Fundamentals of Joint Sealants in Building and Construction Applications

Introduction

• Sealants have been in use for many hundreds of years. The Tower of Babel was reportedly built with mortar and tar or pitch as a sealant. Naturally occurring bitumen and asphalt materials have been widely accepted as sealants for many centuries.

• Prior to the 1900’s most sealants evolved from vegetable, animal or mineral substances. The development of modern polymeric sealants coincided with the development of the polymer industry, sometime in the early 1930’s.

  • 1950’s - Polysulfide
  • 1960’s – Polyurethane
  • 1970’s – Silicone
  • 1990’s – Silyl-Terminated Polyether (MS Polymer)

Caulks vs. Sealants

What’s the Difference?

• Sealants (Preferred term)
  • Prevent passage of air and water
  • Aesthetics
  • Accommodate differential movement ± 12-1/2% or greater
  • Structural integrity
  • Fire and smoke barrier

• Caulks (Archaic term should not be used)
  • Prevent passage of air and water
  • Aesthetics
  • Low Quality and Limited Service Life

Joint and Specialty Sealants

• Joint sealants are used to seal joints and openings (gaps) between two or more substrates, and are a critical component to durable building design and construction.

• The main purpose of sealants is to prevent air, water, and other environmental elements from entering or exiting a structure while accommodating movement of the substrates.

• Specialty sealants are used in special applications, such as for fire stops, electrical or thermal insulation, and aircraft applications.

• Sealants are broadly used in a variety of commercial and residential applications. Common sealant types include silicones, acrylics, urethanes, butyls and other polymeric types.

• Various formulations have been developed over the years for differing levels of performance including high movement capability and continuous water immersion.

Typical Applications

• High- and low-rise commercial buildings:
  • Exterior windows - construction and perimeter
  • Roofing terminations
  • Interior windows and doors perimeters, baseboards, moldings
  • Airport runways and aprons (pavement)
  • Bridge and highway joints
  • Commercial parking lots and flat work
  • Public works (pavement, sidewalks)
  • Water and wastewater treatment facilities (including submerged environments)
  • Fire-stop material in joints and penetrations
  • Structural sealant glazing (SSG) (curtain walls, windows)
Typical Sealed Building Products and Materials

• Brick
• Vinyl and Aluminum Siding
• Wood, Plywood, and Cement-Based Siding
• EIFS (Exterior Insulation and Finish Systems)
• Cement Stucco
• Stone, Manufactured Stone, Cultured Stone
• Painted Products
• Foam Plastic Panels
• Concrete
• Ceramic Tile
• Metal Panels (Coated and Uncoated)

Systems include Doors, Windows, Skylights

Sealant Functions: Non-Structural Sealant

• Primarily a Joint Sealer
  • Resist Weather Infiltration
  • Accommodate Movement
  • Function as Part of an Air Barrier System
  • Function as Part of a Vapor Retarding System
  • Acoustic Control

• Minimum Specification Requirements
  • Product Submittals
  • Adhesion Testing
    ➢ Laboratory Before Construction
    ➢ On-Site During Installation

Sealant Uses

• Exterior Joint Sealing
  ➢ Between Different Materials and Systems
    ➢ Water Infiltration Control
    ➢ Air Movement Control

• Interior Joint Sealing
  ➢ Between Different Materials
    ➢ Air Movement Control
    ➢ Vapor Movement Control
    ➢ Energy Conservation
    ➢ Acoustic Control
    ➢ Transitions

Basic Definitions

• Caulk (n): An archaic term used to describe materials used in joints; generally applied to oil-based compounds, but later applied to materials with low movement capability (ASTM C24 recommends that the term caulk be replaced by sealant).

• Sealant (n): “In building construction, a material that has the adhesive and cohesive properties to form a seal” (ASTM C717); sometimes defined as an elastomeric material with movement capability greater than 10-1/2%.

• Adhesive failure (n): Failure of the bond between the sealant and the substrate surface (ASTM C717).

• Cohesive Failure: Failure characterized by rupture within the sealant (ASTM C717).

• Precured Sealant (n): A preformed, factory cured elastomeric material that when adhered to a joint forms a seal (ASTM C717).

Selection of Sealants

The proper application of sealants involves not only choosing a sealant with the correct physical and chemical properties, but also requires proper joint design, knowledge of the substrates to be sealed, and the performance needed.

The cost of a sealant (usually less than 1% of a project’s cost) should be a consideration but should not overrule the needs of the application, which is to use the most suitable sealant to form a durable seal with a long service life.

