Precast concrete–to–precast concrete facade joints using precompressed expandable foam

Edward S. Farrington, Tom Anderson, Leon Grant, and Rita Seraderian

- A PCI committee was formed in 2013 to evaluate methods of sealing joints between precast concrete panels in building enclosures. This paper reviews the use of precompressed expandable foam as a joint treatment option.
- Field and laboratory testing of both full-scale and smaller-scale specimens was conducted using three joint-configuration details: precompressed foam only, precompressed foam with sealant, and precompressed foam with sealant and backer rod.
- Specimens constructed with the industry standard of dual sealant and backer rod were also tested to serve as the control specimens and benchmark for data comparison.

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This paper discusses precompressed expandable foam as an option for sealing the joints of an architectural precast concrete panel building enclosure (referred to as precast concrete). The building enclosure is defined as the physical component or system of components of a building that separates the interior from the exterior environment. Architectural precast concrete building enclosures provide the facade of the building with more than just the environmental separation. Architectural precast concrete has had a successful long-term track record of use for building enclosures to control water and air penetration. Precast concrete wall designs are typically specified with a two-stage sealant joint between the concrete elements. This industry has accepted and recommended this approach. All exposed joint sealants require inspection, maintenance, and repair over time. Typical sealants degrade over time, and exposure to weather and ultraviolet rays can result in delamination and, subsequently, water leakage through the joint.

In December 2013, PCI Northeast launched the PCI Northeast Envelope Committee to evaluate methods of sealing the joints in building enclosures between architectural precast concrete panels. The committee developed a list of topics related to precast concrete building enclosure design, including window details, roof interface, foundation connections/interface, and joints. After much discussion, the committee began focusing its efforts on the typical panel-to-panel joint system. The committee determined that there were many new materials on the market and that a new joint material would be an appropriate topic to explore.

The committee members are Edward Farrington of Simpson Gumpertz & Heger (SGH), Tom Anderson of Tremco Inc., Rob Delvento and Leon Grant of Coreslab Structures (CONN) Inc., Nesil Normile of Oldcastle Precast, Gerry Grassby of Strescon Ltd., Michelle Haman of Blakeslee Prestress, and Rita Seraderian of PCI Northeast.

The corresponding members are Kevin Rooney of Tremco Inc., Jeff Ceruti of SGH, Sal Capobianco of SGH, and Sid Freedman, who is retired from PCI.

Development of alternative joint treatment

The typical solution for sealing precast concrete–to–precast concrete joints has historically been to install sealant and a backer rod, often in a dual-layer configuration where there is a primary seal set deep in the joint and a secondary seal at the exterior face of the joint. This secondary seal is meant to protect the primary seal while allowing water to weep out in case water gets back to the primary seal level. The committee wanted to find an alternative to this widely used method and to determine whether the alternative was viable through testing and research.

As the committee began its research for such a technology, precompressed foam material emerged as a product category that should be considered. This material is usually composed of a polyurethane-based, open-cell foam that is impregnated with an acrylic, hydrophobic resin and subsequently compressed and slit into narrow widths. This type of product appealed to the committee because it offers many advantages over the standard solution, namely the following:

- the ability of the material to expand and withstand shear at greater distances than sealant and to contract with the joint as it moves

Figure 1. Precompressed foam.

- the claim by manufacturers that the material provides watertightness as a standalone product without the addition of sealant
- an *R*-value, which is a measure of resistance to the flow of heat through a given thickness of a material, that may provide some improvement over the typical joint
- relatively easy installation

Tremco's precompressed foam, known as Illmod 600 (**Fig. 1**), was used in all of the testing for this program. This product originated in Europe and has been in use for over 50 years, so there is a track record of its use and success. It is known in the United Kingdom as Compriband 600, and the Compriband TP600 Sealing Tapes Certificate 96/3309 Product Sheet contains a report from a test conducted with this material in the United Kingdom.

When reviewing liquid sealant technology options for testing, the committee wanted to use a technology that would be the most representative of current industry practices in the field. Based on input from SGH and Tremco, it was determined that silicone is the most frequently used waterproofing for exterior sealant conditions, so Tremco's Spectrem 1 sealant was selected.

Configuration of alternative joint treatment

The committee's original intent was to compare any new alternative solution to the existing typically used solution of dual-layer sealant and a backer rod. When determining combinations of materials to test, it was evident that this original configuration (referred to as the control) needed to be part of the testing to set a benchmark for comparison.

The committee then reviewed the merits of several different configurations using various combinations of the precompressed foam, typical backer rod, and silicone sealant.

The committee wanted to be able to show the potential advantages of using this precompressed foam product but understood that there may be varying opinions on whether the material should be used alone, with sealant, or with a secondary seal layer. As part of the testing, the committee also wanted to determine whether a secondary layer is necessary with this type of system.

