“The Anatomy of Sealants and their Relative Performance with Building Materials in Different Environments”

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World’s Largest Adhesive & Sealant Company

North American Adhesive Market Segments

Aerospace Example

Hyssol® metal bonding film adhesives & primers
Turco® aircraft appearance products
Turco® metal treatments
Frelko® mold release
Turco® jet engine maintenance
Hyssol® core fill adhesives & paste syntactics
SynCore® material
Alodine® conversion coatings
Hyssol® composite bonding film adhesives
Hyssol® liquid shims
SynSkin® surfacing & lightning strike
Turco® chemical milling
Turco® paint strippers
Hyssol® needle film adhesives & primers
SynSpand® core materials
Presentation Outline

- Sealant physical (movement) properties and chemistry.
- Types of Joint
- Thermo-mechanical Effects
- Sealant Use Considerations
- Sealant Failure Modes

Building Idioms Change Over Time

- 6-9th Century AD
  - Exterior (walls 1.2 meters thick)
  - Interior

- 21st Century AD
  - Exterior
  - Interior

Sag in wall –

Likely caused by harsh prevailing winds. Structure deformed over time to alleviate applied stress. High mass allows for high energy dissipation. Lack of elasticity leads to permanent deformation.

Types of Sealant Joint Movement

Sealant extension:
Usually as temperatures drop, materials shrink.

Sealant compression:
Usually as temperatures rise, materials lengthen or swell.

Total movement comparison:
Sealants: up to 25%  
Mortar: up to 0.4%
Sealant Chemistry Impacts Suitability for Certain Applications

- **Physically Drying Sealants**
  - Water-based: Latex Acrylics, PVA
  - Solvent-based: e.g. Thermoplastic, Acrylics, and Butyl

- **Chemically Curing Sealants**
  - Silicones
  - Polyurethane
  - MS (Modified Silicone) Polymer
  - Polysulfide

Physically Drying Sealants: Latex

- Skin formation
- Film forming
- Water evaporation
- Volume shrinkage

Physically Drying Sealants: Solvent Based

- Skin formation
- Film forming
- Polymer molecules get closer and wind around each other. No cross linking.
- Solvent evaporation

Chemically Curing Sealants: Silicone & Polyurethane

- Skin formation
- Hardening
- Set-free split-products
- Water absorption
What is a Sealant?

- A sealant is a material that has the adhesive and cohesive properties to form a seal between surfaces while permitting limited movement of the substrates.
- Flexible material, polymer based
- Installed in a "wet" or soft form
- Fills gaps
- Compensates for movements between different elements of the construction
- Provides airtight joint, protects against wind.
- Waterproofs joint
- Prevents ingress of microorganisms, pollutants, smoke, fire
- Improves building aesthetics
- Helps dampen noise

Types of Joints

**Expansion Joints:**
- Connects large construction elements i.e. Facade coverings, building extensions like garages or balconies
- Sealant requires a high degree of elasticity

**Sanitary Joints:**
- Sealing of bathtubs and showers, sinks, tiled walls and floors
- The joints are attacked by water, cleansers and mechanical loading.

**Glass Joints:**
- Sealing, supporting glass to window frames
- Sealant requires high durability in terms of UV and temperature resistance

**Connecting Joints:**
- Connection of construction elements, such as bricks, siding, stairs, decking as well as window frames/doors
- Minimal movement.

Thermomechanical Effects

**Coefficients of Thermal Linear Expansion (CTLE) of Building Materials**

<table>
<thead>
<tr>
<th>Building Material</th>
<th>CTLE (m/m °C x 10^-6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylic glass</td>
<td>80</td>
</tr>
<tr>
<td>Aluminum</td>
<td>24</td>
</tr>
<tr>
<td>Concrete / concrete steel</td>
<td>11</td>
</tr>
<tr>
<td>Glass</td>
<td>8.5</td>
</tr>
<tr>
<td>Wood, lengthwise to the fiber</td>
<td>7</td>
</tr>
<tr>
<td>Wood, crosswise to the fiber</td>
<td>40 - 50</td>
</tr>
<tr>
<td>Brick</td>
<td>5</td>
</tr>
<tr>
<td>Sand lime brick</td>
<td>8.5</td>
</tr>
<tr>
<td>Tiles</td>
<td>6</td>
</tr>
<tr>
<td>Copper</td>
<td>16.5</td>
</tr>
<tr>
<td>Brass</td>
<td>18.4</td>
</tr>
<tr>
<td>Polyester</td>
<td>25 - 40</td>
</tr>
<tr>
<td>PVC - windows</td>
<td>78</td>
</tr>
<tr>
<td>Steel</td>
<td>12</td>
</tr>
</tbody>
</table>