Typical considerations in selecting a sealant type for an application are:
• Designing a joint for movement and other effects
• Sealant physical and chemical properties that are required
• Required durability for the application
• Application and installation properties
Joint Design Considerations

- Weatherproofing the Exterior Envelope
- Air Movement Control
- Water Vapor Movement Control
- Energy Conservation
  - USGBC’s LEED – one of the more well recognized building rating systems
    - New Construction (LEED – NC)
    - Existing Buildings (LEED – EB)
    - Core and Shell (LEED – CS)
    - Homes (in development)
    - Schools (in development)

Overview of Sealant Chemistries

Liquid-Applied
- Latex (water-based, including ethylene vinyl acetate [EVA], acrylic)
- Acrylic (solvent-based)
- Butyl (solvent-based)
- Polysulfide (chemically curing)
- Silicone (chemically curing)
- Polyurethane (chemically curing)

Foamed In Place
- Factory Fabricated (Rigid Products)
  - Gaskets and strips
  - Extruded strip-seals
  - Compression systems

Cure Mechanisms

Evaporation – Water Based
- Examples of Sealant Types
  - EVA
  - Acrylics
- Advantages
  - Water clean-up
  - Typically are paintable
  - Non-flammable
  - Low cost
- Disadvantages
  - Slow rate of cure
  - Shrinkage due to water evaporation (as much as 30% to 50%)
  - Joint movement limited to no more than ± 25%
  - Ultraviolet (UV) light instability

Evaporation – Solvent Based
- Examples of Sealant Types
  - Acrylic,
  - Butyl rubber (SBR/SBS)
- Advantages
  - Faster rate of cure than water based
  - Low cost
- Disadvantages
  - Shrinkage
  - Joint movement is limited
  - UV light instability
  - Solvent clean-up
  - Flammable
  - VOC regulatory limits

Chemically Curing (Ambient Humidity)
- Examples of Sealant Types
  - One-part sealants (silicones, polyurethanes, polysulfides)
- Advantages
  - Faster rate of cure than water or solvent based sealants
  - Low shrinkage
  - Excellent joint movement capability up to +100, -50%
  - UV light stability (silicones)
- Disadvantages
  - Solvent clean-up
  - Higher cost than water or solvent based sealants

The following table shows different sealant formulations, rated for selected applications: (1=poor, 2=good, 3=excellent)
Sealant Performance Categories

Low Performance (no specification)
- 0-5% joint movement
- 2 – 15 year service life

Medium Performance (ASTM: C534, C1311)
- 5 to 12½% joint movement
- 5 – 15 year service life

High Performance (ASTM: C920, C1184)
- Greater than 12½% joint movement
- 10 – 50 year service life

Joint Types

- Static Joint -- Joints that are mechanically restrained to prohibit movement, (e.g. air and water seals in curtain walls)

Examples of Movement Joints

- Butt Joint
- Fillet Joint
- Lap Joint
- Interlocking Joint

Joint Design

General Guidelines

- The spacing of joints must be rationally determined using the guidelines described by ASTM Guide C1472 and experience
- Joint design must allow access for backer rod or bond breaker tape placement and sealing of the joint
- Allow sufficient substrate bonding area (min. ¼-inch)
- Consider Energy Conservation measures; going “green” (e.g. LEED, Green Globes, NAHB Residential Guidelines)
Joint Design
General Guidelines

Measuring Joint Movement – measured in fractions of an inch and expressed as % change

Design for Sealant Movement Capabilities

• Minimum sealant bond depth of 1/4” (6 mm) at the substrate, and minimum width of 1/4” (6 mm) opening is necessary
• Movement-related: Allow for both conditions
  • A joint sealed at the lowest temperature will ALWAYS experience compression
  • A joint sealed at the highest temperature will ALWAYS experience extension
• Wider joints can accommodate more movement than narrow joints
• Use backer rod or bond breaker tape to preclude “three-side adhesion”
• Use 2:1 width to depth ratio. Consider an “hourglass” shape.
• For a joint wider than 1”, depth should be kept to no more than 3/8” (9 mm)
• Spacing of joints is critical to performance

Determine Joint Dimensions

ASTM Guide C1472 should be used to establish the required joint dimensions; however, at least the following should be performed
Step 1: Calculate thermal movement
(Movement = ΔT x L x 12 x coefficient of linear expansion)
[12 converts L in feet to inches]
Step 2: Calculate joint width
([100/Sealant Movement Capability] x Thermal Movement)
[e.g. 50% movement capability expressed as 50]
Step 3: Add appropriate tolerances to joint width
[e.g. Material, Fabrication, Erection, Shrinkage, Creep, etc.]

Sealant Dimensions

Application

Hour glass shape:
Tool, Tool, Tool.

