positive recommendation that the manufacturer will stand behind, it is best to completely remove the sealant to the concrete edge and expose virgin substrate by grinding prior to reinstalling sealant in the joint. Primer is generally recommended in this case and is considered inexpensive insurance, considering the overall expense of the repair.

Once the surfaces are properly prepared, installation can proceed as outlined in "Installation." Protect the repaired sections until sufficient cure has been achieved to allow exposure to traffic. This may be done by fastening wood or metal covers over the repairs. It is recommended that the fastening be done with adhesives or duct tape rather than mechanical means to prevent damage to the concrete. Also, be careful to fix the covers to one side of the joint only, allowing the other side to move with the joint.

LONG-TERM JOINT MAINTENANCE

Joint Failures—Types and Causes

Before an owner implements a preventive joint maintenance program, it is useful to understand the causes of joint failure.

In *Sealants, The Professionals Guide*, published by the Sealant, Waterproofing and Restoration Institute,[12] it is noted that "there are four basic types of joint failures:

- Adhesion Failure
- Cohesive Failure
- Substrate Failure
- Loss of Sealant Properties"

Adhesion failures are typically the result of improper substrate preparation, poor installation of sealants (for example, installing sealants outside the recommended temperature limits or with moisture on the substrate), contamination of the substrate, or any combination of these factors. A clean separation of the sealant from the substrate is characteristic of an adhesion failure.

Cohesion failures are typically the result of incorrectly sized joints, incorrectly proportioned sealant, missing backer rods or bond breakers, or any combination of these factors. Rips or tears within the sealant, not near the edges, is indicative of this type of failure.

Substrate failures are typically the result of poor substrate preparation. It is not uncommon to see the *ski jump*, or square edges, on the precast concrete flanges. These areas are subjected to wheel and or plow impact loads, which can cause cracking. Microcracking around connections in the double-tee flanges is also common in older garages and spalling can result from freezing and thawing cycles. Sealant detached from the substrate with pieces of the substrate still adhered to the sealant is indicative of this type of failure.

Loss of sealant properties can be the result of age, exposure, and/or improper mixing of components in multi-component sealants.

Joint Life

According to PCI, ACI, NPA (National Parking Association), joint-sealant manufacturers, and industry experts, the typical life expectancy of joint sealants in a parking structure is 7 to 10 years, depending on exposure and the owner's commitment to maintenance of the joints. In no case should it be expected that any parking structure with joint sealants will not have isolated leaks or failures. It is important to note that this is not a maintenance-free system. It should be expected that the maintenance of joint sealants will include replacement of portions of joints, concrete repair, and cleaning.

It is standard practice for many sealant manufacturers to provide material warranties for up to five years. Therefore, a successful joint-sealant system should start with a reputable material manufacturer and an experienced sealant installer who will stand behind the product and workmanship, respectively.

Preventive Maintenance

Listed in this section are some basic maintenance practices that can help maximize the lifespan of the joint sealant system on a parking structure:

Proper Joint Detail and Material—Make sure prior to original installation that a proper detail has been rendered and executed and that the sealant chosen is designed to operate in that detail and under expected conditions.

Proper Preparation of Substrate and Installation of Sealant—Most sealed joint failures can be traced back to improper preparation. Make sure that the surface is free of contaminants, has been properly profiled, and has received an adequate coat of the correct primer, if required. Look for joint conditions that will accelerate failure, such as mismatched or improperly formed joint edges.

Ensure Proper Use of Facility—Do not exceed design/posted loads and install plastic or rubber edges on snow-removal equipment.

Flush and Inspect—Conduct biannual flushing of all joints and an annual joint inspection.

Clean—The structure should be swept, vacuumed, or cleaned using controlled compressed air or blowers (on a regular basis or weekly as recommended in the *PCI Maintenance Manual*).[13]

Repair All Spot Failures Annually—This practice should continue for the life of the structure, but is especially important during the warranty period.

Proper joint details, materials, preparation, and installation (as discussed in "Seven Steps to Quality Sealing Joints") are critical to the success of the sealed joints. The owner and anyone responsible for the maintenance of the structure should be aware of the intended use of the structure and ensure that vehicles, especially snow-removal equipment, do not exceed the design loads. It is also critical to ensure that the appropriate snow-removal and sweeping equipment is used.