After reviewing several drafts of joint detail configurations, the committee decided to test four distinct configurations for both a solid precast concrete panel (panel A) and an insulated precast concrete panel (panel B).

Insulated panels were added to the test program because this panel type has grown in the marketplace and has become more common for certain building applications. Following are the tested panels:

- detail 1A: precompressed foam only for solid panel (**Fig. 2**)
- detail 1B: precompressed foam only for insulated panel (**Fig. 3**)
- detail 2A: precompressed foam with silicone sealant applied directly to foam for solid panel (**Fig. A.1**) (for appendix figures, go to pci.org/2019Nov-Appx-Ser)
- detail 2B: precompressed foam with silicone sealant applied directly to foam for insulated panel (**Fig. 4**)
- detail 3A: precompressed foam with silicone sealant applied directly to foam as primary seal and backer rod and sealant as secondary seal for solid panel (**Fig. 5**)
- detail 3B: precompressed foam with silicone sealant applied directly to foam as primary seal and backer rod and sealant as secondary seal for insulated panel (**Fig. A.2**)

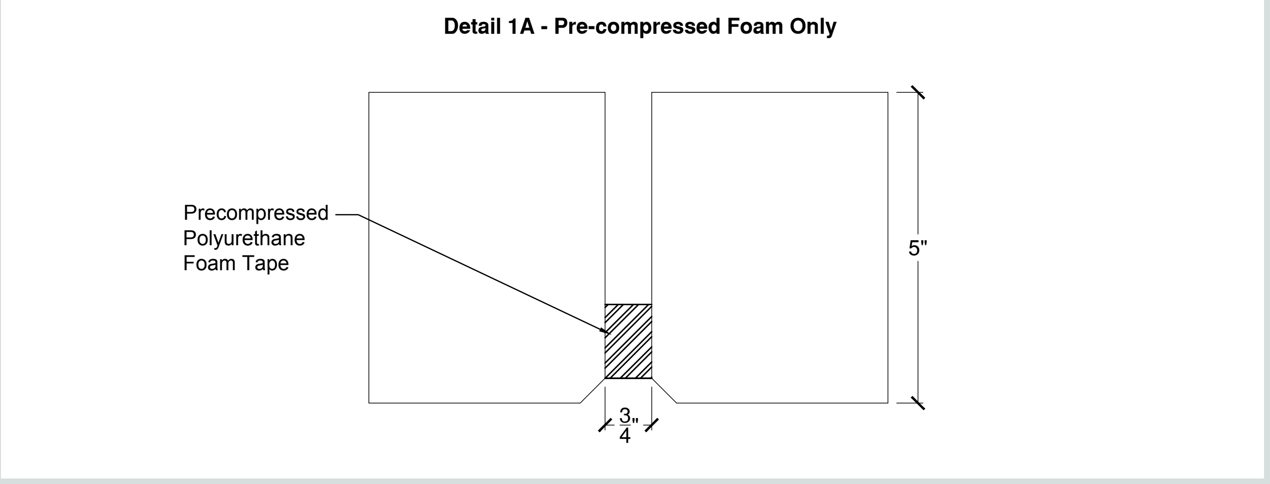

Figure 2. Test configuration of detail 1A: precompressed-foam-only detail for solid panel. Note: 1″ = 1 in. = 25.4 mm.

