Secondary Weather Factors

Introduction

While the primary weather factors of solar radiation, temperature, and water (moisture) are primarily responsible for the weathering of most organic materials exposed outdoors, it is not uncommon for secondary factors to have a significant influence as well.

Overview

Often, particularly in laboratory accelerated artificial weathering, we focus only on the three main weathering stresses above and ignore others. However, in many cases, secondary environmental or applied stresses can contribute substantially to product failure. While it is often difficult or impossible to combine these stresses in combination with the primary stresses, the entire lifecycle of a product should be considered as well as the range of environments and service use conditions, which may be encountered and perform additional tests, if required.

Salt corrosion

Common salt, or NaCl, is highly corrosive and can be found in two principal locations. The first is in coastal marine settings where wet deposition of seawater can occur through immersion or spray, such as during storms. The alternating cycle of wet and dry is particularly aggressive towards metals such as iron and aluminum balcony railings, steel bridges, ferrous metals, etc. (Figure 1).

Figure 1. Failure of protective coating in preventing corrosion on ferrous metal.

A secondary source of salt corrosion is common road salt used for deicing purposes on roadways and sidewalks. This is particularly harmful to infrastructure elements such as concrete and steel. Also, of critical concern is the effect of road salt on vehicles and rolling stock.

There are many standard salt fog (spray) steady-state and cyclic corrosion test methods by ASTM, ISO and other standards developing organizations (SDO) as well as proprietary ones, particularly by automotive OEMs. Therefore, it is not easy to make recommendations as to specific materials and substrate combinations, nor the best test method to use in this short document. Also note that these test methods universally do not indicate any correlation to field performance, nor in many cases do they specify test durations; these are usually in material performance specifications rather than test methods. Therefore, it is largely up to the customer to research the literature as to appropriate test methods and test durations for their application. However, it can be generally said that while steady state continuous salt solution tests are the most common, cyclic tests which combine, at a minimum, wet and dry cycles typically produce better correlation with field performance than do steady-state tests.

Large and Small-Scale Events

It is said that “climate is what we expect, and weather is what we get.” Large-scale events such as El Niño/La Niña and the North and South Atlantic Oscillations (NAO, SAO), among others, can have a significant impact on local weather conditions. Therefore, when comparing published weather data as a basis for determining accelerated test "equivalence," it is best to use longer term data such as a ten-year running average.

Major volcanic eruptions can spew large volumes of gas and particulates (Figure 2) which can turn to acids and be globally distributed, as well as reducing solar radiation levels. Note that historical climate data may no longer be relevant due to changes in both climate and measuring technology. However, smaller scale events cannot be ignored. For example, retro-reflective traffic signs failed in one area on a road in China; this was traced to high levels of high-sulfur coal dust from transport trucks depositing on the signs when wet, turning to sulfuric acid. Another example is Blount Island in Jacksonville, Florida. Downwind from a coal-fired power plant and pulp and paper mills, rainfall is acidified, especially during the summer months. Since the port is the major debarkation point for new automobiles from Europe, it has become a benchmark for testing automotive paint systems for acid etch of paint.

Figure 2. Volcanic eruptions can emit gases which create acid rain.

Figure 3. Mildew growth on paint film on non-sun exposed side.

Biological and Microbiological Stresses

Microbiological growth such as algae, mold and mildew can produce unsightly appearance as well as attack organic matter such as untreated wood, paint films and building siding materials. Damage is usually particularly severe on the side facing away from the sun, such as the north side of structures (in the northern hemisphere). This is particularly true in hot, humid environments such as subtropical South Florida, making it a preferred testing location for polymer degradation (Figure 3).

Not only building materials can be attacked by mildew. Figure 4 shows mildew growth, with subsequent pinholes being developed, in a high quality automotive clear coat. While this attack can happen in many climates, South Florida is particularly conducive to mildew formation.

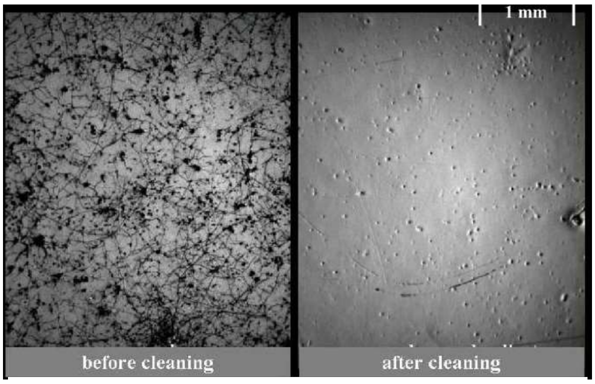

Figure 4. Mildew growth automotive clear-coat with development of pinholes.

Service Use Stresses

Although not technically considered environmental stresses, in-use service stresses can also play a part in what we can consider "weathering", although they may not be natural in origin. Some examples:

- PABA-based sunscreen can etch automotive clear coats.
- DEET insect repellent can attack automotive paint and plastics.
- "Picnic stains" such as ketchup, mustard and grease from cooking grills, as well as some household cleaners, can cause environmental stress cracking (ESC) on polymers such as wood-plastic composite decking (WPC).

- Some “wet tire look“ products can decrease tire sidewall thickness, and automotive interior cleaners can promote cracking of plastics used in the instrument panel and trim materials.
- Dust and dirt deposition and retention can spoil the appearance of outdoor structures.

Weathering can be both chemical and physical in nature. Therefore, in-service mechanical stresses should also be considered when testing a product. For example, fenestration devices such as doors and windows are mechanically constrained once installed. This can place physical stress on the product due to thermal expansion stress, resulting in deformation. Sealants also weather differently when not under tension or compression. Unsecured cables can be placed under dynamic load when buffeted by wind. And condensing or freezing moisture can cause corrosion or physical expansion.

Further, the entire lifecycle of the product should be considered. For example, polyurethane athletic shoe uppers were found to yellow in shipping container transport from Southeast Asia to Europe and the USA due to a combination of temperature, humidity, and ship stack gases coupled with shrink-wrap plasticizers. Non-woven polymeric house wrap insulation was found to degrade when exposed to the environment during extended construction delays. Palletized and shrink-wrapped construction materials were found to degrade at the jobsite due to the combination of UV, high temperatures from solar load and trapped condensing moisture. Nail “pops“ were found to penetrate the insulating backsheet of photovoltaic roofing shingles. Finally, an ocean-going ships' binnacle (compass) suffered several degradation and failure modes, including internal moisture condensation, when exposed to several specific environments; a climate severity index matrix was created to understand how to best test the next generation product.

Summary

While the main environmental stress factors of heat, light, and moisture are usually the dominant degradation factors in weathering, secondary environmental and related in-service stresses may also be very important. Therefore, we must often consider more than a one-case scenario. Factors to consider:

- Range of climate conditions which may be encountered in—use.
- Special test mounting fixtures to reproduce mechanical stresses.
- Conditions encountered throughout the service life, including transportation, storage, installation, and use.
- Robustness to mis-installation or unanticipated use.

The development of a proper weathering test program may involve more than one test method, and it may be necessary to prescreen to determine if a stress factor is relevant. Considering possible degradation mechanisms entire lifecycle of the product are more likely detect and prevent field failures.

References

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