An annual visual inspection of the joints and joint sealants is recommended and is usually a provision of maintaining the joint system's warranty. This is best performed during or immediately after the structure is washed down. The wash down provides a twofold benefit to the personnel conducting the visual inspection: first, by flushing the deck down, most of the leaks in the joints will be revealed; second, the joints will be clean and free of debris, which will allow the inspector to view the entire joint.

Repair

When any failures are noted, spot repairs should be completed at the affected areas. These repairs can include sealant replacement, concrete repair, or both. Many of these repairs can be covered under the warranty and should be actively pursued with the sealant manufacturer and installer. Industry experts recommend that once the total of these spot repairs reaches 30% of the original installation, complete joint replacement should be seriously considered.[5, 14]

Replacement

Replacement of the original sealant requires attention to the same details as the original installation, in terms of material selection; surface preparation; and priming, mixing, gunning, tooling, and protecting of the fresh sealant. However, if large sections have to be replaced, make sure to chose the proper sealant. If the original sealant failed prematurely, one must determine whether the failure was due to a fault in the sealant, the installation, or the conditions of installation. Only then can the replacement proceed with any assurance that the newly installed product will perform better than that which has been removed.

CONCLUSION

Many factors can affect the proper long-term performance of sealed joints in precast concrete parking structures. The performance of these joints is absolutely critical to the acceptance of precast concrete as the material of choice for the owners and designers of parking structures. Thus, it is imperative that all the activities surrounding the final quality of the joints are properly coordinated so that the joint that is sealed by the contractor is of the right design, concrete has been cast and prepared in such a way as to provide a sound surface, precast concrete members have been properly erected and connected, and that the sealant joint has been installed by a reliable, qualified sealant contractor.

The coordination of the efforts of the parties involved in these activities is an essential part of ensuring a good design and installation. It is also an extraordinarily difficult and complex undertaking, given the conflicting priorities that these parties frequently demonstrate.

One way to alleviate this difficulty is to place the responsibility for not only fabrication, but erection, completing connections and installation, on the precaster, which will be in a position to orchestrate all these critical activities and deliver the quality product that the owner and designer expect.

APPENDIX

Examples of Joint Movement Determination

Determine the anticipated joint movement for a normal-weight 12 ft × 30 in. pretopped double tee, 62 ft long, located in Chicago, Ill. Assume sealant installation is in July, 40 days after casting, and average prestress is 400 psi.

Case 1: Joint at Bearing End

Assumptions:

Annual average ambient relative humidity = 70%

Shrinkage strain at sealant installation = 299×10^{-6} in./in.

Final shrinkage strain = 560×10^{-6} in./in.

Creep strain at sealant installation = 150×10^{-6} in./in.

Final creep strain = 315×10^{-6} in./in.

Creep correction factor (CF) for prestress = 0.67 (f'_{ci} = 3500 psi)

CF for relative humidity = 1.0

CF for volume–surface ratio: V/S = 2.3

At sealant installation: CF = 0.77 for creep; CF = 0.79 for shrinkage

Final strain: CF = 0.90 for creep; CF = 0.92 for shrinkage

Shrinkage strain $= (560 \times 0.92 - 299 \times 0.79) \times 10^{-6}$
$= 113 \times 10^{-6}$ in./in.

Creep strain
$= 0.67\ (315 \times 0.90 - 150 \times 0.77) \times 10^{-6}\ (62\ \text{ft} \times 12)/2$
= 0.15 in.

Assume concrete temperature at installation = 70 °F

Maximum concrete temperature = 95°F; Minimum = 0 °F

Temperature joint opening
$= 70\ °\text{F} \times 6 \times 10^{-6}$ in./in./°F × 62 ft × 12 × ½ = .16 in.

Temperature joint closing
$= 25\ °\text{F} \times 6 \times 10^{-6}$ in./in./°F × 62 ft × 12 × ½ = 0.15 in.

Total joint opening = 0.15 in. + 0.16 in. = 0.31 in.