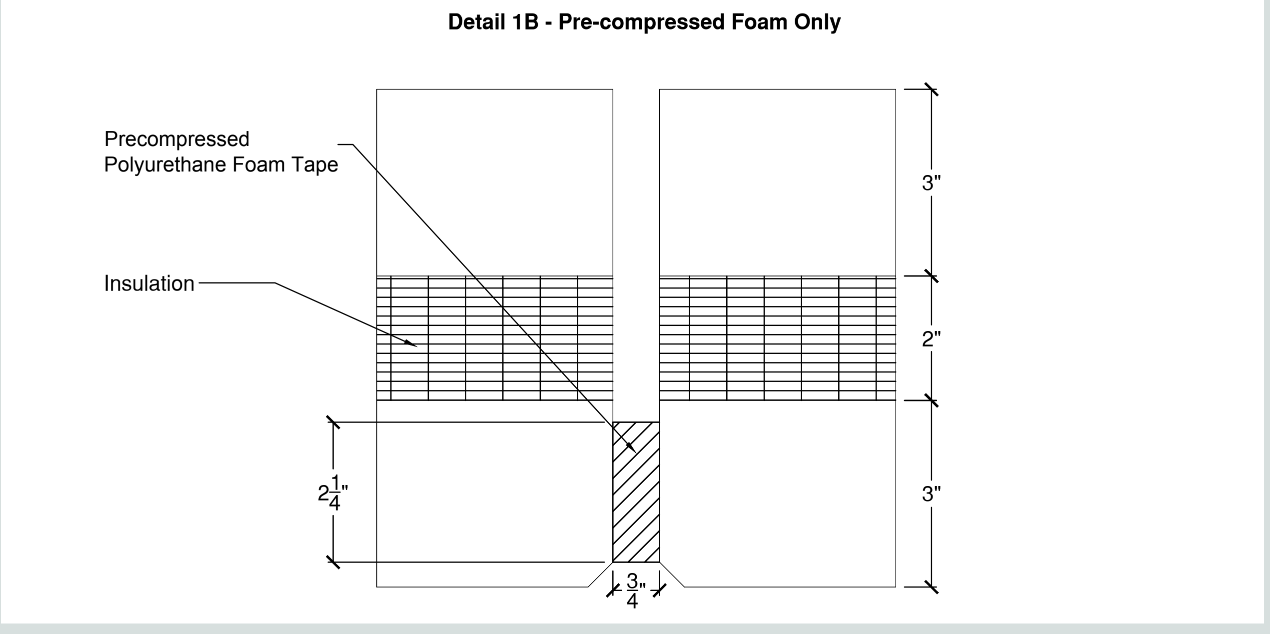

Figure 3. Test configuration of detail 1B: precompressed-foam-only detail for insulated panel. Note: 1″ = 1 in. = 25.4 mm.

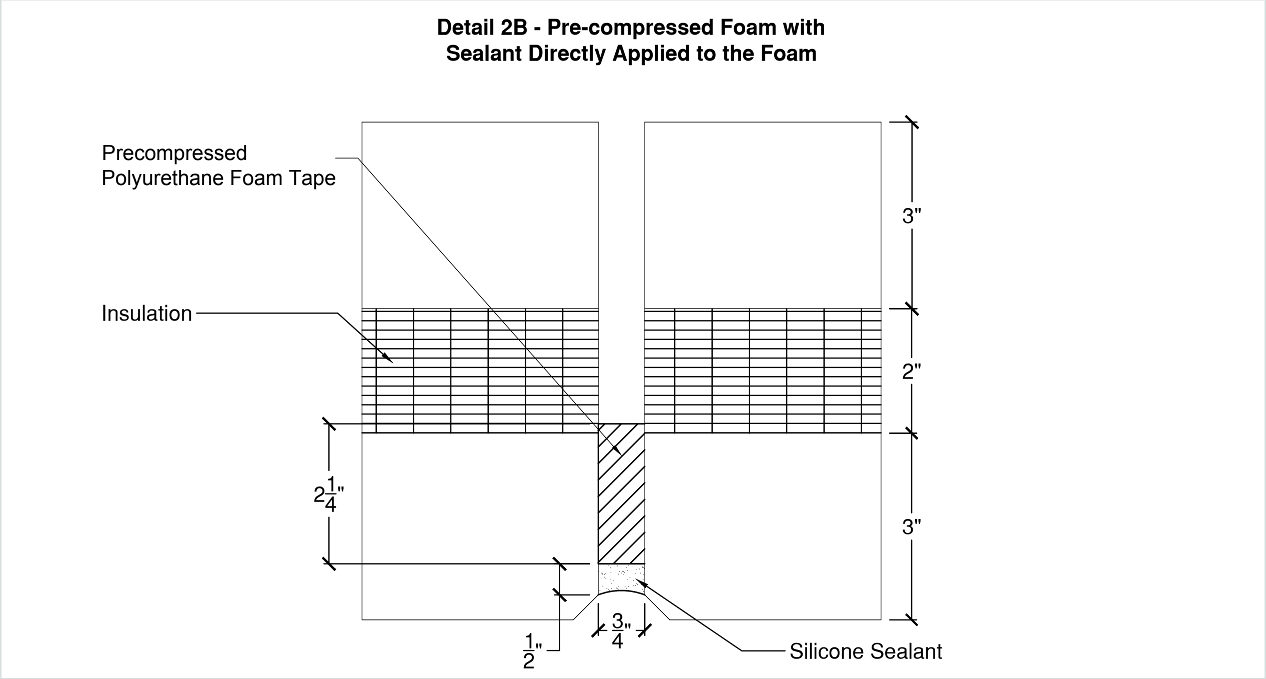

Figure 4. Test configuration of detail 2B: precompressed foam with sealant detail for insulated panel. Note: 1″ = 1 in. = 25.4 mm.

