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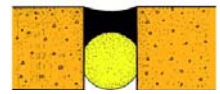
07900: Joint Sealers
INTRODUCTION



Sealants were used many thousands of years ago.

- 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 itself, sometime in the early 1930's.

The Pitch Lake of Trinidad and Tobago

Hong Kong's Cross Harbour Tunnel, Austria's Transalpine Highway, and England's Jubilee Way Viaduct all have something in common:

- Paved highways containing a mixture of a unique asphalt—
  - Asphalt that comes from the Pitch Lake of Trinidad and Tobago.
    - The great Pitch Lake is a natural surface deposit of asphalt. '
- **A Walk on the Lake**
  - The lake covers approximately 115 acres **[47 ha]** and is about 250 feet **[80 m]** deep at the center.
  - The lake and its surface is unexpectedly solid, although uneven.
  - The lake can easily support the weight of a truck and other heavy machinery.
    - (These would, however, slowly sink if left for a long time in one spot.)

  - There is a pungent odor of hydrogen sulfide.
    - Small amounts of hydrogen sulfide form in the lake, together with methane, ethane, and carbon dioxide.
      - A small piece of asphalt from the lake looks like Swiss cheese—full of holes formed by trapped bubbles of gas.
- **Used for 400 Years**
  - In 1595, British explorer Sir Walter Raleigh anchored in Trinidad and Tobago.
    - At that time the lake, which now lies in a low depression, was a level plain with streams of asphalt reaching to the coast.
    - Raleigh used the asphalt to caulk his leaking ships and declared it to be "most excellent good," …and therefore for shippes trading south portes very profitable."
  - In 1846, Canadian Dr. Abraham Gesner, later dubbed the Father of the Oil Industry,
    - Distilled a new illuminating oil from Trinidad's asphalt.
      - He called it kerosene.
    - Trinidad's lake asphalt really came into its own when its value for paving roads was discovered. In 1876,
      - Engineers suggested that it be used to pave Pennsylvania Avenue in Washington, D.C.
        - Despite heavy traffic, the pavement reportedly remained in excellent condition for 11 years.
        - This helped to establish the reputation of Trinidad's asphalt.
  - In recent years
    - Oil companies have been able to produce cheaper bitumen as a by-product of petroleum refining.
    - Yet, engineers have continued to use Trinidad's natural asphalt in building highways, bridges, airports, and seaports.

A Unique Blend

- When included in paving mixtures,
  - This asphalt is known to impart strength, durability, stability, and nonskid properties to the paved surfaces—
  - not to mention a mat-gray finish that enhances visibility for night driving.
- Lake asphalt has been successfully used for road surfaces where temperatures exceed 100 degrees Fahrenheit **[40°C]** in summer and fall below minus 20 degrees Fahrenheit **[-25°C]** in winter.
- Airport runways built with this asphalt have performed well,
  - —in spite of the stresses placed on them by the constant takeoff and landing of heavy aircraft.
- These pavements are also resistant to degradation from deicing fluids as well as fuel and oil leaks. Many of these paved surfaces have lasted more than 20 years with little or no maintenance.

- The characteristics of Trinidad's lake asphalt have been attributed to its special composition.
  - The bitumen in it is composed of
    - 63 to 67 percent malthenes
    - 33 to 37 percent asphaltenes.
      - Malthenes are a class of sticky petroleum chemicals that give bitumen its adhesive properties.
        - Those malthenes present in this lake asphalt have been described as "extremely sticky and cementitious rather than oily."
        - Asphaltenes are another group of hydrocarbons that help to make bitumen a thermoplastic material—
          - One that softens and flows when heated and hardens as it cools.
      - The character and relative proportions of all these components give the asphalt properties that are not easily duplicated by refineries.

Mining and Refining

Over nine million tons of asphalt have been mined from this site since the late 1800's!

- At the current rate of consumption,
  - the estimated ten million tons that remain
    - are projected to last another 400 years.
- After several tons of asphalt are removed from the lake,
  - The hole that was formed shrinks and disappears within a few weeks.
  - This gives the impression that the lake replenishes itself.
  - However, the "solid" asphalt is really a very viscous fluid and adjacent material simply flows into the depression.
    - The entire lake is thus in a state of constant but imperceptible motion.

Production

- The raw asphalt is dumped into large vats,
  - Each with a capacity of over 100 tons.
  - Here the asphalt is melted by coils of pipe carrying steam that is heated to about 330 degrees Fahrenheit **[165°C]**.
    - This liberates trapped gases and drives off the excess water that constitutes about 30 percent of the raw asphalt's weight.
    - Next, the asphalt is screened to remove bits of wood and other vegetable matter.
    - Finally,
      - the hot asphalt is drawn off into fiberboard drums lined with silicone paper.
      - The drums hold about 530 pounds **[240 kg]**.
        - The entire refining process takes approximately 18 hours.