Total joint closing = 0.15 in. (neglect shrinkage and creep)

Case 2: Joint between Double Tees:

Creep strain = 0

Shrinkage strain = 279×10^{-6} in./in.

Shrinkage movement
$= 279 \times 10^{-6}$ in./in. × 12 ft × 12 in./ft
= 0.04 in.

Temperature movement
$= 70\ °\text{F} \times 6 \times 10^{-6}$ in./in./°F × 12 ft × 12 in./ft
= 0.06 in. (joint opening)
$= 25\ °\text{F} \times 6 \times 10^{-6}$ in./in./°F × 12 ft × 12 in./ft
= 0.02 in. (joint closing)

Total joint opening = 0.04 + 0.06 = 0.10 in.

Creep and shrinkage strains: See Table 1

Correction factors for prestress and concrete strength (creep only): See Table 2

Correction factors for relative humidity: See Table 3

Correction factors for volume-surface ratio: See Table 4

Table 1. Creep and Shrinkage Strains (Millionths)

Time, days	Creep		Shrinkage	
	Normalweight	Lightweight	Moist Cure	Accelerated Curve
1	29	43	16	9
3	51	76	44	26
5	65	97	70	43
7	76	114	93	58
9	86	127	115	72
10	90	133	124	78
20	118	176	204	136
30	137	204	258	180
40	150	224	299	215
50	161	239	329	243
60	169	252	354	266
70	177	263	373	286
80	183	272	390	302
90	188	280	403	317
100	193	287	415	329
200	222	331	477	400
1 yr	244	363	511	443
3 yr	273	407	543	486
5 yr	283	422	549	495
Final	315	468	560	510

Note: Concrete release strength = 3500 psi; average prestress = 600 psi; relative humidity = 70%; volume-to-surface ratio = 1.5 in.; 1 in. = 25.4 mm; 1 psi = 6.895 kPa.

Table 2. Correction Factors for Prestress and Concrete Strength (Creep Only)

Avg. P/A, psi	Release Strength, f'_{ci}, psi						
	2500	3000	3500	4000	4500	5000	6000
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
200	0.39	0.36	0.33	0.31	0.29	0.28	0.25
400	0.79	0.72	0.67	0.62	0.59	0.56	0.51
600	1.18	1.08	1.00	0.94	0.88	0.84	0.76
800	1.58	1.44	1.33	1.25	1.18	1.12	1.02
1000	1.97	1.80	1.67	1.56	1.47	1.39	1.27
1200	2.37	2.16	2.00	1.87	1.76	1.67	1.53
1400	2.76	2.52	2.33	2.18	2.06	1.95	1.78
1600	—	2.88	2.67	2.49	2.35	2.23	2.04
1800	—	3.24	3.00	2.81	2.65	2.51	2.29
2000	—	—	3.12	3.12	2.94	2.79	2.55
2200	—	—	—	3.43	3.23	3.07	2.80
2400	—	—	—	3.74	3.53	3.35	3.06
2600	—	—	—	—	3.82	3.63	3.31
2800	—	—	—	—	—	3.90	3.56
3000	—	—	—	—	—	4.18	3.82

Note: 1 psi = 6.895 kPa.

Table 3. Correction Factors for Relative Humidity

Average Ambient Relative Humidity (from Figure 3.10.12)[4]	Creep	Shrinkage
40	1.25	1.43
50	1.17	1.29
60	1.08	1.14
70	1.00	1.00
80	0.92	0.86
90	0.83	0.43
100	0.75	0.00

Table 4. Correction Factors for Volume-to-Surface Ratio (V/S)