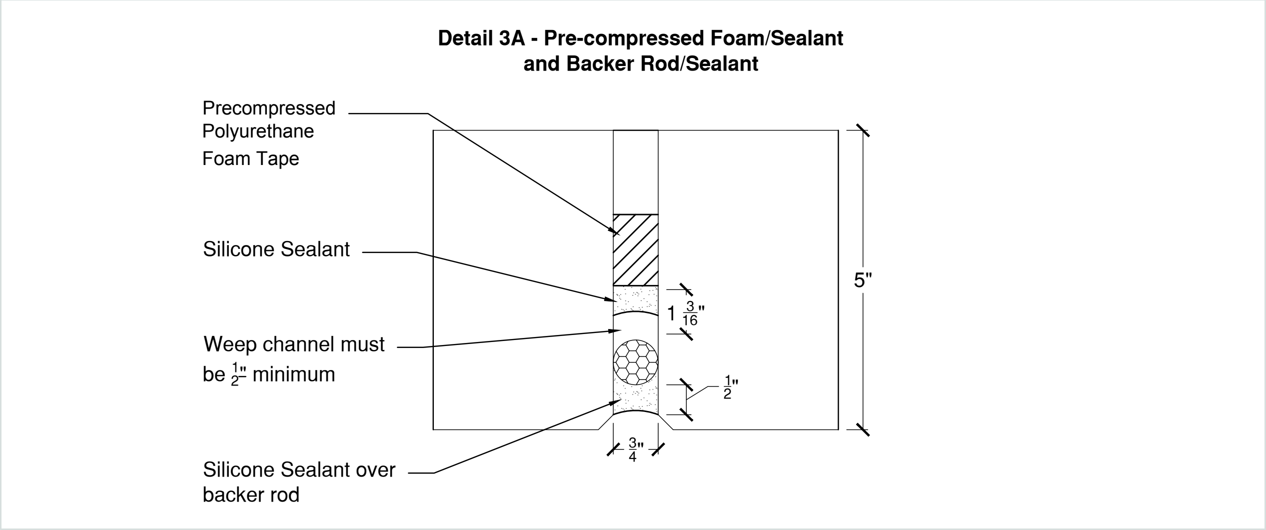

Figure 5. Test configuration of detail 3A: precompressed foam with sealant and backer rod detail for solid panel. Note: 1″ = 1 in. = 25.4 mm.

- detail 4A: dual sealant and backer rod (control) for solid panel (**Fig. A.3**)
- detail 4B: dual sealant and backer rod (control) for insulated panel (**Fig. 6**)

The goals of this testing were the following:

- to understand the air- and water-leakage performance of a precompressed-foam-only system in a precast concrete wall
- to understand the air- and water-leakage performance of a joint with precompressed foam as a secondary seal with silicone sealant installed on the foam

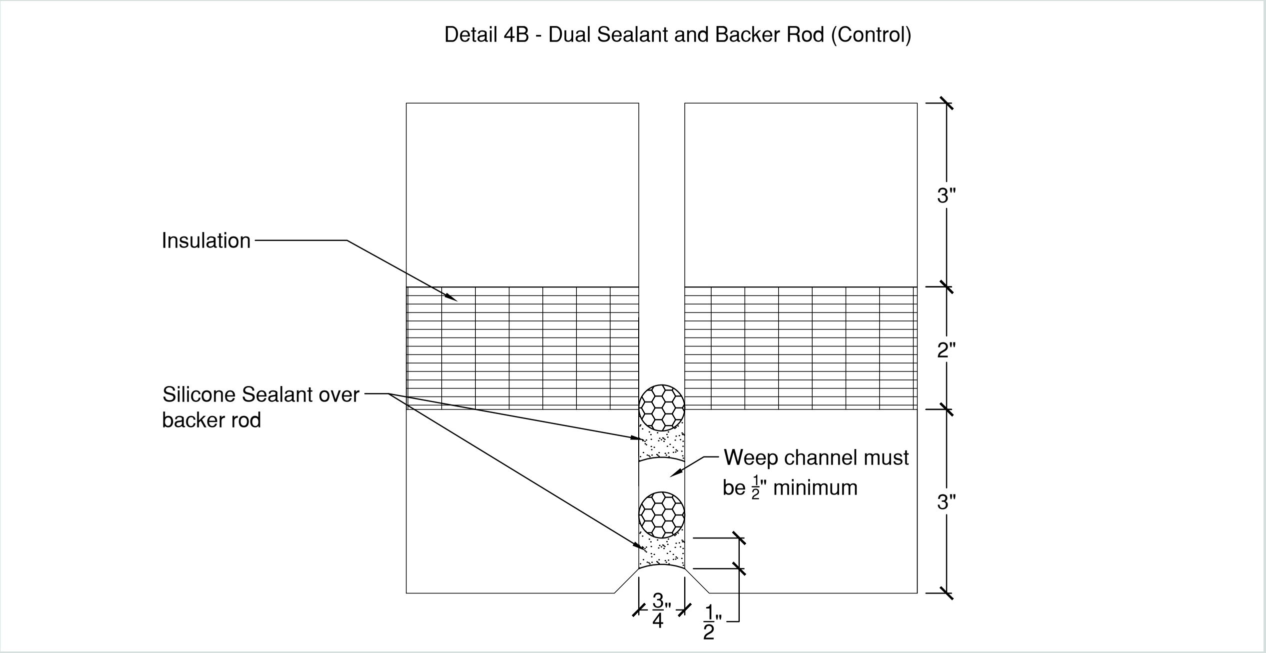

Figure 6. Test configuration of detail 4B: dual sealant and backer rod (control) detail for insulated panel. Note: 1″ = 1 in. = 25.4 mm.