Preparing and placing the sealant
• Mix multi-component sealants properly (no entrained air)
• Tape outside edge of joints if necessary
• Gun sealant into joint at constant pressure and flow
• Prevent overlapping sealant (follow ASTM and SWRI practices)
• Dry tool to press sealant against substrate bonding surface
• Check work frequently and keep samples
• Contractor should maintain a job log (e.g. lot no., weather conditions, application procedure)
Materials
Questions to Consider

• Will the selected sealant handle the anticipated joint movement requirements?
• Will the sealant adhere to the substrate(s) properly?
• Will the sealant endure the anticipated weathering exposure?
• Is the sealant compatible with adjacent materials?
• Does the joint size allow for sufficient placement of sealant, backer rod, bond breaker tape, etc.?
• Will the sealant perform under the stated conditions of use?
• Is there a history of application success?
• Does the sealant supplier have the necessary in-house resources to support your application in case of problems?
• Do you want third party testing to confirm sealant performance?

Substrate Types

• Porous – brick, concrete, unpainted wood, building stones
• Non-porous – stainless steel, lead-coated copper, anodized aluminum, factory-applied organic coatings, paints, glass

Surface Preparation

• Most common mode of sealant failure is adhesive
• Must remove all weak material on bonding surface of porous substrates
• Surfaces must be clean, dry, and free of dew or frost
• Use best practices as recommended by industry experts and the sealant manufacturer:
  • Porous: abrasive, high pressure water (allow to dry after), grinding, wire brushing, compressed air (oil-free)
  • Non-porous: 2 rag method (clean, lint-free, and absorbent - solvent wipe followed by an immediate dry cloth wipe)
**Priming** - When Required by the Sealant manufacturer
Prime joints with sealant supplier’s recommended primer
- Maximizes adhesion
- Ensures adhesion to special substrates

Proper primer application with brush
- Prime only sides of the joint.
- Primer outside the joint may stain the substrate.
- Prime & seal the same day

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**Adhesion Testing**
- Always test for adhesion
- Test actual substrates on site
- Document locations and times

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**Backing Materials**
- Why use a backer rod?
  - To attain proper wetting of substrate when sealant is tooled
  - Controls sealant depth
  - Prevents 3-side adhesion
- Recommended backer rod Materials
  - Closed cell: a foam material with a surface skin
  - Open cell: a foam material without a skin
  - Bond breaker tape: a self-adhesive polyethylene or Teflon material
- Not recommended:
  - Any rigid materials or silicone sealant as bond breaker and joint filler

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**Types of Backer Rods**
- Closed Cell
- Soft Cell
- Expansion joint filler
- Open Cell

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**Correct use of backer rod in joint**

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**Incorrect use of backer rod in joint**
Weatherproofing

Weatherproofing helps to control water and air infiltration and exfiltration from degrading a building. The following parameters must be considered:

Joint movement may occur as a result of:
- Thermal movement
- Seismic movement
- Elastic frame shortening
- Structural load creep
- Live and dead loads
- Concrete shrinkage
- Moisture-induced material movements
- Design errors

**Movement Capability** — The ± percent value that indicates the amount of movement the sealant can take in “extension (+)” and/or “compression (−)” from its installed cured joint width

### Weatherproofing Applications

**Movement (Mt) = CTE x Temp Change x Length of Material**

<table>
<thead>
<tr>
<th>Material</th>
<th>CTE x 10^-6</th>
<th>CTE x 10^-6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass</td>
<td>5.0</td>
<td>9.0</td>
</tr>
<tr>
<td>Stainless Steel</td>
<td>5.0-6.0</td>
<td>9.0-12.6</td>
</tr>
<tr>
<td>Concrete</td>
<td>6.7-9.6</td>
<td>10.4-17.3</td>
</tr>
<tr>
<td>Marble</td>
<td>3.7-12.3</td>
<td>6.7-22.1</td>
</tr>
<tr>
<td>Granite</td>
<td>2.8-6.1</td>
<td>5.0-11.0</td>
</tr>
<tr>
<td>Aluminum</td>
<td>12.9-13.2</td>
<td>23.2-23.8</td>
</tr>
<tr>
<td>Polycarbonate</td>
<td>38.0</td>
<td>74.0</td>
</tr>
<tr>
<td>Acrylic</td>
<td>41.0</td>
<td>77.0</td>
</tr>
<tr>
<td>Stainless Steel</td>
<td>5.0-6.0</td>
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</table>

All materials have a coefficient of linear thermal expansion (CTE). Refer to table below for some examples:

**NOTE:** Coefficient of expansion for natural materials (bird, stone, wood, etc.) or fabrications of natural materials can be highly variable. It is suggested to consult architectural drawings to ensure proper joint design and specification. Movement of joint opening will affect the bond to joint liners, and return joint tabs over time for life of the building.

