

# Challenges in Sealant Application

By Roy Cannon

## Early Joint Movement During the Sealant Cure Cycle

**A** seasonal, but all too frequent occurrence, in what is often one of the final phases of construction, excessive expansion joint movement during the curing cycle of freshly installed architectural sealants can plague a project.

This article will describe the causes, effects and remedies for this problem of excessive expansion joint movement. Understanding the cure cycle of various types of sealants is an important place to start. Armed with basic knowledge of polymer-based architectural sealants, it is possible to understand the cure cycle, which transforms a liquid polymer into a durable elastomeric sealant.

### Curing Process

Not surprisingly, the process of transforming a liquid polymer system into an elastomer is varied based upon sealant chemistry with specific chemistries requiring different environmental influences to make the transition. Table 1 illustrates environmental effects on the curing process based upon sealant chemistry.

The effects of temperature and humidity play a completely different role depending on the type of sealant being used. It is important to understand the cure characteristics of a sealant before starting a project. Armed with the knowledge of how the particular sealant being used cures, a contractor can better plan and manage a project and in the process minimize inefficiency due to issues which can sometimes arise when temperature and humidity extremes catch you by surprise.

Unfortunately, manufacturer's literature does not always predict sealant behavior under all environmental conditions. Most literature refers to standard conditions

**Table 1: Environmental Effects on Sealant Cure Chemistry**

Conditions ► Cure Type ▼	Higher Temperature	Lower Temperature	Higher Humidity	Lower Humidity
<b>Chemical Cure- Two component</b>	Reduces cure time	Increases cure time	Little effect	Little effect
<b>Moisture Cure- One component</b>	Reduces cure time	Increases cure time	Reduces cure time	Increases cure time
<b>Drying - Solvent evaporation</b>	Reduces cure time	Increases cure time	Little effect	Little effect
<b>Drying- Moisture evaporation</b>	Reduces cure time	Increases cure time	Increases cure time	Reduces cure time



All architectural sealants have common components with very specific functions regardless of the polymer or curing chemistry employed in building a particular sealant.



The components that combine to create a commercial sealant product illustrate the complexity of sealant formulations and the challenges presented to the formulator.

# Tackling Sealant Composition

The first step in understanding architectural sealants is reviewing the components that combine to create a commercial sealant product.

The varied chemistries used in the formulation of sealant materials can be intimidating. All architectural sealants have common components with very specific functions regardless of the polymer or curing chemistry employed in building a particular sealant. The following list illustrates the common components with associated general functionality.

## Base Polymer

This is the elastomeric portion which is generally a translucent viscous liquid at the time of formula compounding. The base polymer has a dominant effect on the physical properties as well as the ultimate durability of the final sealant formulation. The array of base polymers available to the sealant formulator is extensive and varied.

## Plasticizer

Plasticizers come in many varieties, but ultimately are also translucent liquids of varying viscosity ranging from a water consistency to that of corn syrup. The role of a plasticizer is multi-functional from increased sealant flexibility or modulus reduction to allowing higher loadings of other components such as mineral fillers like calcium carbonate or silica sand, which contribute their own special properties to sealants.

## Dehydrating agents

Dehydrating agents are also varied in composition with the use of a particular type defined by the class of base polymer and curing mechanism used in the specific sealant formulation. But, the purpose and function of the drying agent is universal in that they are used, as one might guess, to eliminate free moisture from a sealant formulation. Drying agents are most commonly used in one component moisture cure sealant systems with the sole purpose of removing moisture from raw materials during the manufacturing process to manufacture a shelf stable product. Drying agents are generally added before the addition of reactive polymers and crosslinking compounds.

## Mineral Fillers / Extenders / Reinforcers

Mineral fillers such as  $\text{CaCO}_3$ , Silica, Barytes and Calcium Sulphate also come in many forms characterized mainly by particle size, surface treatment and processing differences. One function of mineral fillers is to reduce formula costs while imparting beneficial physical properties in the form of reinforcement. Reinforcement generally refers to increased tear resistance.

Rheological properties, which refer to flow properties of liquids, are also

greatly influenced by filler selection and concentration.

## Crosslinkers

Crosslinkers are small molecules which are usually found at the end of a liquid polymer chain. They are chosen by level of reactivity and functionality and do the work of building an elastomer during the process of transformation of liquid to an elastomeric solid in sealant formulations. The density of the crosslinks (the number of crosslinks per unit volume) in a sealant material along with the length and structure of the liquid polymer chain play a strong role in determining physical properties of an architectural sealant.