Mismatched CTLEs, particularly of contacting materials in a structure, can lead to development of deforming strains upon heating.

The temperature of application of a sealant (the temperature at which an interface is developed between different materials) can have a profound impact on performance.

Sealant Use Considerations

**Ease of Extrusion at Various Temperatures:**
- As the product temperature is dropped extrusion can become very difficult. This may require heating of the product.
- At higher temperatures the sealant consistency may become too sloppy resulting in poor control by the applicator.

**Sagging and Leveling:**
- In vertical and over head joints the product must not sag after application. This affects aesthetics of the job and the performance of the sealant.
- Higher temperatures will tend to increase sag.
- In horizontal butt joints (pavement seams), a sealant that flows to form a level surface is desirable. This type of sealant is not suitable for vertical and over head applications.
Sealant Use Considerations

Skinning and Skin Formation Time:
As a sealant dries or cures it develops a dried film on the outside before the inside material dries out or cures. Skinning minimizes dirt pickup. The time to achieve this property is the skin formation time. Excessively fast skinning impedes tooling should tooling be required.

(Typical value -10 to 20 minutes)

Curing Speed:
Indicates the amount of time that a sealant layer requires to reach its intended performance properties. Refers to both chemically reactive and physically drying sealants. The speed depends on sealant chemistry, cure temperature and relative air humidity.

(Typical value - Latex Acrylics per 5 mm = Approx. 2 days)

Adhesion to Different Substrates:
Certain sealant chemistries have inherently poor adhesion to certain substrates or under certain conditions, i.e. Acetoxy silicones because of the acetic acid by product during cure show poor long term adhesion to substrates such as cement and concrete.

Long term adhesion can be affected by:
1. water, (2) plasticizer migration from one substrate to another, (3) from repeated movement, (4) effects of sunlight.

Various sealant types and formulations will show different bonding characteristics to various substrates. (Measured by peel strength)

Tips for Sealant Application

Application Environment: Temperature
• Apply sealant in moderate temperatures between 41°F (5°C) and 86°F (30°C). When this is not possible changes in application method, joint design or sealant choice may be required.
• Applying sealant to joints at temperature extremes – either high or low – will reduce the joint movement capability.
• Low temperatures will prevent proper curing (coalescence) of water based sealants.
• Excessively hot weather may accelerate the sealant cure time resulting in bubbling and shortened working life and tooling time. It may also cause sagging.

Sealant Failure Factors

Surface Condition & Preparation:
• Application surface not clean
• Coatings completely dry before sealant (i.e. paint, primers)
• Coatings may interfere with sealant adhesion
• Release agents (both tub and tub surrounds), surface sealers and coatings (water proofing compounds)
• Raw wood not sealed. Raw wood expands and contracts due to moisture changes - probably more then the sealant can handle
• Application substrate was not sound – i.e. rotten wood, crumbling concrete

Weather Factors:
• Applying latex sealant in cold weather – will not cure properly
• Sealant is too cold to flow
• Not enough moisture in air (hot and dry or cold and dry) for sealant cure
• Applying at extremes of temperature range results in less of movement capability
• High temperatures may result in sagging or may cause premature skinning of the sealant resulting in blistering
• Applying to wet or frozen surfaces
• Exposure to water too soon after application (i.e. rain or from shower). Latex sealant will wash away