- to understand the air- and water-leakage performance of a joint with precompressed foam as a primary seal with a typical backer-rod sealant joint as the secondary seal
- to validate joint configurations 1, 2, and 3 against the air- and water-leakage performance of a typical dual-joint system using a backer rod system

A test protocol was developed by SGH and was reviewed by the committee. SGH also recommended a full-scale assembly (referred to as field test mock-up) to test and approve the protocol. The committee reviewed many options for testing the assembly. The options included on-site testing at a current project site or at SGH's laboratory facility in Waltham, Mass. Size limitations, transportation, and assembly would have been cost-prohibitive for testing at SGH's facility; therefore, Coreslab Structures (CONN) agreed to produce the panels and build a test assembly outdoors at its plant in Thomaston, Conn. PCI Northeast contracted with SGH to conduct field tests over four visits at Coreslab's plant.

Field test mock-up and construction of joints, including material and installation

Test mock-ups were used to show how construction of the configuration details would be performed in a typical field application, what the final product would look like, and to provide key information for decisions and changes as needed before construction. The committee reviewed multiple options for test mock-ups and agreed that full-scale concrete wall mock-ups, as opposed to smaller-scale mock-ups, would be the most similar to field conditions despite the fact that the smaller-scale mock-ups would be easier to build for testing purposes. The mock-ups also needed to include intersections, weeps, shim packs, and connections representative of an actual project. The committee agreed that for each test configuration, one mock-up would be installed in a precast concrete panel (panel A) and a second mock-up would be installed in an insulated precast concrete panel (panel B).

The precast concrete panel sizing selected was two 6 × 4 ft (1830 × 1220 mm) panels set on two 2 × 4 ft (610 × 1220 mm) panels with a ¾ in. (19 mm) wide sealant joint forming a cross between all four panels. The committee agreed that this 8 × 8 ft (2440 × 2440 mm) mock-up would have the exterior face mounted to a steel frame and a pressurization chamber mounted to the interior face of the wall. The steel frame was required for accessing all sides of the mock-up for installation and testing purposes. The pressurization chamber would comprise 2 × 4 in. (51 × 102 mm) lumber installed along the perimeter of the mock-up panel with multiple cross members at approximately 1.5 ft (457 mm) on center to support the membrane enclosure. The membrane used for the pressurization chamber enclosure would be a 10 mil (0.01 in. [0.254 mm]) clear plastic sheet for full visibility of the joints. All seams in the plastic and around the wood frame would be sealed with tape or sealant to the concrete panels (**Fig. 7** and **8**).

While the site mock-up was full scale and provided a platform for testing, it did not simulate installation difficulties that may

Figure 7. Test panel assembly chamber side.

be expected in a practical application from an aerial lift or a swing stage. The panel supports created difficulty for sealant installation similar to working from scaffolding.

Field test selection

The committee selected the following ASTM air-leakage and water-penetration tests because they allow linear and area measurements as well as quantitative and qualitative results in the field. These tests also use a similar site-built frame and enclosure, where measurable pressure can be applied by a laminar airflow system and adjusted as needed to evaluate the installed sealant joint.

The mock-up panels were tested to the following ASTM standards, modified for sealant joints:

- ASTM E783 *Standard Test Method for Field Measurement of Air Leakage through Installed Exterior Windows and Doors*[1]
- ASTM E1105 *Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls, by Uniform or Cyclic Static Air Pressure Difference*[2]
- ASTM E1186 *Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems*[3]

The ASTM E783 test method is a standard procedure for determining the air-leakage characteristics of installed exterior windows and doors under specified static air pressure differences. Systems are tested at a minimum static air pressure differential of 6.24 lb/ft^2 (0.3 kPa), with an allowable air leakage of not more than 0.10 cfm/ft^2 (0.03 cmm/m^2) of sealant joint.

The ASTM E1105 test method is a standard procedure for determining the resistance to water penetration under uniform or cyclic static air pressure differences of installed exterior windows, skylights, curtain walls, and doors. It is intended primarily for determining the resistance to water penetration through such assemblies for compliance with specified performance criteria, but it may also be used to determine the resistance to penetration through the joints between the assemblies and the adjacent construction. Systems are tested at the minimum cyclic static-air-pressure differential listed for tests 1 and 2. No leakage is allowed on the interior surface of the concrete panels in order to pass this ASTM test.

