Sealant Joint and Annular Space Design for Functionality, A Sealant and Waterproofing Perspective

By:

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Outline

- Fire-resistive joints vs. weather joints
- Factors influencing performance of joints
- Joint movement
- Material selection
- Installation
Fire-resistive Joints vs. Weather Joints

- Weather joints (sealant joints)
  - Protect against air and water intrusion
  - Resistant to UV
  - Resistant to freezing and thawing
  - Resistant to moisture exposure
  - Accommodate movement
  - Expected to be replaced over time
Fire-resistant Joints vs. Weather Joints

- Expected life of weather joints
  - Acrylics: Less than 5 years
  - Urethanes: 7 to 10 years
  - Hybrids - Silyl Terminated Polyether Technology (STPE): 15 to 25 years
  - Silicones: 20 to 30 years
Fire-resistive Joints vs. Weather Joints

- Fire-resistive joints
  - Resist fire, smoke, etc.
  - Resist movement
  - Long lasting….typically not accessible for replacement over life of the structure
  - Sometimes exposed to UV
  - Sometimes required to resist water
Fire-resistant Joints vs. Weather Joints

- Both are required to resist movement
Factors Influencing Performance of Joints

- Material durability
- Joint design
- Quality of installation
Factors Influencing Performance of Joints

- Material durability
  - Weather joints
    - UV resistance
    - Retaining flexibility
    - Moisture resistance
Material Durability

- Accelerated weathering or aging
  - Typically done by Xenon light
Silicone Sealant Staining
Factors Influencing Performance of Joints

- Material durability
  - All materials deteriorate over time
  - Expected deterioration
    - Loss of elasticity (movement capability)
    - Shrinkage
  - Unexpected deterioration
    - Material defects
    - Improper mixing
Sealant Reversion
Factors Influencing Performance of Joints

- Material durability
  - Fire-resistive joints (and firestops?)
    - Retaining flexibility
    - Retaining fire-resistant properties
    - Moisture resistance
Factors Influencing Performance of Joints

- Joint design objectives
  - Minimize stresses on joint
  - Maximize movement capability
Joint Movement

- Compression / extension
- In-plane shear
- Out-of-plane shear
Compression / Extension
Out-of-Plane Shear
In-Plane Shear
Joint Movement

- Most joints are designed for compression / extension only
  - ASTM C920 – weather joints
  - ASTM E1966 – fire-resistive joint systems
  - ASTM E2837 – Fire Resistance of Head-of-Wall Joint Systems
  - ASTM E814 – Standard test method for Fire Tests of Penetration Firestop Systems (*no movement requirements*)
ASTM C920 - Classification of Sealants

Class

- **Class 100/50** - shall withstand an increase of 100% and a decrease of 50% of joint width at the time of application.
- **Class 50** - increase/decrease of at least 50%....
- **Class 35** - increase/decrease of at least 35%...
- **Class 25** - increase/decrease of at least 25%...
- **Class 12.5** - increase/decrease of at least 12.5%.
ASTM C920 - Classification of Sealants

Use

- Use T for pedestrian and vehicular traffic
- Use NT in non traffic areas
- Use I submerged continuously in a liquid
- Use G tested on glass specimens
- Use M tested for mortar specimens
- Use A tested on aluminum specimens
- Use O tested on other than standard substrates
### TABLE 1 Conditions of Test Specimen Cycling

**Note 1**—The terms used for movement are indicative of the cyclic rate in expansion and contraction of the joint system and not of the magnitude or direction of movement.

<table>
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<th>Movement Type</th>
<th>Minimum Cycling Rates (cpm)</th>
<th>Minimum Number of Movement Cycles</th>
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<td>100</td>
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<td>followed by:</td>
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### ASTM E2837

**Standard test method for Determining the Fire Resistance of Continuity of Head-of-Wall Joint Systems**

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<td>100, 400</td>
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**Note 4**—Terms used for movement are indicative of the cyclic rate in **expansion and contraction** of the *test specimen* and not of the magnitude or direction of movement.
Joint Movement

- Standards emphasize expansion / contraction capability of joints
  - Not realistic in weather joints or fire-resistive joints
- Joint size will depend on
  - Joint movement
  - Movement capability
  - Tolerances
Designing Joints for Movement

- 2-sided adhesion
- Widen the joint: Increase movement capability
- Make the joint thinner: Increase movement capability
Common Joint Configurations

D = (1/2 of W)

D = W

D = (1/2 of W)

D = W
Substrate Failure at Sealant Joint
Common Joint Configurations

FILLET JOINT

\[ A = \text{JOINT MOVEMENT} \] (JOINT MOVEMENT CAPABILITY IN \%)