- The purified asphalt is called "Epuré,"
  - It blends readily with refinery bitumen and other materials to produce high-performance paving mixtures.
    - In recent years it has also been used to make a variety of paints
    - cementing,
    - insulating,
    - and waterproofing products.
      - Thus, purified asphalt it has found its way into many homes and buildings around the globe.

[As a Footnote]

- The terms *bitumen, asphalt, tar,* and *pitch* are often used interchangeably.
- However, *bitumen* is a generic term for a class of dark, heavy hydrocarbon compounds found in tar, pitch, and petroleum.
- ***Tar*** is a dark sticky substance obtained as a condensate from the destructive distillation of materials such as wood, coal, and peat.
- Further evaporation of tar yields ***pitch*** as a semisolid residue.
  - Tar and pitch have a relatively low bitumen content.
- Petroleum, or crude oil, when evaporated leaves a residue composed almost entirely of bitumen.
- Petroleum-derived bitumen is also called ***asphalt.***
  - However, in many places "asphalt" refers to bitumen mixed with mineral aggregates like sand or gravel, often used in the paving of roads.

FOR THE PURPOSE OF THIS COMMENTARY, "asphalt" refers to either the crude or the refined product from the Pitch Lake.

Interestingly, the Bible also acknowledges the waterproofing property of asphalt or bitumen.

- Noah, on being instructed to build the ark, was told to "cover it inside and outside with tar." (Genesis 6:14)
- And according to Exodus 2:3, the papyrus ark in which Moses was concealed was coated with "bitumen and pitch."

JOINT SEALANTS…

JOINT SEALANTS are used to seal joints and openings (gaps) between two or more substrates, and are a critical component to building design and construction.

1. The main purpose of sealants is to prevent:
   a. air, water, and other environmental elements from entering or exiting a structure;
   b. While permitting limited movement of the substrates.
2. Specialty sealants are used in special applications, such as,

a. Fire stops, electrical or thermal insulation, and aircraft applications.

b. Sealants are broadly used in a variety of commercial and residential applications.

   i. Common sealants include:

      1. Silicones, acrylics, urethanes, butyls and other polymeric types.

         a. Various formulations have been developed over the years, which meet performance specifications as mandated by building codes, as well as per the specific and unique needs of the end user.

DESCRIPTION

Selection of sealants

The proper application of sealants involves not only choosing the material with the correct physical and chemical properties, but also ensuring:

- The good understanding of the joint design,
- The substrates to be sealed,
- The performance needed,
- And the economic costs involved in the ***installation*** of the joint sealant.

Typical considerations in selecting a sealant type for the construction industry are:

- ***Joint Design***:
  - The specifics of the joint design and configuration must match up with the sealant's movement capabilities in installed conditions.
  - The practicality of placement and aesthetics also need consideration.

- ***Physical and chemical properties***:
  - Mechanical properties of the sealant like
    - Modulus of Elasticity,
    - Stress/strain recovery characteristics,
    - Tear strength,
    - And fatigue resistance are all factors—
      - That influences the sealant performance in a joint.

- The polymeric composition along with other additives will affect the regulatory compliance of the product.

- ***Durability properties***:
  - The adhesion properties of the sealant to the specific substrates—
  - The aging properties of the cured sealant—
    - as they relate to its resistance to:
      - ultra-violet radiation,
      - moisture, temperature,
      - cyclic joint movement
      - and bio-degradation
        - Can profoundly influence the service life of the installed sealant.

Application/installation properties:

- Considerations important to the consistency of the sealant include:
  - Open/tool time (pot life),
  - Tack free time,
    - Application temperature range, and low temperature "gunnability"
      - (i.e. ability to be dispensed easily by sealant gun).
    - Sealants used for interior applications,
    - Properties and needs different from those used in other applications,
      - Such as structural glazing or exterior building facades.

