CORROSION OF FASTENERS

Results from BRANZ's 3-year field exposure test on the performance of typical fasteners in timbers treated with waterborne copper-containing preservatives show stainless steel to be best for long-term durability.

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Over the past 3 years, BRANZ has been studying the performance of typical fasteners in timbers treated with water-borne copper-containing preservatives (CCA, CuAz and ACQ). The field exposure testing has been conducted at two Wellington sites – Judgeford, near Porirua, and Oteranga Bay, on the Makara coast facing Cook Strait.

The nails and screws made from mild steel, galvanised steel and austenitic stainless steel have now been retrieved. Their degradation behaviours have been assessed using morphological characterisation and corrosion rate measurements, with some interesting results.

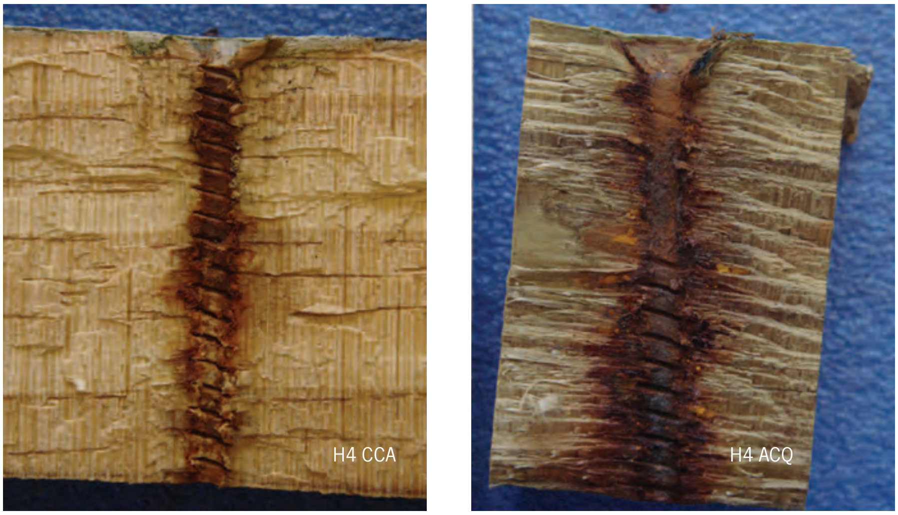

Figure 1: Iron stain formed by corrosion of zinc-coated screws in H4 CCA and H4 ACQ treated timbers exposed at Judgeford for 3 years.

ACQ and CuAz more corrosive

The 3-year exposure confirmed that CuAz and ACQ are more corrosive than CCA:

- At Oteranga Bay, the corrosion rate of mild steel in the H4 ACQ treatment was 3.8 times greater than that in H4 CCA treatment samples.
- At Judgeford, CuAz and ACQ treatment showed a corrosion rate 1.9 greater than CCA.
- For zinc-coated fasteners, the maximum levels of corrosion acceleration were:
  - 3.6 within CuAz and ACQ treated timbers at Judgeford
  - 3.8 within ACQ treated timbers at Oteranga Bay.

CCA

Metal deterioration in the CCA treated timbers progressed steadily over the 3 years and H3 and H4 CCA treated timbers were found to have very similar corrosivity.

CUAZ AND ACQ

The corrosivity of timbers treated with CuAz and ACQ appeared to decrease with extended exposure. However, fasteners in these timbers may still not be durable long term because of the initial fast metal deterioration, particularly of zinc coatings (see *Build* 113 August/September 2009, pages 47–48).

The more severe corrosion in CuAz and ACQ treated timbers also resulted in heavy iron stain on the surrounding timber after only 3 years (see Figure 1). This made it difficult to retrieve fasteners, particularly screws. With longer exposure, the iron and hydroxyl ions released from the corrosion chemically attack the cellulose components of the timber and cause loss of strength and structural integrity of the joint – a phenomenon called 'nail sickness'.

Environment affects corrosion rates

Atmospheric corrosivity tests showed that Oteranga Bay is severely marine-influenced, whereas Judgeford lies in a rural region of average corrosivity. The influence of the macro-environment on the corrosion process can be easily seen by comparing the corrosion rates and surface morphologies of the fasteners embedded into the timbers exposed at these two sites for 3 years (see Figure 2).