- test 1: 8 lb/ft^2 (0.38 kPa) (AAMA [American Architectural Manufacturers Association] ⅓ reduction)

Figure 8. Test panel assembly water spray side.

- test 2: 12 lb/ft^2 (0.58 kPa) (full design pressure)

The ASTM E1186 test, or fog test, method covers standardized techniques for locating air-leakage sites in building envelopes and air barrier systems. The test described is of a qualitative nature in determining the air-leakage sites rather than determining quantitative leakage rates. Systems are tested at a static-air-pressure differential of 6.24 lb/ft^2 (0.3 kPa) until the system either fails the air infiltration test or the air infiltration testing is unable to be performed (unable to pull the tare, which is material covering all joints). The pressurized fog testing is a qualitative test method that allows the testing agent to observe fog exiting the chamber at leak points. The expectation is to not have fog leak from the test chamber.

Preparation of joint substrate for material installation/reinstallation for field testing

As is standard in the industry, joint substrates must be very clean to ensure successful adhesion of the joint sealants. In the case of concrete, the concrete must also be cured for a full 28 days (industry standard) to avoid inadequate levels of moisture and pH in the concrete.

The committee agreed on a number of standard installation procedures that would be used throughout the testing program to provide a true comparison from one test to the next. In addition to the concrete being sufficiently cured as mentioned, these requirements were as follows.

The material for each test would need to be applied against virgin precast concrete surfaces. Therefore, if material had already been installed there, the old material would need to be stripped out and ground off the face of the concrete completely. Each precast concrete face within the joint would then need to be wiped clean with a suitable solvent and the solvent allowed to flash off before application of any foam or sealant. For tests where precompressed foam would be used on its own, a primer would have to be applied before installation of the foam to seal up the pores surrounding the foam itself.

Following any testing where the assembly had been soaked with water, sufficient time would need to be given for the concrete to dry out again before application of a new joint-sealant configuration. The guideline for drying was approximately seven days, with a recommendation to perform a moisture test if there was any uncertainty about the moisture level being low enough before application.

Field test procedures and qualifications

With field testing, the protocol was to first perform the ASTM E783 air-leakage test. The initial pressurization test was performed using a laminar (air moving at the same speed and in the same direction) airflow system to draw pressure from the enclosure with a tare installed. This provided a base level to compare part two of the ASTM E783 test. Part two of the ASTM E783 test was performed after removal of the tare. The initial results were compared to the results after the tare was removed, and the expected quantitative result of this test was a leakage rate of less than 0.10 cfm/ft^2 (0.03 cmm/m^2). If the testing agents were unable to pull (create negative pressure within the chamber) the tare, then the testing agents would run ASTM E1186. With the ASTM E1186 fog testing, laminar airflow to the enclosure was applied at 6.24 lb/ft^2 (0.3 kPa) of pressure. The pressurized fog testing allowed the testing agent to observe whether fog was exiting the chamber at leak points. The expectation was to not have fog leak from the test chamber.

After the air-leakage testing was complete, the testing agents then performed ASTM E1105, a water test with cyclic pressure applied to the chamber. The water was applied to the exterior face of the mock-up using a calibrated spray rack, creating a sheen of water cascading down the exterior face of the mock-up. The sheen of water simulates a heavy rain. The testing agents applied negative pressure to the enclosure using the laminar airflow for predetermined cycles to simulate typical pressure changes that a building would experience. The expectation for this test was to not have water infiltrate the test chamber from the exterior face of the mock-up.

Figure 9. Precompressed foam at interface location.

Results of SGH field tests

Test 1: Precompressed foam only for details 1A and 1B

Test 1 was October 6, 2015. On both panel A and panel B, air and water testing failures were identified where the expanding foam tape met the concrete panel edge.[4] The test administrators discussed installation methods with the manufacturer's representative, who explained that the expanding foam tape has adhesive on one edge, which is only meant to hold the foam in place while it expands; once expanded, the foam holds itself in place through compression. The protocol set forth by the manufacturer for installation of a foam-only joint dictated that primer be used to seal up the pores of the concrete before installation of the foam. Unfortunately, the primer was not installed. The configuration as installed was not able to withstand the ASTM E783 test pressure or the ASTM E1105 tests. The committee recommended the test be repeated in test 2 using the solid panel (panel A) with detail 1A joint configuration with a primed substrate. This test would provide performance of the material without a sealant. The committee recommended deleting the detail 2A test and allowing the detail 2B test to represent 2A and 2B conditions.

Test 2: Precompressed foam only for detail 1A and precompressed foam with sealant for detail 2B

Test 2 was October 30, 2015.

