Corrosion of metal in timber and concrete

The rate at which metal elements corrode in timber and concrete depends on things like the type of metal involved, treatment of the timber, concrete strength and cover and the local atmospheric environment. A basic understanding of how corrosion occurs in these materials can help ensure that the right materials and protective measures are specified and building elements meet durability requirements.

AS WITH ALL types of corrosion, the corrosion of metals in timber and concrete requires the presence of moisture. Below a particular moisture level, corrosion will not occur because a chemical or electrochemical reaction cannot be initialised or sustained on the metal surface. In addition to moisture, the presence of substances such as chlorides in sea salt or copper from timber treatment can speed up the corrosion processes.

Corrosion of metal in timber

Corrosion in timber can involve a number of different mechanisms. There can be a reaction between the metal and the copper preservatives in the timber.

For 3 years, BRANZ tested the performance of mild steel, galvanized steel and stainless steel nails and screws in timbers treated with waterborne copper-containing preservatives, including chromated copper arsenate (CCA), copper azole and alkaline copper quaternary. The field exposure testing was done at Judgeford, a semi-rural location near Porirua, and Oteranga Bay, an aggressive marine environment facing Cook Strait.

Copper azole and alkaline copper quaternary treatments have higher levels of copper left in the timber than CCA. The trial confirmed that copper azole and alkaline copper quaternary are more corrosive than CCA. For example, at Oteranga Bay, the corrosion rate of mild steel in the H4 alkaline copper quaternary treatment was approximately 3.8 times greater than that in the H4 CCA treatment samples.

Mild steel nails/screws and mechanically plated screws in the timbers exposed at the coastal site generally had a higher corrosion rate than those at the more rural site. However, for hot-dip galvanized nails, results at the coast were not always higher than those in the country.

The corrosivity of timbers treated with copper azole and alkaline copper quaternary appears to decrease with extended field exposure. However, fasteners in these timbers may still not be durable for long-term applications because of the initial fast metal deterioration, particularly of zinc coatings.

Fastener corrosion may also lead to heavy iron stains forming in the timber treated with copper azole or alkaline copper quaternary at high hazard levels (Figure 1). This made it very difficult to remove the screws. With longer

Figure 1. Iron stains formed around zinc-coated screws after just 3 years in H4 CCA and H4 alkaline copper quaternary-treated timbers in an exposed rural environment.

exposure, the cellulose components of the timber are attacked, causing loss of strength and structural integrity – sometimes referred to as nail sickness.

Stainless steel (grade 304) 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. This is due mainly to the fact that stainless steel can develop a passive film on its surface for enhanced corrosion resistance.

Copper-based timber treatment is not the only cause of environments inside timber that are hostile to metals. Some timbers are acidic naturally and can attack metals through direct contact. In general, harder timbers are more acidic than softer timbers. Western red cedar has a pH of 3.5, for example. Acidic resins can leach out of cedar and corrode unprotected non-ferrous metals. Rain flowing over new cedar shingle roofs, picking up acids from the timber, should never be allowed to flow over zinc surfaces.

NZS 3604:2011 *Timber-framed buildings* recommends the use of stainless steel or silicon bronze fasteners with western red cedar. Western red cedar should never be fixed with mild steel, brass or copper fixings.

Corrosion of metal in concrete

Corrosion of reinforcing steel is a common cause of poor concrete durability. This is most likely to be a problem with poorer-quality concrete that is porous or has tiny cracks in it, allowing access by moisture and pollutants such as sea salt, or where there is less concrete cover to the steel. With cracks, the steel is more at risk of corrosion where cracks are bigger (more than 0.3 mm) or they run parallel to the steel rather than crossing it. Corrosion begins when the environment immediately around the reinforcing changes.

This change in the concrete can come from loss of alkalinity (reduction in pH) as carbon dioxide enters the concrete (so-called carbonation). Fresh concrete has a pH of 12.5–13. This strong alkalinity helps a passive layer some nanometers thick to develop around the reinforcing steel. When the pH in the concrete has been reduced to around 9 or less around the reinforcing steel, the protection is lost and corrosion can begin.

Chlorides (such as from sea salt) can also lead to corrosion in steel reinforcement in concrete. New Zealand concrete structures in coastal areas (B1/B2 exposure classification in NZS 3101:2006 *Concrete structures standard*) are often exposed to moist salt-laden winds. Given a high enough level of chlorides, corrosion can start even in an alkaline environment. The corrosion threat from chlorides is greater than the threat for loss of alkalinity in coastal locations. Damaged concrete is often seen very close to the sea because repeated wetting with salt-laden moisture provides the ideal situation for fast corrosion.