## UV and anti-oxidant additives

UV and antioxidant additives are materials used in relatively small concentrations to slow degradation caused by exposure to the elements, particularly solar radiation. Sealant formulas are varied in this regard and may or may not require UV or AO additives. The base polymer used is a strong determining factor defining the need for such additives.

## Wetting or leveling agents

Wetting or leveling agents are compounds that work to adjust surface tension which can be useful in modifying forces between liquid and solid components of a sealant formulation. They are also sometimes required to achieve proper surface appearance in self-leveling materials.

## Thixotropes and thickeners

Thixotropes and thickeners are materials used in relatively low concentrations to adjust rheological properties. There are many different types with a range of functionality in how they achieve the desired affect. In combination with mineral fillers and base polymer these materials play a large part in creating the "feel" of a sealant material. They can also assure sag-free performance. Application and tooling characteristics are influenced by the proper selection of thixotropes and thickeners.

## Adhesion additives

The use of adhesion additives is common to most sealant types. Adhesion additives are used in small concentrations with the selection based upon sealant chemistry and the specific adhesion desired. As with most other formula components, adhesion additives may contribute and modify properties other than strictly adhesive characteristics such as rheology and cure speed.

## Catalysts

Catalysts are materials that either make possible or accelerate chemical reactions leading to ultimate sealant cure. Catalysts are used in very low concentrations with selection being critical to the final material application and physical properties.

**Table 2: Predominant cure phase by sealant type**

	Two component chemical curing	One component moisture curing	One component solvent or water release
Liquid paste phase	Yes	Yes	Yes
Surface putty phase <sup>1</sup>	No	Yes	Yes
Elastomeric surface skin phase	No	Yes	Yes
Viscosity increase, Putty phase <sup>1</sup> throughout cross section	Yes	No	Moderate
Uniform elastomer formation through cross section	Yes	No	Moderate

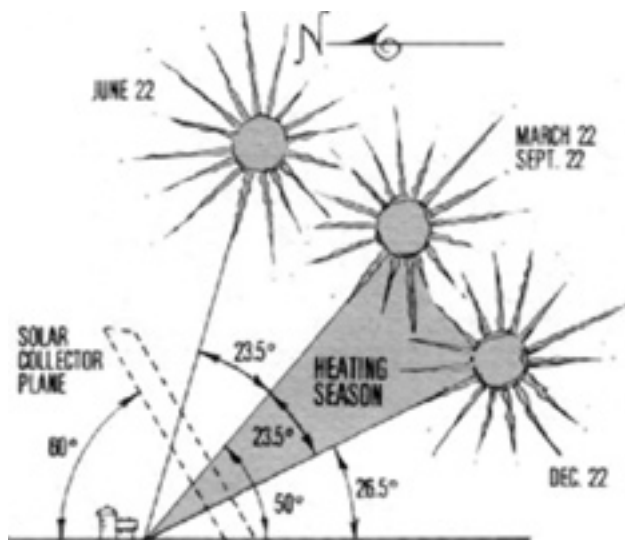
<sup>1</sup> "Putty phase" is a term used to describe a condition where the sealant is particularly vulnerable to even slight joint movement.

**Table 3: Failure Risk**

	Two component chemical curing	One component moisture curing	One component solvent or water release
<b>Risk of Failure</b>			
Surface wrinkling	Low	High	Moderate
Surface cracking	Low	High	Moderate
Cohesive failure	Moderate	Moderate	Moderate
Adhesive failure	High	Low	Moderate

**Table 4: Failure Incidence Sealant Application Time vs. Elevation in Spring and Fall**

Elevation ▶ Application Time ▼	Northern	Southern	Eastern	Western
	Adverse Sealant Condition			
Early morning	None	Surface Wrinkling	Surface Wrinkling	Surface Wrinkling
Afternoon	None	None	Surface Cracking	None
Evening	None	Surface Cracking	None	Surface Cracking



**Figure 1: Solar radiation angle of incidence, summer vs. winter**

of 75F and 50 percent RH when listing sealant properties. Lower and upper service and application temperatures ranges are generally listed with notes to contact technical service when venturing outside of those ranges. In some cases, optimum application temperatures are also listed. Once again those optimum temperatures are the golden standard of 75F and 50 percent RH.

In the real world, environmental conditions are in a constant state of flux with day and night time temperatures sometimes shifting radically. With deadlines and schedules to meet in the commercial construction process, and the inability of Mother Nature to cooperate with the work flow schedule, construction processes are sometimes carried out under less than optimum conditions. Pressure to meet deadlines often forces work to continue in the face of compromise for quality. The good news is that when faced with challenging conditions, the more knowledge of the materials used in the construction process, the less likely a serious problem will surface.

