STUDY REPORT

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Two-Year Field Exposure Corrosion Results

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Abstract

This short report summarises the results obtained from the second year field exposure tests carried out at BRANZ's Judgeford site. It discusses the corrosion performance of typical metallic fasteners embedded into pinus radiata treated with water-borne preservation chemicals, copper chrome arsenate (CCA), copper azole (CuAz) and alkaline copper quaternary (ACQ), to H3 and H4 treatment levels.

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1. SUMMARY

This short report summarises the results obtained from the second year field exposure test carried out at BRANZ's Judgeford site. It discusses the corrosion performance of typical metallic fasteners embedded into pinus radiata treated with water-borne preservation chemicals, CCA, CuAz and ACQ to H3 and H4 treatment levels.

2. DISCUSSION

Visual inspection showed that mild steel nails suffered uniform corrosive attack in all timbers. This was indicated by the formation of iron-rich red rust on their surfaces. On some nails inserted into CuAz or ACQ treated timbers, consumption of metal was serious, leading to observable thickness reduction in some areas. On mild steel screws, serious corrosion was mainly found in the thread area. On their shank areas, the corrosion mainly manifested as high-density small pits.

Measurements showed that the corrosion rates of the mild steel nails and screws inserted into the untreated timbers were higher than those of the nails and screws inserted into H3 & H4 CCA treated timbers. This result is different from what was observed after one year of exposure. This might be related to the enhanced hydrolysis of hemicelluloses induced by degraded lignin due to high moisture contents. However, more work is needed to verify this result and develop a better understanding of the mechanism behind it.

Deterioration of galvanised zinc coatings is observable by the formation of white products on the surface. When the zinc coating is consumed completely the steel substrate is exposed to the timber and this leads to the formation of iron-rich red corrosion products. This gives a clear indication of the progress of corrosion on galvanised items and also acts as an indicator of the aggressivity of timbers treated with different preservation chemicals.

It was observed that after two years' exposure, the formation of red rust on the galvanised nails embedded into untreated timbers and timbers treated to an H3 level with CCA, CuAz and ACQ was limited. This indicates that most areas were still protected by zinc. In timbers treated to an H4 level, in particular those treated with CuAz and ACQ, rust formation was quite obvious.

In comparison with hot-dip galvanised nails, rust was more pronounced on the galvanised screws driven into the same timbers. Thread areas appeared to be more vulnerable. Due to the presence of heavy rust, it was difficult to retrieve screws from the timbers. Some of the screws were broken. After the removal of corrosion products, it was found that on some screws, the treads were severely damaged in some areas, even to the extent of partial loss of thread. This might suggest that stresses associated with the driving-in process have damaged the zinc coating, introducing more physical defects into this area.

These morphological observations were also supported by mass loss measurements. Galvanised nails and screws in CuAz and ACQ treated timbers were losing their coatings at a higher rate than those in untreated and CCA treated timbers. In particular, timbers treated with H4 ACQ had a very high aggressivity towards the galvanised fasteners. The mass loss rate in H4 ACQ treated timber was anywhere from two to four times higher than that in CCA and CuAz treated timbers. This is much the same as observations in the previous study (SR153: The Corrosion of Metallic Fastener Materials in Untreated, CCA-, CuAz- and ACQ-based Timbers and DC1396: Preservative Leaching and Metal Corrosion in CCA, ACQ, and CuAz Treated Timbers).

Untreated H4 CCA H4 CuAz H4 ACQ

Surface morphologies of galvanised nails and screws retrieved from timbers exposed at BRANZ's Judgeford site for two years

A comparison was made between the corrosion rates of mild steel and galvanised steel fasteners obtained after the one-year and two-year field exposures. The corrosion process was found to have slowed down and this trend fits well with general observations on the rate of corrosion of metals as exposure progresses. However, abnormal behaviour was also observed with the galvanised nails inserted into H4 CCA and H3 ACQ treated timbers.

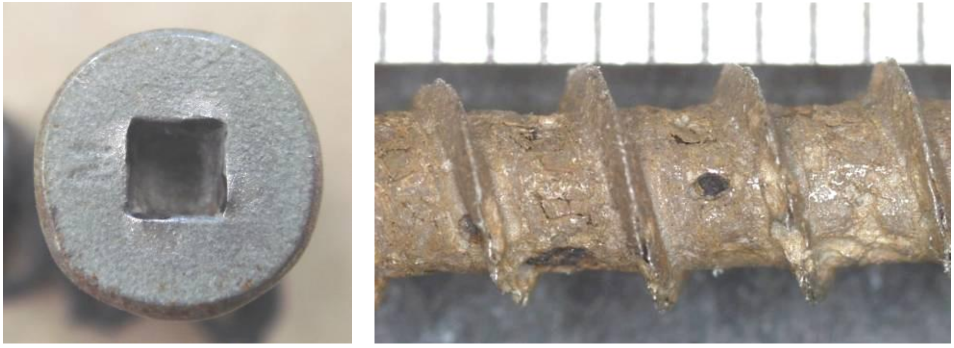
The relationship between the initial copper content in the treated timbers and the experimentally measured corrosion rate was investigated. It was shown that an increase of copper content generally led to an increase in corrosion rate. For example, the copper content in H4 ACQ treated timber is about three times as high as the content in H3 ACQ treated timber, while the corrosion rate in H4 ACQ treated timber is about twice as high as the rate in H3 ACQ treated timber. However, a decrease of corrosion rate with copper content was also observed. These results indicate that the reduction of copper ions by active metallic components of steel is not the only mechanism responsible for the fastener deterioration. Hydrolysis of wood structure, dissolution and migration of preservation components makes the environment in treated timbers very complicated and the differences in the composition of the preservatives makes this situation even more complex.