Key Features of Sealant Chemistries

Joint sealants come in many different types, and include:

Liquid Applied in the Field

- **Latex** (water-based, including EVA, acrylic)
  - Used mainly in residential and light commercial construction applications
  - Interior and/or exterior uses
  - Premium products meet ± 25% movement (ASTM C 920, class A)
  - Excellent paintability (with latex paints)
  - Very good exterior durability
  - Exhibit some shrinkage after cure
  - Sometimes referred to as caulk
  - Not used for exterior applications on high rise construction or for applications undergoing significant cyclic movement

- **Acrylic** (solvent-based)
  - Used in residential and light commercial construction, mainly for exterior applications
  - Generally meet ± 12.5% movement (ASTM C 920, class B)
  - May need special handling for flammability and regulatory compliance

- Can be painted
- Short open time; difficult to tool
- Exhibit some shrinkage upon cure
- Often used for perimeter sealing; low movement joints

- **Butyls** (solvent-based)
  - Excellent adhesion to most substrates
  - Limited movement capabilities, generally up to ± 10%
  - Excellent weathering
  - Good use as adhesives in industrial and packaging applications
  - Sometimes used in curtain wall applications where adhesion to rubber compounds is needed
  - Most are stringy and difficult to apply neatly
  - May show some shrinkage after cure; may harden and crack over time on exposed surfaces

- **Polysulfides**
  - First "high performance" sealant chemistry; mainly used in industrial applications
  - Poor recovery limits their use in joints with high cyclic movements
  - Can be formulated for excellent chemical resistance (especially for aviation fuel)
  - Good performance in submerged applications
  - Require primer on almost all substrates

- **Silicones**
  - Structural bonding and stop-less glazing of glass to frames
  - Very good joint movement capabilities; can exceed ± 50% (ASTM C 920, class A)
  - Excellent UV and heat stability
  - Good adhesion to many substrates especially glass; often a primer is recommended on many substrates, particularly porous substrates
  - Not paintable
  - Used in protective glazing systems and to insulate glass to improve thermal performance (reduce heat loss). Also designed for missile impact and bomb blast situations)
  - Acetoxy chemistry based sealants have strong odor, but newer chemistries have very low odor
  - Adhesion is adversely affected by less than perfect application conditions
  - High, medium and low modulus materials available
  - May stain some types of natural stone without primers

- **Polyurethanes**
  - Used in industrial and commercial applications
  - Excellent movement capabilities, up to ± 50% (ASTM C 920, class A)
  - Not used in structural glazing applications (avoid direct contact to glass)
  - Excellent bonding, generally without a primer for many surfaces
  - Can be formulated for good UV resistance
  - Paintable
  - Some formulations may contain low levels of solvent

Factory Molded

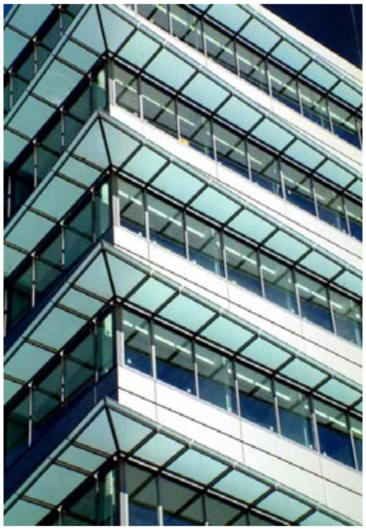
- Gaskets and seals
- Strip-seals
- Compression systems

The following table shows different sealant formulations, rated for selected applications: (1=no rating, 2=poor, 3=good, 4=excellent)

Use	Latex	Acrylic	Butyl	Polysulfide	Silicone	PU
Submerged	1	4	3	4	1	4
Interior	4	4	3	3	3	4
Exterior	1	2	1	3	4	4
Structural Glazing	1	1	1	1	4	1
Window Perimeter	1	2	1	3	4	4
Expansion Joints	1	1	1	2	4	4
Traffic Joints	1	1	1	3	2	4
Wide Joints	1	1	1	1	2	3
Paintable	4	3	2	1	1	4
Chem. Resistant	1	1	1	4	1	3
EIFS	1	1	1	1	4	4
Tilt-up	1	1	1	2	3	4
Pre-Cast	1	1	1	2	4	4
Cast-In-Place	1	1	1	2	3	4
Brickwork	1	1	1	2	2	4
Curtain Wall	1	1	2	2	4	2
UV Resistance	1	3	2	3	4	3

APPLICATION

Joint sealants are used in various architectural applications, which include:



- High-rise and low-rise commercial buildings:
    - Exterior window/perimeters
    - Roofing terminations
    - Expansion joints
    - Interior windows/doors perimeters, baseboards, moldings
- Plaza and parking decks
- Tilt-up concrete exteriors
- Institutional (prisons, schools, hospitals)
- 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 glazing

Joint Types

- Working Joint (expansion and isolation) -- Joints where the shape and size of the sealant joint changes significantly when movement occurs (e.g. control joint, expansion joint, lap joint, butt joint, stack joint)

- Fixed Joint (construction) -- Joints that are mechanically fixed to prohibit movement, generally defined as less than 15% of the joint (e.g. air and/or water seals in curtain walls)
- Control -- Generally non-moving (but have potential to move)

Common problems

- Sealants are often the least thought about and contribute the lowest percentage to a project's overall cost; however, they can become the biggest problem if a structure starts to leak.