Time, days	Creep						Shrinkage					
	V/S						V/S					
	1	2	3	4	5	6	1	2	3	4	5	6
1	1.30	0.78	0.49	0.32	0.21	0.15	1.25	0.80	0.50	0.31	0.19	0.11
3	1.29	0.78	0.50	0.33	0.22	0.15	1.24	0.80	0.51	0.31	0.19	0.11
5	1.28	0.79	0.51	0.33	0.23	0.16	1.23	0.81	0.52	0.32	0.20	0.12
7	1.28	0.79	0.51	0.34	0.23	0.16	1.23	0.81	0.52	0.33	0.20	0.12
9	1.27	0.80	0.52	0.35	0.24	0.17	1.22	0.82	0.53	0.34	0.21	0.12
10	1.26	0.80	0.52	0.35	0.24	0.17	1.21	0.82	0.53	0.34	0.21	0.13
20	1.23	0.82	0.56	0.39	0.27	0.19	1.19	0.84	0.57	0.37	0.23	0.14
30	1.21	0.83	0.58	0.41	0.30	0.21	1.17	0.85	0.59	0.40	0.26	0.16
40	1.20	0.84	0.60	0.44	0.32	0.23	1.15	0.86	0.62	0.42	0.28	0.17
50	1.19	0.85	0.62	0.46	0.34	0.25	1.14	0.87	0.63	0.44	0.29	0.19
60	1.18	0.86	0.64	0.48	0.36	0.26	1.13	0.88	0.65	0.46	0.31	0.20
70	1.17	0.86	0.65	0.49	0.37	0.28	1.12	0.88	0.66	0.48	0.32	0.21
80	1.16	0.87	0.66	0.51	0.39	0.29	1.12	0.89	0.67	0.49	0.34	0.22
90	1.16	0.87	0.67	0.52	0.40	0.31	1.11	0.89	0.68	0.50	0.35	0.23
100	1.15	0.87	0.68	0.53	0.42	0.32	1.11	0.89	0.69	0.51	0.36	0.24
200	1.13	0.90	0.74	0.61	0.51	0.42	1.08	0.92	0.75	0.59	0.44	0.31
1 yr	1.10	0.91	0.77	0.67	0.58	0.50	1.07	0.93	0.79	0.64	0.50	0.38
3 yr	1.10	0.92	0.81	0.73	0.67	0.62	1.06	0.94	0.82	0.71	0.59	0.47
5 yr	1.10	0.92	0.82	0.75	0.70	0.66	1.06	0.94	0.83	0.72	0.61	0.49
Final	1.09	0.93	0.83	0.77	0.74	0.72	1.05	0.95	0.85	0.75	0.64	0.54

Sample Specification for Joint Sealants

SECTION 07 92 13

Note to Specifiers: The purpose of this guide specification is to assist the specifier in developing a project specification for the use of sealants in the driving surfaces of precast concrete parking structures. It is not intended to be a "stand-alone" document nor to be copied directly into a project manual. This guide specification will need to be carefully reviewed for appropriateness for the given project and edited accordingly to comply with project-specific requirements.

PART I—GENERAL

System Description

A: Section Includes:
Joint sealants designed for concrete applications where flexibility, abrasion and puncture resistance are required.

B: Related Sections:
1. Section 03 30 00 – Cast-In-Place Concrete.
2. Section 03 40 00 – Structural Precast Concrete.
3. Section 04 21 00 – Masonry Assemblies Unit Masonry.
4. Section 07 95 13 – Expansion Joint Cover Assemblies.
5. Section 07 62 00 – Flashing and Sheet Metal Flashing and Trim.
6. Section 07 84 00 – Firestopping.
7. Section 08 41 00 – Aluminum Entrances and Storefronts.
8. Section 08 81 00 – Glass Glazing.
9. Section 32 12 13 – Asphalt Paving.
10. Section 32 13 13 – Concrete Paving.

System Description

A: Design Requirements: Add language to address field-topped system and V-groove. This paragraph addresses pretopped only.
1. Design number of joints and joint widths for maximum of ±25% movement.
2. Design depth of sealant to be ½ width of joint.
3. Maximum Depth: ½ in. (13 mm).
4. Minimum Depth: ¼ in. (6 mm).
5. Maximum recommended width: 2 in. (50 mm).

B: Performance Requirements: ASTM C920 Type S or M, Grade P or NS, Class 25, Use T, M.

C: Product Data: Submit manufacturer's technical bulletins and material safety data sheets on each product.

D: Samples:
1. Initial Selection Purposes: For each product exposed to view, manufacturer's standard bead consisting of strips of actual products.
2. Verification: Two sets of each type and color of joint sealant required. Install joint sealant Samples in ½-in.-wide joints formed between two 6-in.-long strips of material matching appearance of exposed surfaces adjacent to joint sealants.