Sealant Failure Factors

Poor Joint Design:
• Joint too narrow (less than ½”): Expansion of substrate causes the joints to close too much forcing the sealant out of the joint.
• Joint was too wide (greater than 1-2 inches depending on the sealant):
  - Sealant may sag out of the joint
  - A joint that is too wide requires a deeper sealant bead to avoid cohesive failure - makes the sealant less able to stretch causing failure at the substrate. For example: Two rubber bands of the same length but one is thin and one is thick. The thicker one will not stretch as easily
  - If the sealant bead is too thick it will take a very long time to dry. Joint movement before sealant is cured may cause adhesion failure

Incorrect Sealant Selection:
• Sealant lacks sufficient movement capability for intended use
• Incompatibility between sealant and substrate, i.e. staining or etching of the substrate, negative effects on the sealant due to migration from substrate, i.e. discoloration
• Poor adhesion to substrate, i.e. acetoxy silicone to concrete or galvanized metal
Thermomechanical Effects – Sealant Deformation
Apparatus designed to measure pressure required to deform a sealant -> bubble

Deformation Example

Sample Holder for Bubble Measurement

Examples of holes where vapor exits – blowing out sealant

Flextec Technology Has Superior Deformation Resistance

Main Effects Plot for Deformation Pressure Data Collection

Henkel Flextec Technology
Aggregate Data – More curing takes place in the first 6 minutes

Sealant Formulations: Guess Which Technology?

Many contributing variables are substrate related

Experiment to Measure impact of Direct Sunlight

If fastened to a frame coated Western Red Cedar, this piece (dark stain) is a piece of OSB. To that was fastened a 30 inch piece of uncoated Western Red Cedar. Applied related to the joint between the two pieces of Cedar. Stabilized a thermocouple (thermometer sensor) to the surface of the cedar to measure surface temperature. This setup was in the lab at 72 degrees F and the boards were immediately moved outside and leaned up against the building’s brick wall.

The video was then started. Note that the thermocouple (the wire end) and the uncoated joint start out in the shade. Surface temperature was ~90°F (within a minute!) in the shade and by 9 minutes had risen to over 100°. Off-site and during the exposure with both the thermocouple and the video recording. On-site.

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Impact of temperature on sealant deformation is clearly seen.

Sealant Deformation and Bubbling: Cause, Effect, and Recommendations

Summary: What Do We Know? What Have We Learned? What Can We Do?

Resources: R&D + QC + Engineering + Technical Services + Sales/Marketing + Building-Industry Scientists + Forensic Building Consultants

Test/Sample Environments: Field + Job-Site + Laboratory/Technical

Conclusions:
1) There is No Single Cause of Deformations.
2) All Sealants Experience Deformation.
3) Major Job-Site/Environmental Variables Must Occur.
4) Solutions are Complex because Substrates, Material Composition, and the Environment Interact and Change.

Sealant Deformation: FAQs and Points of Interest

The Role of Sealants:
- “Resistance” to Bubbling Builds Over Time (Due to Drying and Curing)
  - 300 minutes builds good resistance (over 1 PSI resistance) for most technologies
- Thermoplastics (both “regular” and VOC formulations) take longer to dry and cure, which may leave them more vulnerable to immediate bubbling pressures
- MS Polymers and Polyurethanes show slightly more resistance due to faster drying and curing times, but aren’t significantly better solutions
- Only ONE Current Sealant Formulation Showed Significantly Better Resistance to Bubbling vs. Any Other Sealant Formulation
- Henkel’s FlexTec Technology (Proprietary)

Is There a “Silver Bullet” Sealant Solution?:
- All Sealant Technologies Bubble
  - Some are Slightly More “Resistant” (Dry, Cure Faster)
  - Manufacturing Issues are Negligible
  - Bubbles aren’t “pre-loaded” into a tube of sealant
  - Formulation Changes?
  - VOC formulations show no meaningful difference
  - Thermoplastics, MS Polymers, Polyurethanes, etc. ALL BUBBLE