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- There is both science and art to completion of proper joints from design to sealant placement

- Sealants cannot make up for poor structural or joint design. Need to have:
    - Proper joint design
    - Proper product
    - Proper application




General Joint Design
The following guidelines should be followed in designing and installing sealants properly:

Joint Spacing
- Must allow access for sealing joint and, if necessary, backer rod placement
- Allow sufficient bonding surface to be present
    - Window perimeters
    - Exposed aggregate butt joints
    - Termination details

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Design for sealant movement capabilities

For weatherproofing, minimum depth of 1/4" (6 mm) sealant/substrate bond, and (in most cases) minimum width of 1/4" (6 mm) opening is necessary to ensure that sealant applied from a caulking gun will flow into the sealant joints properly

- **For moving joints,** also need to consider:
    - Wider joints (minimum of 1/4" width) as wider joints can accommodate more movement than narrow joints.
    - Use backer rod or bond breaker tape to eliminate a situation of "three-sided adhesion"
    - Use 2:1 width to depth ratio to accommodate more movement than a thick joint (i.e. 1.5:1 or 1:1 ratio). Consider "hourglass" shape.
    - For joint size larger than 1", depth should be kept to about 3/8" to 1/2" (9 mm to 12 mm)
    - The number and spacing of joints is critical to performance

- **Placing the sealant**
    - Mix 2-part 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 UNIPRO practices)
    - Dry tool sealant to press material against joint walls or bonding surface
    - Check work frequently and keep samples
    - Maintain a job log (e.g. lot no., weather conditions, application procedure)

Materials

- Will the selected material handle the anticipated joint movement requirements?
- Will the sealant adhere to substrate properly - this is probably the most critical element in the selection process?
- Will product endure anticipated weathering exposures?
- Is product compatible with adjacent materials?
- Does the joint size allow for sufficient placement of selected materials?
- Will the product perform under the stated conditions of use?
- Is there history of application success?
- Does the sealant supplier have the necessary in-house resources to support your application in case of problems?

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, free of dew or frost
- Use best practices as recommended by industry experts:
    - Porous: abrasive, high pressure water (allow to dry after), grinding, wire brush
    - Non-porous: 2 rag method

Priming

- Improves the bond in many situations
- Is not substitute for good preparation
- Many products perform w/out primers
- Most commonly used on horizontal and submerged applications
- Must be done properly to work (primers are not error free: may cause "ponding", waiting time, etc.)

Backing materials: Why use backer rod?

- Attain proper wetting of substrate when sealant is tooled
- Control sealant depth
- Prevent 3-sided adhesion
- Recommended Materials
    - Closed cell backer rod: primarily a foam material with a surface skin
    - Open cell backer rod: primarily a foam material without a skin
    - Backing tape: primarily a self-adhesive polyethylene or Teflon material

Not recommended:

- Any rigid materials
- Silicone sealant as bond-breaker and joint fill

Keys to success:

- Must be 25% larger than joint width so remains during joint movement
- Don't poke holes in any backing materials, this can cause air bubbles in sealant
- Must be compressed against side walls to prevent leakage through joint and to get proper bond line dimensions
- Function ceases once sealant is applied and tooled

Structural Glazing Applications

Structural glazing involves attaching glass, metal, or other panel materials to a building's metal frame in place of using gaskets and other mechanical attachments. High-performance sealants must be able to withstand wind load and other stresses, and help to transfer these forces to the structure of the building.

For effective structural joint design, the following parameters should be considered:

- "Structural bite" - defined as the minimum contact surface of sealant required on both the panel and frame to account for such environmental factors.
- "Deadload" - the weight that a panel places on a sealant
- "Glueline Thickness" - used to facilitate the installation of a sealant; helps to reduce stress on a structural joint that might result from a differential thermal movement.

Weatherproofing Applications

Weatherproofing helps keep rain and other weather elements from entering a building.

To apply properly, the following parameters must be considered:

- "Joint Movement" - may occur as a result of: changes in temperature, seismic movement, elastic frame shortening, creep, live loads, concrete shrinkage, moisture-induced movements, and design errors.
- "Movement Capability" - The +/- percent value that indicates the amount of movement the sealant can take in "extension (+)" and/or "compression (-)" from its original cured joint width.