E: Submit laboratory tests or data validating product compliance with performance criteria specified.

F: Submit list of references from five projects similar in scope to this project.

Quality Assurance

A: Comply with Section 01 40 00.

B: Manufacturer Qualifications: Company regularly engaged in manufacturing and marketing of products specified in this Section.

C: Installer Qualifications: Qualified to perform Work specified by reason of experience or training provided by product manufacturer.

D: Mock-Ups:
1. At start of Project, perform mock-up of required sealant work at one area of the structure. Perform minimum of one mock-up for each different combination of substrates to be sealed. Coordinate mock-up areas with Architect/Engineer.
2. Install mock-ups and test in presence of sealant manufacturer's authorized representative and Architect/Engineer to ensure installation procedures are consistent with warranty requirements.
3. After sealant has achieved sufficient cure as coordinated with manufacturer's representative, conduct adhesion pull-tests, or non-destructive testing, at discretion of Architect. Conduct tests per ASTM C1521.
   a. Confirm results of adhesion tests as acceptable by Architect, Owner, or Owner's representative and sealant manufacturer prior to proceeding with Work.

Table 5. Recommended Joint Tolerances for Pretopped Parking Structure Joints

Joint Type	Detailed Min. Width, in.	Detailed Max. Width, in.	Erected Min. Width, in.	Erected Max. Width, in.
Double-tee flange to flange (actual precast joint)	¼	¾	¼	1 ¼
Double-tee flange to loadbearing element (critical issue with dry systems)	¼	1 ¼	¼	2 ¼
Double-tee flange to non-loadbearing element	½	1 ½	¼	2 ½
Double-tee flange to flange (actual sealant joint)	¼	1 ½	¼	2

Note: 1 in. = 25.4 mm.

4. Leave approved mock-ups in place to establish standards and guidelines for acceptable installation of sealant Work and acceptable appearance.

Delivery, Storage, and Handling

A: Comply with Section 01 60 00.

B: Deliver products in original factory packaging bearing identification of product, manufacturer, and batch number. Provide material safety data sheets for each product.

C: Store products in a location protected from freezing, damage, construction activity, precipitation, and direct sunlight per manufacturer's recommendations.

D: Condition products to approximately 65 ˚F (18 ˚C) to 75 ˚F (24 ˚C) for use per manufacturer's recommendations.

E: Handle products with appropriate precautions and care as stated on Material Safety Data Sheet.

Project Conditions

A: Do not use products under conditions of precipitation, or in inclement or freezing weather. Verify that substrates are clean, dry, and frost-free. Use appropriate measures for protection and supplementary heating to ensure proper curing conditions per manufacturer's recommendations if application during inclement weather occurs.

Warranty

A: Provide warranty from joint sealant manufacturer and installer for material and labor for five years.

B: Include coverage for replacement of sealant materials that fail to achieve watertight seal, exhibit loss of adhesion or cohesion, or do not cure, provided sealant has been installed per manufacturer's recommendations.

PART II—PRODUCTS

Manufacturers

A: Subject to compliance with requirements, provide products from the following manufacturer:

B: Substitutions: Comply with Section [01 60 00] [__ __ __].

C: Specifications and drawings are based on manufacturer's proprietary literature. Other manufacturers shall comply with minimum levels of material, color selection, and detailing indicated in Specifications or on Drawings. Architect will be sole judge of appropriateness of substitutions.

Materials

A: Polyurethane Sealant: Multi-component, self-leveling, elastomeric polyurethane sealant that is mixed and poured in place, ASTM C920, Type M, Grade P, Class 25, Use T, M. (For sloped areas, a non-sag product conforming to ASTM C920 Grade NS, either Grade P or Grade NS, or a slope-grade product, may be used).

B: Silicone Sealant: Single-component, self-leveling, elastomeric silicone sealant that is poured in place, ASTM C920, Type S, Grade P, Class 25, Use T, M. (For sloped areas, a non-sag product conforming to ASTM C920 Grade NS, or a slope-grade product, may be used.)

