Corrosion in coastal buildings

Sea salt in coastal atmospheres can significantly increase the rate of corrosion of metals used in construction. Having a basic understanding of how this happens and how it can be reduced or managed can lead to buildings with greater performance and a longer service life.

ATMOSPHERIC CORROSION requires the presence of moisture and oxygen. Below a particular moisture level, corrosion will occur extremely slowly because there is not enough moisture to create an electrolyte layer on the metal surface.

When atmospheric pollutants such as sea salt dissolve in the moisture layer on a metal, they can significantly increase the rate of corrosion. This explains why corrosion is a more serious problem for coastal buildings.

Chlorides from sea salt are the main pollutant affecting corrosion in New Zealand. Many New Zealand buildings are within 5 kilometres of the coastline, but even buildings further away can be vulnerable. BRANZ testing has found that winds sweeping over the ocean can carry salt particles more than 20 kilometres inland.

BRANZ has tested the performance of mild steel, galvanised steel and stainless steel components in both coastal and rural locations. Mild steel and galvanised steel components exposed at the coastal site generally had a higher corrosion rate than those at the rural site (Figure 1). The accelerated corrosion at the coast was partly due to airborne salt particles being deposited on the surface of the fasteners.

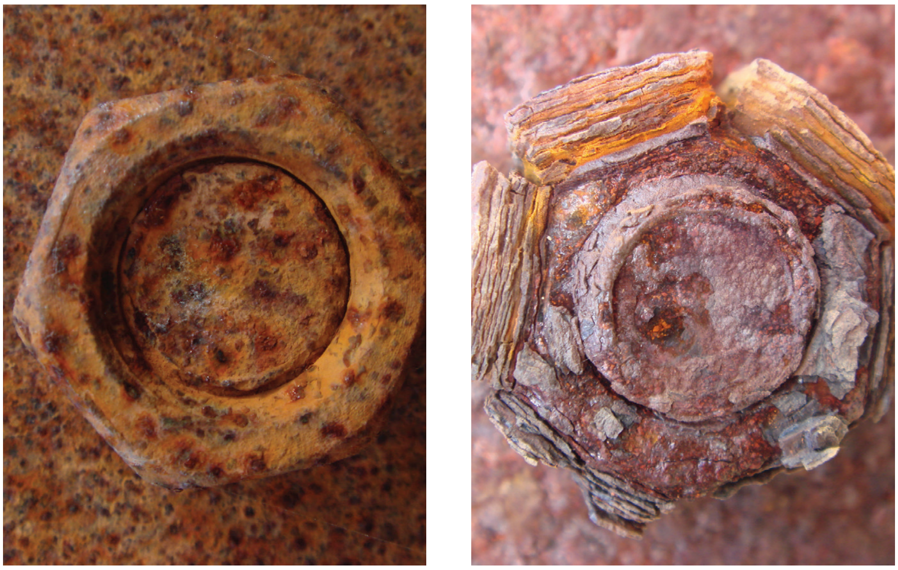

Figure 1. Mild steel nuts after 3 years' exposure to a rural atmosphere (left) and a severe marine atmosphere (right).

Environmental categories and maps

The severity of coastal environments is categorised by a number of local and international standards.

NZS 3604:2011 *Timber-framed buildings* has exposure zone (atmospheric corrosivity) maps dividing New Zealand into zones B, C and D, depending on the severity of exposure to wind-driven sea salt (Figure 2):

- Zone B (low): inland areas with little risk from wind-blown sea-spray salt deposits.
- Zone C (medium): inland coastal areas with medium risk from wind-blown sea-spray salt deposits. Mainly coastal areas with relatively low salinity.
- Zone D (high): coastal areas with high risk of wind-blown sea-spray salt deposits. It includes all areas within 500 m of the coast including harbours, 100 m from tidal estuaries and sheltered inlets, all offshore islands and all other areas shown in white in the map.

Acceptable Solution E2/AS1 also has a zone E (severe marine – breaking surf beach fronts) for material selection in Table 20. The corrosion protection requirements for structural fixings in zones D and E are the same, so zone E does not appear in NZS 3604:2011. (Zone E in E2/AS1 is also effectively the same as atmospheric corrosivity category E in AS/NZS 2728:2013 *Prefinished/prepainted sheet metal products for interior/exterior building applications – Performance requirements*.)