Mild steel fasteners (nails and screws) and zinc-coated screws inserted into the timbers exposed

Figure 2: Mild steel nuts exposed at Judgeford (left) and Oteranga Bay (right) for 3 years.

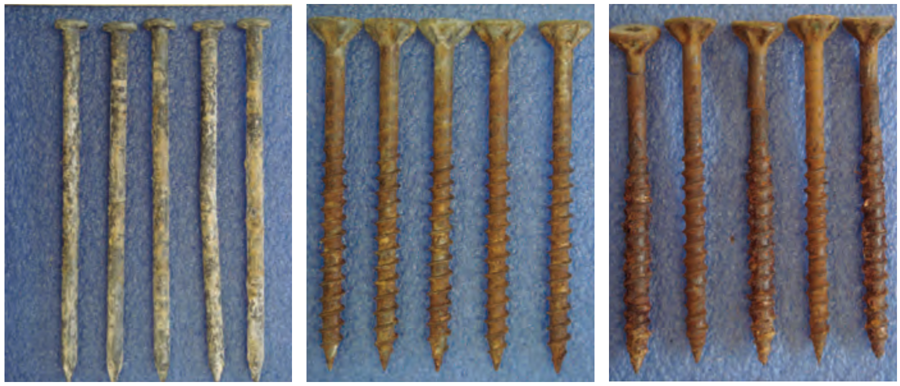

Figure 3: Fasteners removed from treated timbers exposed at Judgeford for 3 years – galvanised nails in H4 CCA (left), zinc-coated screws embedded in H4 CCA (middle) and H4 ACQ (right).

at Oteranga Bay generally had a higher corrosion rate than those at Judgeford. However, for hot-dip galvanised nails, results at Oteranga Bay were not always higher than those at Judgeford.

The atmosphere influences the exposed sections (such as the head top) and probably the section immediately below the head if the surrounding timber is free of cracks. This caused the formation of iron-rich rust on the heads of *all* zinc-coated screws exposed at Oteranga Bay, while at Judgeford, some screws (19 in 35) still had relatively good zinc coatings on their heads. Deposition of airborne salt particles on the surface contributed to this accelerated corrosion.

The differences in the climatic parameters of these two sites, such as rainfall, mean temperature and wind pattern, influence timber moisture content and hence corrosion. Detailed climatic information would be required to fully understand these macro-environment-related corrosion performance differences.

MICRO-ENVIRONMENT INSIDE TIMBER

Clearly the deterioration of metal in the treated timbers was mainly controlled by the micro-environment inside the timber – the moisture content and the active preservative species. This could also partially explain why the mild steel nails and screws and the zinc-coated screws exposed at Oteranga Bay did not exhibit a significantly higher corrosion rate than those exposed at Judgeford.

Take care with zinc-coated screws

After 3 years' exposure at either Judgeford or Oteranga Bay, almost all zinc-coated screws were heavily rusted. Little zinc coating was found on the smooth shaft section below the head of the screws embedded into the untreated or CCA treated timbers. No coating remained on their spiral sections (see Figure 3) where numerous pits of diverse morphologies were easily seen. In most cases, part of the spiral burr was corroded away.

The heavy corrosive attack on the screws was related to the nature of the zinc coatings. The screws were mechanically plated, rather than hot-dip galvanised like the nails tested. Zinc coatings formed by mechanical plating normally have a higher porosity and a lower bonding strength at the coating-substrate interface (see *Build* 117 April/May 2010, pages 34–35).

A thick and uniform coating is difficult to achieve on the spiral section, which has sharp edges and irregular surfaces. This makes these areas more vulnerable to corrosion. The driving-in process always damages the coating integrity to some extent and introduces more physical defects. As a result, zinc-coated screws are less corrosion resistant than hot-dip galvanised nails, particularly when embedded into timbers treated with copper-bearing preservatives and exposed to the atmosphere. →