[Diagram of FILLET JOINT configuration]
JOINT SEALED AT 50°F (SEALANT EXTENSION AND COMPRESSION EQUALIZED)

JOINT SEALED AT 90°F (SEALANT ALWAYS UNDER TENSION)

JOINT SEALED AT -5°F (SEALANT ALWAYS UNDER COMPRESSION)

*TEMPERATURE AT TIME OF APPLICATION IS RELATIVE TO SEALANT PERFORMANCE

JOINT DESIGN & APPLICATION
Determining Joint Size (Weather Joints)

- Use ASTM C 1472 - Standard Guide for Calculating Movement and Other Effects When Establishing Sealant Joint Width
**ASTM C 1472**

- Provides information on *performance factors such as movement, construction tolerances and other affects* is primarily applicable to single and multi component cold applied joints sealants.
- And *secondarily to pre-cured sealant extrusions*.
- Also applicable to *horizontal slabs and paving systems as well as various sloped building surfaces*. 
ASTM C 1472

- This guide does not describe the selection or properties of joint sealants (see ASTM C 1299) nor their use and installations (see ASTM C 1193).
ASTM C 1472

- Thermal movements
- Moisture induced growth
- Shrinkage
- Live load movement
- Dead load movement
- Elastic frame shortening
- Wind load movement
- Creep
- Seismic movements (typically addressed by preformed expansion joint products)
- Movement during curing
- Construction tolerances
ASTM C 1472

- **Thermal movement**
  - Expected temperature range (Table 1)
  - Coefficient of thermal expansion/contraction (Table 3)
  - Dimensions
  - Surface temperature
ASTM C 1472

- Thermal movement
  - Surface temperature
    - Winter: Coldest temperature minus evaporative cooling and radiation cooling
    - Summer:
      - Hottest surface temperature ($T_s$)
      - $T_s = T_A + A_x (H_x)$
      - $T_A =$ Hottest expected summer temperature (Table 1)
      - $A_x =$ Solar absorption coefficient (Table 5)
      - $H_x =$ Heat capacity (Table 6)
**ASTM C 1472**

- **Determine the design temperature range for a red brick wall in Chicago**
  - Table 1: Range -6°F to 90°F
  - Table 5: $A_x = 0.85$
  - Table 6: $H_x = 75$
  - $\Delta T = (90 + (0.85 \times 75) - (-6)) = 160°F$
Determine the total thermal movement for vertical expansion joints on a 30-foot wide brick wall for same project in Chicago.

- Table 3: Coef. of Thermal Exp ($\alpha$): $3.6 \times 10^{-6}$
- $\Delta L_t = \alpha \times L \times \Delta T$
- $\Delta L_t = (3.6 \times 10^{-6}) \times (30 \times 12) \times 160 = 0.21$ inch
Determine the total moisture expansion for a 30-foot wide brick wall for the same project in Chicago

- Table 4: Coef. of Irreversible Linear Moisture Growth (I): 0.09%
- $\Delta L_i = I \times L$
- $\Delta L_i = (0.09/100) \times (30 \times 12) = 0.32$ inch
Determine the total moisture expansion for a 30-foot wide brick wall for same project in Chicago

Table 4: Coef. of Irreversible Linear Moisture Growth (I): 0.09%

\[ \Delta L_i = \frac{I}{100} \times L \]

\[ \Delta L_i = \left(\frac{0.09}{100}\right) \times (30 \times 12) = 0.32 \text{ inch} \]

Table 4: Coef. of Reversible Linear Moisture Growth (I): 0.02%

\[ \Delta L_r = \frac{I}{100} \times L \]

\[ \Delta L_r = \left(\frac{0.02}{100}\right) \times (30 \times 12) = 0.07 \text{ inch} \]

Total Moisture Movement = 0.39 inch
ASTM C 1472

- Determine the total thermal and moisture movement for same project in Chicago

\[ \Delta L = \Delta L_t + \Delta L_i + \Delta L_r \]

\[ \Delta L = 0.21 + 0.32 + 0.07 \]

**Total Thermal and Moisture Movement = 0.6 inch**
In the above example, assume a Class 35 (35% movement capability) sealant is specified. How wide should the sealant joint be?

- \( S = 35\% = 0.35 \)
- \( W_m = \triangle L / S \)
- \( W_m = 0.6 / 0.35 \)
- **Calculated Joint Width = 1.71 inches!**
In the above example, assume that construction tolerances (C) are +/- ¼ inch for the joint, what should be total specified joint width be?