The experimental findings from this study further confirmed that CCA alternatives, ACQ and CuAz, present a higher risk for corrosion to metallic fasteners. Mild steel nails and screws, and even those protected by galvanised zinc coatings, suffered relatively serious attack in some timbers after only two years' field exposure. Based on the corrosion rate data collected from the samples retrieved after two years' exposure, the aggressivity of the timbers towards mild steel and galvanised fasteners generally obeys the following approximate sequences:

- Mild steel: CCA ≤ Untreated ≤ CuAz < ACQ
- Hot-dip galvanised steel: Untreated ≤ CCA < CuAz < ACQ

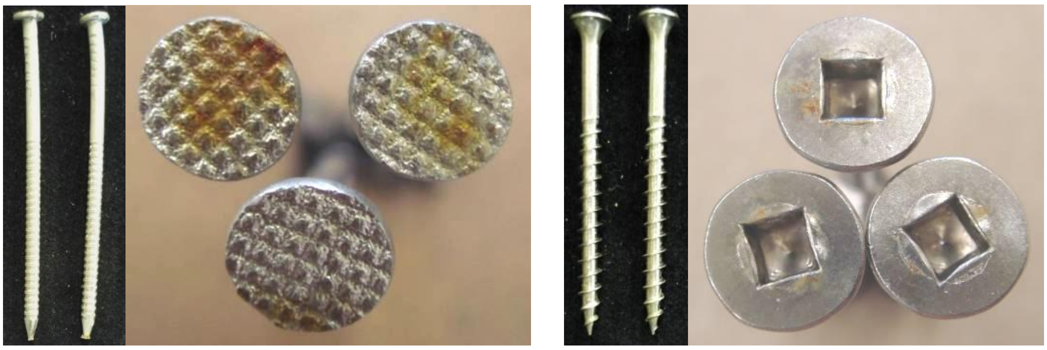
This study has also confirmed that although a hot-dipped galvanised zinc coating can provide excellent protection to mild steel components directly exposed to the atmosphere, this capability might be limited when the coated fasteners are inserted into timbers. This is particularly true for timbers treated with water-borne copper-bearing preservatives, particularly if the moisture content of these timbers will frequently be higher than the threshold moisture content, ~18-20%.

It must be noted that the conditions experienced by the head and the body section of a nail/screw can be quite different during service. In many cases, the head was still in good condition after two years' field exposure, while the body section suffered serious corrosive attack. This is a direct result of the difference in the aggressivity of the atmosphere and the micro-environment inside the timber. This difference in performance makes it very difficult to obtain any warning of the premature failure of metallic fasteners unless they are extracted from the timber structure concerned.



Morphologies of head and thread of a galvanised screw retrieved from H4 ACQ treated timber exposed at BRANZ's Judgeford site for two years

Unsurprisingly, 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 the shaft/shank of the nails and screws. Very limited rust formation was occasionally found on the top surface of the nail head. It is believed that this is a result of local passivation breakdown induced by the hammering-in process and/or ferrous contamination from the hammer head.



Stainless steel nails and screws retrieved from H4 ACQ treated timbers exposed at BRANZ's Judgeford site for two years

These experimental observations are very similar to those obtained from the samples after one year of field exposure. A comparison between the conditions of the rust formed after one year and after two years also indicated that this localised corrosion was progressing extremely slowly. Based on the results obtained from field tests carried out at the Judgeford site, BRANZ still recommends austenitic stainless steel (e.g. AISI 304 and 316) to ensure long-term durability in treated timbers (H3 and above) which will remain wet for a significant portion of their service life.

3. RECOMMENDED FURTHER WORK

It is recommended that corrosion data for metals embedded into treated timbers should be collected from other sites which have lower and higher atmospheric corrosivities than BRANZ's Judgeford site. This would allow mapping of the performance of various metallic components in timbers treated with CCA alternatives under wider New Zealand climate conditions. These tests are essential to determine the performance of galvanised and stainless steel fasteners in timber structures located in regions that are affected by marine aerosols or industrial/geothermal contaminants. In addition, field exposures of longer durations should be carried out to determine the long-term performance of stainless steel in timbers. Although commonly specified for use in durable structural components, no information on this long-term performance is currently available.