All sealant formulations are unique and are based upon the approach taken in the development process from one manufacturer to the next. The process of formulating sealant materials blends both art and science. The result is dictated by the unique abilities of the individuals on the formulating team to obtain the specific properties targeted by specification driven products. The uniqueness of sealant formulations, regardless of meeting identical specifications, cannot be escaped.

It's impossible to address all sealant formulas specifically, so a general discussion of the phases of sealant cure is illustrated in Table 2.

Depending on the type of sealant used, the effects of excessive expansion and contraction of a sealant joint can be different. As discussed previously, generalizing brings with it the possibility of making inaccurate assumptions. Even within one sealant type, behaviors under excessive joint movement conditions may display variability based on the uniqueness of a particular sealant formula.

Table 3 lists relative risk of specific types of failure during the sealant curing process by sealant type.

**Figure 2: Max Temp Extreme (deg F) for 200004**



**Failure Types**

For surface wrinkling to occur, the sealant must be incomplete in elastomer formation or in a “putty phase” at the time of joint compression and reach the elastomer formation stage before joint expansion takes place. Rapid joint compression can take place during the transition from night to day time temperatures during spring and fall. Surface wrinkling can also occur with the use of a backer rod that is too small, coupled with a rapid joint opening causing the backer rod to drop or move in the joint while the sealant is still in its non-elastomer stage. As noted in Table 3, one component moisture curing sealants are the most susceptible to this behavior.

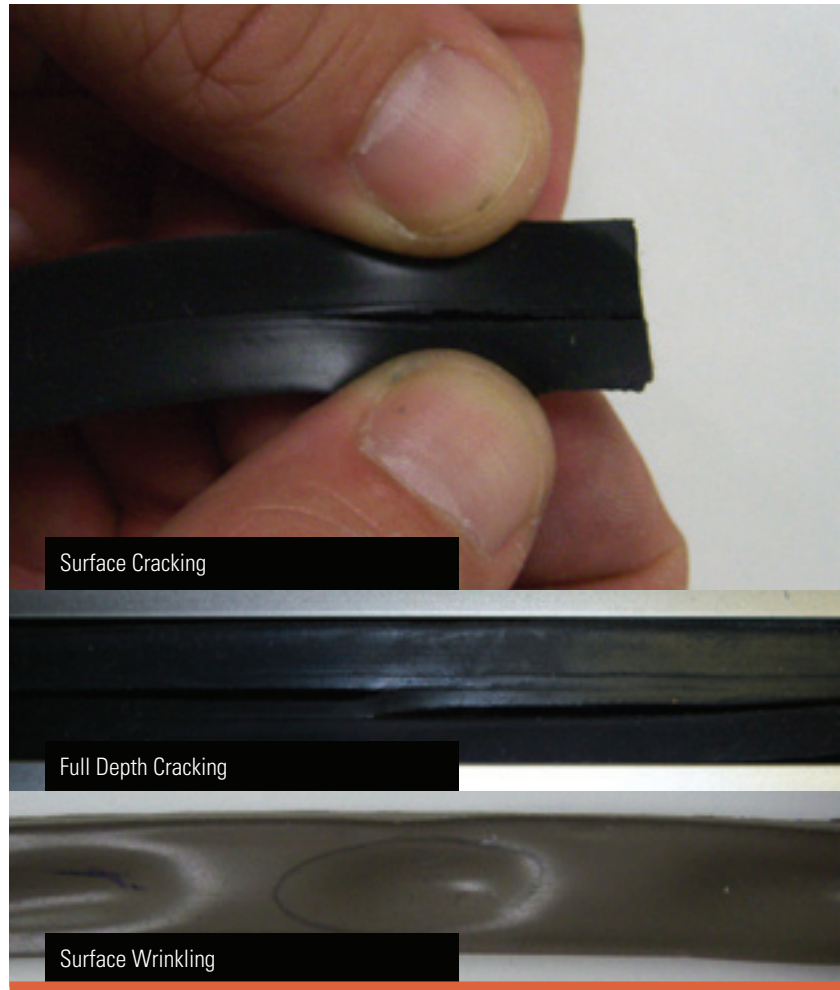
Surface cracking is a result of a sealant skin reaching the “putty phase” of the cure cycle while at the same time excessive joint expansion is taking place. The surface skin putty phase may only be present for a very short duration and is dependent on formulation and temperature and humidity conditions. The window of opportunity may be very short and basically is dependent on all conditions being aligned for the condition to occur. As noted in Table 3, one component moisture curing sealants are the most susceptible to this behavior.