### Avoiding Common Problems

- Sealants are often the least thought about and contribute the lowest percentage to a project’s overall cost; however, they can become a significant problem if they cause a structure to leak.
- There is both a science and an art to achieving a successful sealant joint installation.
- Sealants cannot make up for poor or non-existing joint design, and to achieve proper performance require at least:
  - Joint design for the anticipated movement (ASTM C1472)
  - Sealant selection for the application
  - Joints that can and will be properly installed
- Basic steps to effectively prepare a joint opening and to install a sealant
  - Substrate Cleaning and if Required Priming
  - Sealant Application
  - Sealant Tooling
Common Problems

Staining
- Affects both porous and non-porous surfaces
- Causes
  - Unreacted polymer rundown
  - Sealant heavily plasticized
  - Non-sealant related, such as environmental dirt
- Remedies
  - Proper design for water run-off
  - Careful sealant selection
  - Testing for staining?

Sealant dirtying
- All sealants will get dirty
- Some sooner than others

Sealant color
- White and black best color stability
- Some colors fade with UV exposure

Common Problems: Insufficient Weatherproofing of Building Envelope

- Impact of Moisture in Buildings
  - Occupant Comfort lessened
  - Building and Material Damage
  - Occupant health Impact – Mold?
- Water Penetration
  - Rain and Snow Melt
- Lessened Durability
- Decreased Serviceability
- Increased Energy Usage

Common Problems: Air Movement Control

- Air Leakage Through Building Envelope
  - Through Cracks, Joints, and by Movement
  - Leakage caused by Air Pressure Difference
- Air Barrier Required
  - Install on Warm or Cold Side of Insulation
  - Sealants are an Integral part of an Air barrier
  - Must Achieve Continuity
    - Walls: to Roofs, to Windows, to Doors, Etc.
    - Seal Transitions and Terminations
  - Must be Durable
Air Leakage Through Vinyl Siding Caused by an Inadequate Air Barrier in North Carolina

Common Problems: Water Vapor Movement Control

- Control Vapor Drive Forces
  - Vapor Moves From High to Low Pressure
  - Diffuses Through Porous Materials
  - Moves With Air Currents Through Openings
  - Winter – Vapor Exfiltration
  - Summer – Vapor Infiltration
- Must Achieve Continuity
  - Walls: to Roofs, to Windows, to Doors, Etc.
  - Seal Transitions and Terminations
  - Effective Air Barrier System
  - Effective Vapor Retarder System

Common Problems: Adhesive Failure

- Causes
  - Poor surface preparation
  - Contamination
  - Improper installation
  - Improper priming
- Remedies
  - Grinding
  - Proper cleaning
  - Proper priming
  - Proper tooling

Vapor Flow Around Incompletely Installed Vapor Retarder

Poorly Applied Mastic Vapor Retarder

Looks Can Be Deceiving – Deficient Adhesion
Common Problems: Cohesive Failure

- Causes
  - Poor joint design
  - Improper W/D ratio
  - Wrong sealant

- Remedies
  - Proper joint design
  - Choose the right sealant
  - Install correctly

Common Problems: Substrate Failure

- Causes
  - Weak Substrate
  - High Modulus Sealant on EIFS
  - Sealing to EIFS Finish Coat

- Remedies
  - Grinding or Wire Brushing
  - Lower Modulus Sealant
  - Sealing to EIFS Basecoat

Common Problems: Bubbling (Outgassing)

- Caused by punctured closed cell backer rod
- Open cell backer rod will not outgas
- Trapped moisture

Considerations for Remedial Work

- Try to re-establish a virgin substrate - thorough cleaning required
- Consider the effect of any remaining sealant residue
- Generally, stay with the same sealant chemistry
- Use a primer

Additional Resources

ASTM Standards (www.astm.org)
- C717 Standard Terminology for Building Seals and Sealants
- C834 Standard Specification for Latex Sealants
- C920 Standard Specification for Elastomeric Joint Sealants
- C1184 Standard Specification for Structural Silicone Sealants
- C1193 Standard Guide for Use of Joint Sealants
- C1247 Standard Test Method for Durability of Sealants Exposed to Continuous Immersion in Liquids
- C1298 Standard Guide for Use in Selection of Liquid-Applied Sealants
- C1401 Standard Guide for Structural Sealant Glazing
- C1472 Standard Guide for Calculating Movement and Other Considerations When Establishing Sealant Joint Width
Additional Resources

ASTM Standards (cont'd)

• D5893 Standard Specification for Cold Applied, Single Component, Chemically Curing Silicone Joint Sealant for Portland Cement Concrete Pavements
• E330 Standard Test Method for Structural Performance of Exterior Windows, Curtain Walls, and Doors by Uniform Static Air Pressure Difference
• E331 Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference

Additional Resources

Federal Specifications

• TT-S-00230C Sealing Compound Elastomeric Type, Single Component
• TT-S-01543A Sealing Compound, Silicone Rubber Base
• TT-S-001657 Sealing Compound, Single Component, Butyl Rubber Based Solvent Release Type

(It should be realized that these government standards should not be used, they have been replaced by ASTM and other standards.)

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*Erin Nied*

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