Panel A The manufacturer's representatives installed the precompressed foam tape with primer applied to both sides of the sealant joints. ASTM E783 passed, and the leakage rate reading was below 0.10 cfm/ft^2 (0.03 cmm/m^2). ASTM E1105 did not pass due to water leakage at the butted joints between lengths of the expanding foam tape. There were no failures along the primed compression edge of the expanding foam tape. This identified another issue of properly sealing the butted joints between the foams (**Fig. 9**).

Panel B Silicone sealant and precompressed foam tape with no primer were installed by the sealant manufacturer. ASTM E1186 passed and no fog leakage was observed through joints. ASTM E1105 passed and no water leakage was observed. Due to a passing result of detail 2B, the committee deemed it unnecessary to test the configuration shown in detail 3B. The recommendation was to test 4B.

Test 3: Precompressed foam with silicone sealant as primary seal and backer rod and sealant as secondary seal for detail 3A and dual sealant and backer rod (control) for detail 4B

Test 3 was November 23, 2015.

Panel A The manufacturer's representatives installed the expanding foam tape and sealant dual joint per detail 3A. The test administrator was unable to pull the tare during the initial ASTM E783 test and therefore unable to take pressure

Figure 10. Fog test.

readings without the tare. Often this indicates an assembly that is more airtight than the pressure chamber (**Fig. 10**). A pressurized fog test was performed as a qualitative test, and fog penetrating through the sealant joints was not observed. The leakage rate reading was below 0.10 cfm/ft^2 (0.03 cmm/m^2). The ASTM E1105 passed and there was no water leakage observed.

Panel B The manufacturer's representatives installed detail 4B, the sealant/backer-rod dual control joint. Air and water testing failures were identified at voids in the sealant joint adhesion to the concrete panel edge in multiple locations. The main issue identified during this testing was workmanship and poor installation. The committee decided that detail 4B (control) would be reinstalled using experienced installers and retested during test 4. The committee-recommended detail 4B would represent both 4A and 4B. Test 4 would take place in the summer of 2016, and detail 3A would remain in place to provide an opportunity to see how the material performed when weathered.

Test 4: Weathered joints–precompressed foam with silicone sealant as primary seal and backer rod and sealant as secondary seal for detail 3A and dual sealant and backer rod (control) for detail 4B

Test 4 was August 25, 2016.

Panel A The test administrators were unable to pull the tare during the initial ASTM E783 test and were therefore unable to take pressure readings without the tare. A pressurized fog test was performed as a qualitative test and fog penetrating through the sealant joints was not observed. ASTM E1186 passed. No water leakage was observed and ASTM E1105 also passed.

Panel B The test administrators were unable to pull the tare during the initial ASTM E783 test and were therefore unable to take pressure readings without the tare. ASTM E1186 passed and no fog leakage was observed through joints. ASTM E1105 passed and no water leakage was observed.

Review of issues identified during field testing of joints

The main issues identified during the testing were quality of work and the experience level of the installers.

Precompressed foam installation requires an experienced installer. Initial test failure was directly correlated to an inadequate application of the expanding foam tape. The installer had not been fully trained for this specific material and omitted priming both sides of the joint, which had been a clear directive.

Another issue encountered during the testing was workmanship at joints between lengths of the expanding foam tape and at changes in direction. Joints in the foam need to be scrutinized and installed in a manner that sheds water. The installation team must be clear on the manufacturer's recommendation for how to join successive runs of foam together.

Results of Tremco laboratory testing

The Tremco laboratory test was February 1, 2017.

The committee decided to also perform testing in a controlled environment to have additional data points to compare against the field testing conducted in Thomaston, Conn.[5] The Tremco laboratory in Beachwood, Ohio, was used, and members of the committee attended the testing of the specimens.

Due to physical limitations of the laboratory, the specimens constructed for this test had to be smaller than the specimens constructed for the field testing. Due to size constraints, the insulated panels were not tested at the laboratory. Therefore, they were not part of the laboratory test program. The laboratory test specimens comprised four 1 × 1 ft × 4 in (305 × 305 × 102 mm) beveled-edge precast concrete blocks that were fastened into a 2 × 10 in. (51 × 254 mm) SPF wood buck with

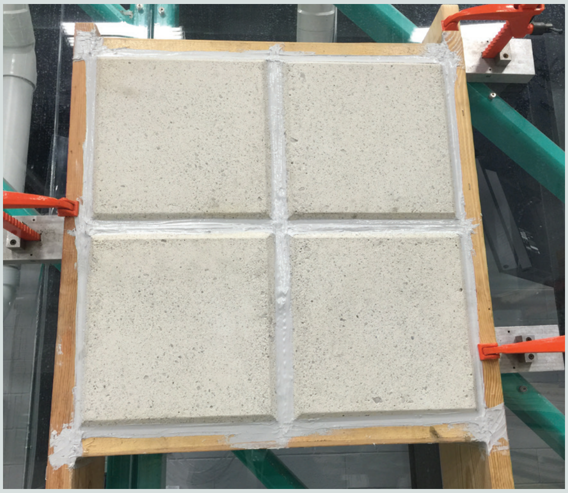

Figure 11. Laboratory 2 × 2 ft (610 × 610 mm) test sample.