Cohesive failure is the complete loss of integrity through the entire sealant depth creating a pathway for water intrusion. As noted in Table 2 this type of failure occurs predominantly in two component chemically curing sealants, which happen to reach a putty phase throughout at the time of excessive joint expansion. Again, that window of opportunity may be short and very dependent on all of the right conditions being present. The sealant cure speed coupled with environmental influences such as cold night temperatures and large daily temperature swings all contribute to this type of failure.

Adhesive failure occurs when the stress and strain associated with excessive joint expansion occurs before adequate adhesive strength is developed, but cohesive strength greater than the bond strength has been achieved during the sealant cure cycle. Again, the window of opportunity is dependent on conditions, cure speed and application time relative to changing daily conditions. Adhesive failure is also limited to two component chemically curing sealants as noted in Table 2.

**Daily Temperature Swings**

Figures One and Two, maps provided by the National Climatic Data Center, clearly illustrate the potential for extreme fluctuations in ambient air temperature during spring and fall months. Ambient temperature swings on average during summer and winter months are also significant. Building surface temperature extremes are more pronounced in spring and fall when radiant heat effects on surface temperature are also taken into account. The relatively large ambient temperature shifts coupled with radiant heat effects on building surface temperature combine to create conditions for extreme movement to occur.



**Table 5: Repairing Compromised Sealant**

	<b>REMEDY</b>
<b>Surface wrinkling</b>	Surface wrinkling can compromise movement capability of the effected sealant and in cases where excessive movement in extension is expected the sealant should be cut out and replaced.
<b>Surface cracking</b>	Surface cracking may lead to more serious cohesive failure and should be addressed. When the surface cracking is shallow, less than 20 percent of total sealant depth a simple skimming over of the existing seal may be appropriate. If this method is employed, the applicator must ensure that proper adhesion can be attained by proper surface preparation which could involve the use of a primer.
<b>Cohesive failure</b>	Sealant must be cut out and re-sealed. Follow manufacturers’ guidelines concerning cut and surface preparation procedures. Ensure proper adhesion of new to existing sealant.
<b>Adhesive failure</b>	Sealant must be cut out and re-sealed. Follow manufacturers’ guidelines concerning cut and surface preparation procedures. Ensure proper adhesion of new to existing sealant.

## Building Materials and Joint Movement

If materials did not experience dimensional changes with temperature fluctuations, sealant formulations would be much simpler. When talking about these dimensional changes in materials, the term “coefficient of thermal expansion and contraction” is often cited. This is nothing more than a measurement made on a standardized sample of material under very controlled conditions to assign a factor which allows us to easily calculate movement experienced in building materials exposed to temperature change. Unfortunately, buildings are not exposed to tightly controlled conditions as lab samples would be. There are many factors that effect joint movement that are not easily calculated or foreseen during the construction process. The following list should lend some appreciation for the complexity of factors attributing to joint movement.

- Seasonal temperature swings
- Daily temperature swings
- Moisture absorption
- Variability in construction material raw materials
- Elevation or building placement relative to radiant heat
- Material thermal conductivity
- Construction schedules
- Structural component influence on building façade
- Composite effects of multiple construction materials closely connected
- Variations in coefficients of thermal expansion and contraction between differing materials
- Non-linear coefficients of thermal expansion and contraction

Our focus is on extreme movement over very short periods of time due to day and night time temperature changes. Given the potential of large daily temperature swings, there are some practices that will help minimize the effects on freshly applied joint sealant. Table 4 outlines application times vs. elevation and possible effects from excessive movement induced by surface temperature swings on the order of 140F and low night time temperature of 30F or below, which are typical of fall and spring temperature extremes. Keep in mind, that when factoring in radiant heat from sunlight, building surface temperatures on eastern, southern and western elevations can easily reach 190F during the course of one day.

## Minimizing Early Movement Effects

One cannot completely eliminate the negative effects of early joint movement. But by recognizing certain sealant problems that can be caused by early movement, precautions can be taken. Adjusting work schedules and/or sealants used can minimize or eliminate negative effects. Changing sealants is often not an option, so even as impractical as a work schedule adjustment may seem, it could save potentially costly cut out and re-caulk.

Most contractors watch the weather as closely as farmers and generally for the same reason:

to maximize production and profit. This weather watching is sometimes picked up on by the field crews, but more often than not it just means a day off or maybe some light duty for that rainy day. So as is often the case, some simple training will go a long way in minimizing, if not avoiding, early joint movement issues.

## Fixing the Problem

Table 5 offers a set of remedies for repairing compromised sealant. Each involves inspection of existing sealant application with consensus reached by contractor, sealant manufacturer and construction project manager on criteria for inspection process and what defines areas in need of repairs. The repair process also involves either selection of a sealant that will perform under adverse conditions of early movement or waiting for extreme conditions to subside before undertaking repairs.

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