Fastener Corrosion: A Ticking Time Bomb?

by Skip Walker

The most common ASTM and AWPA testing methods for fastener corrosion involve the use of test chambers with high temperatures, high humidity, salt compounds, and other factors in order to simulate long-term exposure over a short period of time. This is called accelerated testing, and while useful for quality-control purposes, salt-spray test results don't really predict how well materials and coatings will resist corrosion in the real world. Meanwhile, there has been little multi-year testing done in real-life weather-exposure situations.

The most extensive non-accelerated study seems to be one conducted by BRANZ (Building Research – New Zealand), a New Zealand nonprofit government-funded construction and building-materials research group. In 2007, BRANZ started a three-year study designed to test real-world behavior of mild steel, hot-dipped galvanized (G185) steel, and stainless steel nails, screws, and flashings in untreated wood and in CCA-, CA-, and ACQ-treated lumber in coastal (severe) and mild/non-coastal environments.

The BRANZ study used a softwood species called Pinus radiata (Monterey pine), which is widely cultivated in New Zealand. This species is largely sapwood, so it is probably most similar to southern yellow pine. Sapwood generally absorbs the chemicals used in pressure treating very well, often achieving penetration levels of 90% to 100%. Chemical penetration in species like Douglas fir, which is largely heartwood, tends to be very poor even when the wood is incised. This causes most of the chemicals to reside in the outer edges of the wood.

New Zealand weather-exposure categories use different designations than the AWPA Use Categories (UC) we are familiar with in the U.S. To simulate worst-case situations and account for wood retention variability, BRANZ had the test PT lumber treated with retention levels 10% above the normal amount for the given use level for that chemical. For example, ACQ lumber rated for ground contact that would normally have a minimum 0.41 pcf retention level was treated to a retention level of 0.451 pcf. So while the BRANZ testing is certainly not 100% apples-to-apples, it is close enough to raise some serious concerns.

Testing

Located a few miles from the nearest salt water and protected from the sea by rolling hills, Judgeford has a generally moderate climate. A second site, at Oteranga Bay, was located just yards from the beach to represent a severe coastal/marine-exposure environment. At each site, a series of wood frames made of untreated lumber and CCA-, CA-, and ACQ-treated lumber were installed using mild steel, hot-dipped galvanized (G185 HDG) steel, and stainless steel nails, screws, and flashing material. The metal components were carefully weighed before assembly and were driven into or attached to the test frames in specific patterns, some horizontally and some vertically. Each test frame had the same pattern of nails, screws, and flashings.

At the one-year mark, five nails, five screws, and one flashing of each metal type were removed from test frames representing each wood type. This was repeated at year two. At the year-three mark, the remaining nails, screws, and flashing were removed and sampled.

At the end of the testing, researchers carefully photographed, weighed, and catalogued each of the samples. The before and after weights were tabulated for each component and charted by chemical and wood type. Because we know that corrosion results in material loss, the degree of corrosion correlates directly to the weight loss of the component.

Results

The test results paint a bleak picture. In all cases, accelerated corrosion levels were found in the mild steel and G185 HDG hardware that was in contact with ACQ- and CA-treated lumber. And for CCA-treated lumber, the service life (the length of time the fastener is capable of performing its intended structural purpose) of G185 HDG hardware in the mild (Judgeford) climate was judged to be 8 years, and only 5 years in the severe (Oteranga Bay) environment.

In the U.S., of course, CCA-treated lumber hasn't been available for residential use since December 2003; more often than not, decks are framed with CA- and ACQ-treated lumber, which has higher copper content and is therefore more corrosive. In the study, it was found that corrosion rates for G185 hardware in ground contact (roughly equivalent to UC4A) ACQ were accelerated by a factor of 3.3 to 3.8 times compared with the same hardware in CCA-treated lumber. With mild steel, the corrosion rate increased by a factor of 6.4.

Located a few miles inland from the coast in California, this deck was built in 2006 using lumber treated with copper azole (CA) to retention levels for above-ground use (UC3B). Note the severe corrosion of the 10-year-old joist hangers.

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According to my calculations, if G185 HDG nails in CCA-treated lumber have a service life of 8 years, then G185 HDG nails in ground-contact-rated ACQ would have a service life of between 2.1 and 2.42 years in a mild climate.

In a severe environment, G185 HDG nails that have a service life of 5 years in CCA-treated lumber would have a service life of between 1.31 and 1.51 years in ground-contact ACQ-treated lumber. And while these numbers sound bad, bear in mind that 3.3 to 3.8 was the mean; there were individual cases in which the increase in corrosion was up to 10 times the CCA rate. In a severe coastal environment, the projected service life of a G185 HDG fastener in UC4A ACQ-treated lumber could be as short as 16 to 18 months. And in even a mild environment, the projected service life of that same nail might be as short as 25 to 29 months.

As noted earlier, the wood used in the study was primarily sapwood. In cases where heartwood is used, we could reasonably expect corrosion to be worse with metal connectors and on the portions of the fasteners in contact with the perimeter areas of the wood. This is because with sapwood, the chemicals are more uniformly distributed in the entire piece of wood. With heartwood, however, the same quantity of chemicals is concentrated in the perimeter of the wood member. Even with incised wood, most of the chemicals do not penetrate very deep into the wood. This means the chemical concentrations would be *much* higher on the perimeter, and the corrosion rates would be correspondingly higher as well.

Another takeaway from the BRANZ testing is that the nail and screw heads showed little damage. Almost all corrosion was on the nail shanks and screw threads—where you can't see it. So everything may look fine when it's really not.

Interestingly, in 100% of the test cases, stainless steel showed no measurable levels of material loss in either the mild or severe environments, with all fastener types and against all chemical formulations. In other words, the only material that actually resisted corrosion is stainless steel.

A Bigger Problem?

When people talk about corrosion problems, the focus is usually on larger-diameter bolts, such as might be used to fasten a house to a foundation or a deck ledger to a rim joist. Conventional wisdom says that corrosion will take forever to rust a bolt to the point of failure, but this isn't necessarily true. The corrosion does not have to eat through the entire bolt—it only needs to degrade the threads, and once the threads have been compromised, the nuts will simply pull off under stress. In coastal areas near me, it is not uncommon for a bolt on a deck to corrode so severely that it splits the post, necessitating replacement of the wood and the metal connectors.

As an inspector, I've seen that many decks and balconies are built improperly to start with. Compound improper construction with the corrosion problems identified in the BRANZ study and you have a recipe for disaster. Sadly, it seems that most structural engineers and contractors don't seem to grasp the magnitude of this issue. Yet the statistics are clear—when an elevated deck or balcony collapses, 75% of the people on it will be seriously injured or killed.

And accelerated corrosion is not just a residential problem limited to decks. Accelerated corrosion issues can potentially be found in any wood-framed single- or multi-family home or commercial structure built after 2003. Corrosion is accelerated in coastal, damp, or high-humidity conditions, and when corrosion-degraded structural connections are put under stress, failures can occur. The stress can be from an earthquake, a tornado, a hurricane, or a group of friends and family socializing on a deck or balcony, but no matter the source, the result can be catastrophic. ❖

Skip Walker is an ASHI Certified Inspector, a CREIA Master Inspector, an ICC Certified Combination Residential Building Inspector, and an ICC Certified California Residential Building & Plumbing Inspector. He owns Walker Property Evaluation Services in San Bruno, Calif., and can be reached at skip@codecheck.com.