Ashton
Sealant Deformation: Understanding Risk-Factors

**Risk-Factors, Force-Ranked: Which Matter Most?**
- Rising Surface Temperature
- Environmental Job-Site Presence of Water
- Rising Wall Temperature
- Moisture in Substrate
- Direct Sunlight
- Type of Substrate
- Sealant: Dry Time, Aging, Curing
- Porosity of Siding and/or Trim
- Cedar Surface
- Pine Surface
- Siding and Trim Interaction
- Wall Movement and Loading
- Damaged Backer Rod
- Moisture and Direct Sunlight Can Cause Certain Risk-Factors to Move Up in Rank

**“Other” Variables Include:**
- Substrates
  - 20 Types of Contributing Substrates Currently Identified
- Compositions (of Sealant)
  - 9 Types of Composition Factors Currently Identified
- Environmental
  - 4 Types of Environmental Factors Identified
- Again – No Single “Smoking Gun”
- It is the Interaction of these Variables that Matters

The FlexTec “Intel Inside”

**Henkel FlexTec Advantages:**
- Henkel’s FlexTec Resists Bubbling After 6 Minutes as well as ANY OTHER Sealant Technology
- Resists Bubbling After 300 Minutes
- In addition to drying and curing capability, Henkel’s FlexTec proprietary formulation has built-in properties to resist deformation and bubbling
- Not “fool-proof” ... Remember that All Sealants can Bubble
- Henkel Technology offers over twice the resistance to bubbling vs. any other sealant

Recommended Steps for Bubbling Remediation:
- Allow for Drainage Plain Behind Cladding
- Time of Day for Application
- Avoid direct sunlight, if possible
- Screen from sunlight, if possible
- Control (if Possible) Moisture on Substrate
- Control (if Possible) Temperature on Substrate
- Avoid Tooling or Thinning Thermoplastics
- If Painting with Latex – Wait 3-7 Days for Sealant to Dry and Cure
- Avoid Installing Damaged Trim
- Avoid Installing Damaged Backer Rod
- Create a Capillary Interruption Between the Foundation and the Wall
- Henkel technology constantly improves the property balance of sealant materials

Sealant Deformation: Major Variables Must Interact

The “Fire Triangle”
- Three Variables to Create Fire:
  - Ignition Source (e.g. “spark”)
  - Fuel (e.g. gasoline, wood)
  - Oxygen
- Absence of ANY of these variables means that a fire will not occur

The “Bubbling Pentagon”
- Five Major Variables to Create Bubbling
  - 1. Temperature Rise + Capillary Channels + Moisture
  - 2. Large Voids + Capillary Channels + Wall Movement
  - 3. Capillary Channels + Wall Movement + Moisture + Temperature Rise
  - 4. Moisture + Temperature Rise + Large Voids
- If Any of Four Primary Variable Combinations is Existent, Bubbling Can Occur
- Issue: Detection of Primary Combinations

Summary: What Do We Know? What Else Can We Learn?

Industry Education:
- Water Management
- Heat/Sunlight Impact
- Substrates and Materials Impact
- Composition (of Sealant) Impact
- Combination of Variables
- Risk Factors
- Continued Study and Remediation
- Integrated Solutions
  - With Customers
  - With Manufacturers
  - With Alliance Partners
- Building Science
  - Industry Expertise
  - Full Engagement and Transparency/Visibility

Henkel/OSI Commitment:
- Henkel/OSI is committed to delivering home system solutions
  - Even when the research and the solutions are difficult
  - More Detailed Information is Available from Henkel
  - Testing Procedures/Results
  - Current R&D Efforts
  - Customer/Alliance Partner Joint Projects
  - Industry Collaborative Efforts

Four Primary Combinations of Variables:
1. Temperature Rise + Capillary Channels + Moisture
2. Large Voids + Capillary Channels + Wall Movement
3. Capillary Channels + Wall Movement + Moisture + Temperature Rise
4. Moisture + Temperature Rise + Large Voids

9 Types of Composition Factors
20 Types of Contributing Substrates
4 Types of Environmental Factors
16 Types of Contributing Substrates
5 Types of Contribution Factors
5 Types of Risk-Factors
4 Types of Environmental Factors
5 Types of Risk-Factors
2 Types of Risk-Factors
4 Types of Environmental Factors
5 Types of Contribution Factors
4 Types of Environmental Factors
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