four no. 12 × 2 in. (51 × 15 mm) screw anchors at each block (**Fig. 11**). SPF lumber is a combination of spruces, pines, and firs growing in different regions of the country. All yield high-grade timber with relatively small, sound tight knots. The blocks were placed to have a ¾ in. (19 mm) intersecting four-way joint. In this way, the configuration of the test assembly at the testing laboratory was very similar to that of the assembly in the field, just on a smaller scale.

The laboratory testing was able to accommodate three different joint configurations to be tested on the same day while the committee was present. Based on past tests, it was generally understood and accepted by the group that a sealant joint applied on top of either a backer rod or precompressed foam was going to behave similarly in any testing. Therefore, the group planned to use the data from the field test on the dual-layer backer rod and sealant configuration as the baseline (or control) for the laboratory testing as well. Following are the configurations tested in the laboratory:

- precompressed foam only, flush with face of precast concrete, for detail 1A
- precompressed foam with silicone sealant for detail 2A
- precompressed foam with silicone sealant as primary seal and backer rod and sealant as secondary seal for detail 3A

All three configurations were tested to ASTM E283 and E331,[6,7] which are ASTM standards for laboratory testing. The typical amount of pressure applied for this testing is 2.86 lb/ft^2 (137 Pa), and it is typically applied with water being sprayed on the test assembly for a full 15 minutes. In all three cases, a second phase of testing was also performed where the pressure was increased to 6.27 lb/ft^2 (300 Pa) after the initial 15 minutes and tested for an additional 15 minutes.

The first configuration passed the typical 15-minute ASTM standard with no water penetration observed. When the pressure was increased to 6.27 lb/ft^2 (300 Pa), water penetration was observed just a few minutes later.

The second configuration passed 15 minutes at 2.86 lb/ft^2 (137 Pa) and 15 minutes at 6.27 lb/ft^2 (300 Pa) of pressure.

The third configuration had the same result as the second: it passed 15 minutes of the standard pressure and another 15 minutes of 6.27 lb/ft^2 (300 Pa) pressure.

The only notable difference in the results obtained from the laboratory testing versus the field testing was that the detail 1A configuration (with precompressed foam only) passed the first level of testing in the laboratory. In both the field test and the laboratory test, configuration 1A failed at a pressure of approximately 6.27 lb/ft^2 (300 Pa) after a few minutes. In the laboratory test, however, there was a first phase of testing where 2.86 lb/ft^2 (137 Pa) of pressure was applied for 15 minutes *before* increasing the pressure, and that test was passed successfully.

Conclusion

After the field and laboratory testing, the committee concluded the following:

- The tested precompressed expandable foam joint with silicone applied to the surface is a viable option for sealing precast concrete panel-to-panel joints on solid or insulated panels.
- Installation expectations and procedures must be clearly defined before use. Attention to detail during and after installation will ensure performance of joint treatment.
- Installers require proper training and instruction to ensure a successful application of both the expandable foam and joint sealant following manufacturers' installation requirements.
- Further testing of precompressed foam materials should be done to develop a generic joint treatment process that includes several manufacturers of this technology and a long-term performance study.

Recommendation

The committee recognizes that dual backer rod and sealant joint construction remains an acceptable and appropriate method for sealing between precast concrete panels. As an alternative, the committee's recommendation for sealing building enclosure joints is to use precompressed, self-expanding foam material with silicone sealant. The installers of the materials should be professionals who have been trained by the foam manufacturer on the best installation practices for the specific product. When choosing the size of the material to use, the width of the joint opening should be measured at intervals along the joint and the manufacturer should be consulted on the appropriate size(s) that will best accommodate the joint gap opening along the entire run.

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- Kerkstra Precast Inc., Detroit, Mich.
- International Precast Solutions, LLC, River Rouge, Mich.
- PCI Mid-Atlantic, Lancaster, Pa.

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Abstract

This paper reviews precompressed expandable foam as an option for sealing the joints of an architectural precast concrete panel building enclosure. Precast concrete wall joint designs are typically specified with a two-stage sealant with a backer rod between the concrete elements. This approach has been an accepted and recommended standard by the industry. Both field and laboratory testing were conducted for precompressed foam using three joint configuration details: precompressed foam only, precompressed foam with sealant, and precompressed foam with sealant and backer rod. Specimens with the industry standard of dual sealant and backer rod were also tested to serve as the control and benchmark for data comparison.

Keywords

Expandable foam, foam, joint, joint treatment, leakage testing, panel joint, precompressed foam, sealant.

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