Rust stains and small cracks along the lines of reinforcing may become visible as the first signs of corrosion. Repairs are best undertaken at the first sign of a problem.

Rust occupies approximately three times more space than the steel it forms from, so the increasing volume created as the reinforcing steel rusts can lead the concrete cover to spall or flake off (Figure 2). In extreme cases, entire concrete structural elements can fail.

Good performance requires concrete that is free of cracks and has low permeability. The ratio of water to cement in the mix is critical. Specify the right strength of concrete mix and ensure it is properly vibrated, finished and cured. Getting this right and dealing with any problem immediately it first appears are essential to preventing corrosion of reinforcing in concrete.

NZS 3101:2006 *Concrete structures standard – Part 1: The design of concrete structures* gives minimum values for cover thicknesses to achieve minimum durability requirements. This standard has environmental conditions and exposure classifications from relatively benign environments to aggressive environments.

NZS 3604:2011 gives minimum cover requirements for concrete foundations of buildings within its scope. This standard requires 25 MPa concrete for reinforced concrete exposed to weather in coastal areas.

Figure 2. Chlorides in sea salt can lead to serious corrosion of steel reinforcing in concrete structures subject to salt winds and regular wetting.

Understanding the level of risk and specifying the correct materials for the circumstances can lead to greater durability. Where the component selected is not suitable for the timber or concrete or the environment it is exposed to, the end result is accelerated corrosion and premature failure of the component and/or loss of performance of the building system. Table 4.1 of NZS 3604:2011 requires that, in exposure zone D, all structural fixings in sheltered and exposed locations (excluding nails and screws) are stainless steel (minimum grade 304).

The timber or concrete itself should also be carefully selected, manufactured and maintained to ensure the durability of metals inside or in contact. For example, reinforcing steel in concrete in a very exposed coastal environment will be better protected from corrosion if a better grade of concrete is specified with higher cover to the steel or if reinforcing steel with a significantly enhanced corrosion resistance is used.

Reinforcing steel with better corrosion resistance

Hot-dip galvanized zinc coating has been used to protect reinforcing steel from corrosion in concrete structures and elements and provide a safeguard against premature cracking and rust staining. This enhanced corrosion protection is due mainly to the fact that galvanized steel has a substantially higher chloride threshold for corrosion compared to uncoated steel and is resistant to the effects of carbonation in concrete.

The zinc coating can delay the initiation of corrosion and continue to provide effective barrier protection during the ensuing period when the coating remains intact.

Hot-dip galvanized reinforcing steel has been used in concrete structures and elements exposed to a range of environmental conditions, including coastal, industrial and chemical. It has also been used in building and construction for both cast-in-place and precast concrete elements.

Stainless steels, including grades 304 and 316, have been used as reinforcement in concrete structures where long-term corrosion performance and durability are a big concern. Stainless steels are selected due mainly for their corrosion resistance, mechanical strength and long durability. Typical applications for stainless steel reinforcing bars have historically included bridges, piers and seawalls subjected to corrosive conditions.

Compatibility with aluminium

Aluminium and aluminium alloys have good corrosion resistance to concrete when it has set but should be separated from fresh concrete or cement-based products. Avoid allowing water to flow over concrete or other cement-based products and then on to uncoated aluminium. This is because alkaline products released from freshly mixed concrete may be sufficient to produce an unsightly stained appearance on aluminium.

Conclusion

The corrosion rates of metallic building elements used in timber and concrete depend on the timber treatment, the quality of the concrete and the cover for the metal and the local atmospheric environment.

Further reading

BRANZ Facts: Metal corrosion in New Zealand buildings #1 *Corrosion in coastal buildings*

BRANZ Facts: Metal corrosion in New Zealand buildings #2 *How metals interact in the built environment*

BRANZ Facts: Metal corrosion in New Zealand buildings #3 *Corrosion over the building envelope*

BRANZ Research Now: Positional corrosion #1 *The impacts of natural elements on different parts of the building envelope*

BRANZ Research Now: Positional corrosion #2 *How different micro-environments around a building envelope affect material corrosion*

BRANZ Bulletin 649 *Corrosion of metals in New Zealand buildings*

BRANZ Bulletin 631 *How micro-environments affect material performance*

BRANZ Bulletin 574 *Preventing corrosion of reinforcing steel in concrete*

Choosing a nail or screw for 50-year durability, Build 118, June/July 2010

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