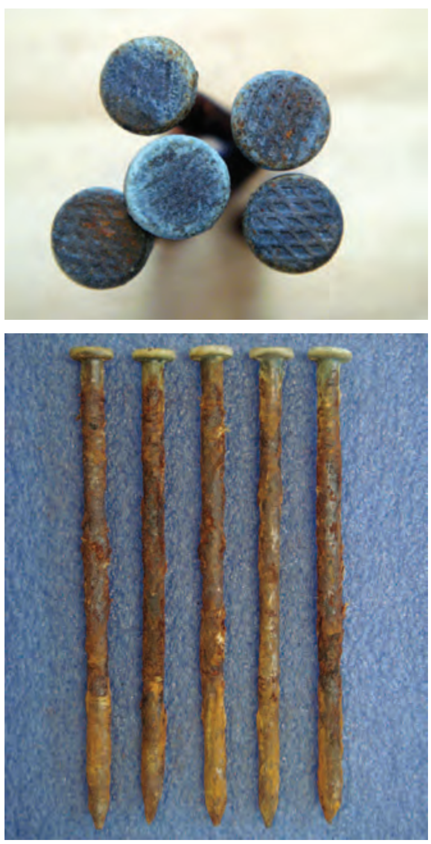

Figure 4: Galvanised steel nails embedded into H4 ACQ treated timbers exposed at Judgeford for 3 years. The condition of the zinc coatings on the head and the body were significantly different.

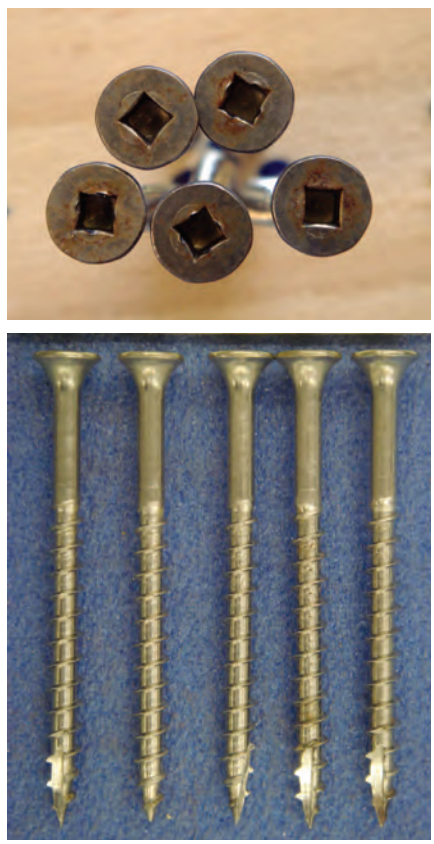

Figure 5: Stainless steel screws embedded into H4 ACQ treated timbers exposed at Oteranga Bay for 3 years. Limited rust was formed only on the head top.

Head and shank performance differs

In the field exposure tests, it was frequently observed that the head of a zinc-coated fastener was still in good condition, while its body was covered with heavy iron-rich rust. This was particularly true for nails exposed at the Judgeford site, the more benign climate (see Figure 4).

This phenomenon is a direct result of the difference in aggressivity of the atmosphere and the micro-environment inside the treated timber. The latter generally attacks the metal at a greater rate due to galvanic corrosion, with the additional influence of oxidisers introduced from the preservation treatment. Timbers treated with CuAz and ACQ have a higher retention of copper ions, leading to faster degradation of metals in contact with them.

This large performance difference between the exposed and embedded sections of fasteners makes it more difficult to identify the premature failure of metallic fasteners, unless they are extracted from the timber.

Stainless steel best for long-term durability

Stainless steel nails and screws performed very well in all combinations of preservative type and hazard class. No obvious signs of corrosion were found on their body sections.

Limited rust on the top surfaces of their heads was more frequently observed on the fasteners exposed at Oteranga Bay (see Figure 5). However, a comparison between the conditions of the rust formed after 1, 2 and 3 years indicated that this localised corrosion was progressing extremely slowly and the extent of material deterioration was not affecting the performance of the fasteners or the timber-metal assemblies.

This head deterioration was probably the result of local passivation breakdown from the hammer-in process and/or ferrous contamination transferred from the hammer head. When exposed to the marine environment, this localised corrosion can be intensified by airborne chloride ions.

BRANZ RECOMMENDS

Galvanised nails and screws in ACQ and CuAz treated timbers may not meet the 50-year durability requirement for structural connections where the timber will get wet, such as outside or in contact with the ground or concrete.

BRANZ recommends austenitic stainless steel (for example, AISI 304 and 316) or silicon bronze in these situations.

To select fasteners for 50-year durability in timber, follow the decision tree published in *Build* 118 (June/July 2010, page 29).

For more information, see BRANZ study reports including SR153 and SR213 at www.branz.co.nz, then BRANZ Shop.