Color

A: Sealant Colors: Selected by Architect/Engineer from manufacturer's full color range.

PART III—EXECUTION

Examination

A: Comply with Section 01 70 00.

B: Inspect areas involved in Work to establish extent of Work, access, and need for protection of surrounding construction.

C: Examine joints for defects that would adversely affect quality of installation.

D: Provide additional joint preparation, beyond that outlined in Specifications, as required by sealant manufacturer and Architect's/Engineer's recommendations based on mock-ups and field adhesion tests.

Preparation

A: Remove loose materials and foreign matter that impair adhesion of joint sealant.

B: Clean joints as required to expose sound surface free of contamination and laitance.

C: Ensure structurally sound surfaces, dry, clean, free of dirt, moisture, loose particles, oil, grease, asphalt, tar, paint, wax, rust, waterproofing, curing and parting compounds, membrane materials, and other foreign matter.

D: New Concrete:

1. Allow fresh concrete to fully cure (typically 28 days minimum).
2. Grind all surfaces to receive sealant.

E: Existing Concrete:

1. For previously sealed joints, remove existing material by mechanical means. If joint surfaces have absorbed oils, remove sufficient concrete to ensure clean surface.

Priming

A: Where circumstances or substrates require primer, comply with the following requirements. In all cases, comply with manufacturer's written recommendation:

1. Conduct test application to verify adhesion.
2. Apply primer full strength with brush or clean, lint-free cloth. Apply primer to a light, uniform coating. Porous surfaces require more primer. Do not overapply. Do not apply primer onto face of substrate.
3. Avoid applying primer beyond joint faces. To minimize contamination of adjacent surfaces, apply masking tape before priming and remove tape before sealant has begun to thicken and set.
4. Allow primer to dry before installing backer rod and applying joint sealants, in accordance with

manufacturer's printed instructions.

5. Prime and seal on same workday.

Mixing

A: Mix sealant and color pack (if necessary) per manufacturer's printed instructions.

Installation

A: Back-Up Material:

1. Backer rod should be either closed cell rod or soft-cell rod, which is essentially an open-cell rod with a continuous skin to prevent moisture absorption. If the use of another type of rod is desired, consult with the sealant manufacturer for recommendations.
2. Install appropriate size backer rod, larger than joint where necessary per manufacturer's recommendations and in manner to provide concave sealant profile.
3. Where joint depth does not permit installation of backer rod, install adhesive-backed polyethylene bond-breaker tape along entire back of joint to prevent three-sided adhesion of joint sealant.

B: Sealant:

1. Verify that temperature and moisture conditions are within manufacturer's acceptable limits.
2. Using fresh sealant and equipment that is in proper working order, completely fill joint with sealant, filling from bottom up to avoid entrapping air.
3. When self-leveling product is used, take measures to contain any excess that may overflow joint, especially in areas where joint is uneven.

Curing Time

A: Curing of joint sealants varies with temperature and humidity. Consult sealant manufacturer's technical representative or technical data sheet to determine expected cure times.

Inspection

A: During execution of Work, inspect Work to ensure compliance with manufacturer's guidelines, these Specifications when they exceed manufacturer's guidelines, and good construction practice.

1. Refer to latest revision of ASTM C1521 for test methods and frequency.
2. Allow inspections of Work and assist in testing requested by manufacturer's representative and Architect/Engineer.

B: Non-Compliant Work: If inspections reveal non-compliant Work or Work that was not installed per Specifications, and/or manufacturer requirements, remove adjacent Work until a location is reached where installation was performed properly. Assist in spot-checking of remainder of Work.

Cleaning

A: Remove uncured sealant and joint filler with xylene, toluene, MEK (methyl ethyl ketone), or other sealant-manufacturer-approved cleaning agent.

B: Remove cured sealant by cutting with sharp-edged tool.

C: Remove thin films by abrading.

D: Remove debris related to application of sealants from Project site per applicable regulations for hazardous waste disposal.

Protection

A: Protect Work from contaminating substances and damage resulting from other construction operations or other causes so that sealed joints are without deterioration or damage at time of Project completion.

REFERENCES

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