- \[ W = W_m + C \]
- \[ W = 1.71 + 0.25 = 1.96 \]
- Specified Joint Width = 2 inches!
This example did not include:
- Load-induced movements
- Seismic movements
- Creep
- Reduction in sealant elasticity over time
- Out of plane movement
- Installation temperature
Slab Deflections
## Slab Deflections

<table>
<thead>
<tr>
<th>Member</th>
<th>Condition</th>
<th>Deflection to be considered</th>
<th>Deflection Limitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat Roofs</td>
<td>Not supporting or attached to nonstructural elements likely to be damaged by large deflections</td>
<td>Immediate deflection due to maximum of L&lt;sub&gt;R&lt;/sub&gt;, S, R</td>
<td>l/180</td>
</tr>
<tr>
<td>Floors</td>
<td></td>
<td>Immediate deflection due to L</td>
<td>l/360</td>
</tr>
<tr>
<td>Roof or Floors</td>
<td>Supporting or attached to nonstructural elements</td>
<td>Likely to be damaged by large deflections</td>
<td>l/480</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not likely to be damaged by large deflections</td>
<td>l/240</td>
</tr>
</tbody>
</table>

*From ACI 318 Table 24.2.2 Maximum permissible calculated deflections*
Slab Deflections

- Using $L/480$: for a 48-foot span,
  - More than 1 inch
Thermal Movement of Pipe

- Temperature range: 120 degrees F
- Length, 40 feet (3 stories)
- Thermal Movement: 0.28 inch
- Add anticipated floor deflection
Specifying Installation

ASTM C 1193

- Addresses issues such as:
  - Substrate
  - Cleaner
  - Primer
  - Sealant Backing
  - Bond Breaker
  - Liquid Applied Sealant
  - Pre-cured Sealant
  - In-Situ Test Methods
ASTM C 1193

- Addresses **single and multi component sealants** and secondarily to **pre-cured sealants**.

- A sealant within this guide **must meet ASTM C834, C920 or C1311**.
ASTM C 1193

- Describes installation rather than material requirements.

- Describes the use of cold liquid applied sealant for joint sealing applications.

- Includes joints on buildings and related adjacent areas such as plazas, decks, and pavements for vehicular and pedestrian traffic.
ASTM C 1193

- Does **NOT** address structural sealant glazing. See ASTM C 1401.

- Does **NOT** address sealant for insulating glass unit edge seal used in structural sealant glazing. See ASTM C 1249.

- Practice C 919 should be consulted for sealant for acoustic joint seals.
ASTM C 1193

Substrates

- **Porous Substrate** – Brick, concrete masonry, concrete, unpainted wood, some building stones and most cement based materials.

- **Non Porous** – Stainless steel, lead coated copper and anodized aluminum, factory applied organic coatings, paints and glass.

- **EIFS** – porous substrate where sealant should be adhered to base coat and avoid adhesion to the top coat which can soften (a low modulus sealant should be used).
Cleaners

- **Porous Substrate** – Grinding, brushing, blowing off with oil free compressed air and wiping with clothes.

- **Non Porous** – degreasing solvents, such as MEK, toluene, xylene, acetone, and mineral spirits have been used as cleaners.

To ensure no residue film exists on cleaned surfaces a second step to the process is wiping the surfaces down with a 50/50 IPA (alcohol) and water.
Primer – the purpose of the primer is to improve the adhesion of a sealant to the substrate.

- **It changes the chemical characteristics of the substrate.**
- **Stabilizes the substrate surface** (fills pores and strengthens weak areas)
- **Reduces capillary pressure** of moisture through a substrate surface.
- **Primers may or may not** be required on porous and non-porous surfaces.
Application Failures

Sealant Tooling
Compression Sealant Failures
Adhesive Sealant Failure
Sealant Installed over Existing Sealant
Sealant Installed over Existing Sealant
Skim Coat over Sealant
Reversion
Cohesive Failure
Sealant Installed over Mortar Joint
Achieving a Good Joint

- Designer Responsibility
  - Design the joint properly to accommodate all movements
  - Do not base the design on the maximum movement capability of the material
  - Consider application temperature
  - Design the joint geometry properly
  - Select the proper sealant type for the application and substrate
Achieving a Good Joint

- Manufacturer Responsibility
  - Provide information regarding joint performance
  - Provide test data
  - Provide recommendations for proper installation
  - Provide recommendations for proper joint geometry
Achieving a Good Joint

- Installer Responsibility
  - Clean the substrate thoroughly
  - Sound and dry substrate
  - Use primers as much as possible
  - Tool the joint
  - Maintain joint profile using backer rods and bond breaker material
  - Be aware of joint width at the time of installation (related to temperature) and curing temperature
Final Thoughts

- Who determines the expected joint movement for fire-resistant joints?
- Who specifies a product that can accommodate that joint movement?
- Is it a moving joint or a static joint (fire-resistant joint or firestop)?
Thank You