Other categorisations subdivide coastal environments according to the level of risk. For example, AS/NZS 2312:2014 *Guide to the protection of structural steel against atmospheric corrosion by the use of protective*

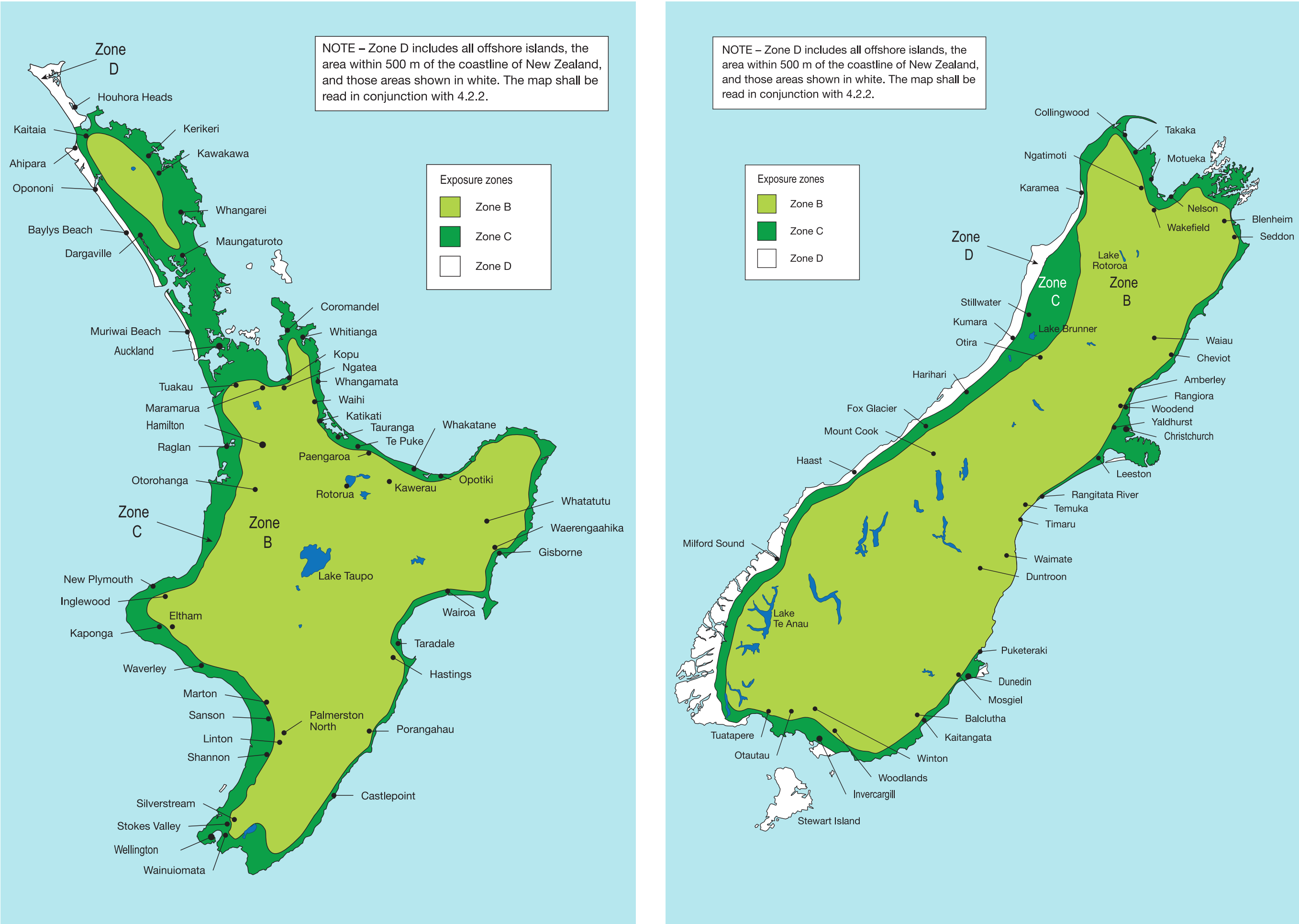

Figure 2. Exposure zone maps in NZS 3604:2011.

coatings (Parts 1 and 2) describes coastal environments with several categories:

- Category C3 (medium): generally covers the area 50–1,000 m from the shoreline. Around sheltered bays, it can extend from 100 m from the shoreline to approximately 3–6 km inland. In coastal areas with breaking surf and significant salt spray, this category can extend from approximately 1 km inland to 10–50 km inland.
- Category C4 (high): mainly found on the coast. It extends up to 50 m inland from the shoreline around sheltered bays. In areas with rough seas and surf, it could extend from several hundred metres to approximately 1 km inland.
- Category C5 (very high): generally found on offshore islands and beachfront in regions with rough seas and surf beaches. It can extend inland for several hundred metres.
- Category CX (extreme): found at some surf beach shoreline regions with very high salt deposition.

Manufacturers sometimes use these corrosion risk categories when indicating whether a specific product is recommended for a particular environment. They may also recommend a product for one use but not another in a given environment. For example, a profiled metal sheet product may be recommended for roofing in a severe coastal environment (because the whole surface will receive rain washing) but not for wall cladding.

Micro-environments

While the presence of salt particles can increase corrosion risk in coastal environments in general, there is another issue to consider when assessing corrosion risks over the building envelope and specifying metallic building materials and/or their protection measures – micro-environments.

Different micro-environments exist around buildings, bringing different levels of risk or corrosivity largely due to whether a particular part of a building is washed by rain, exposed to the sun and/or subject to salt deposits.

Section 4 *Durability* of NZS 3604:2011 defines three main micro-environments:

- Closed: dry, internal location not subject to airborne salts or rain wetting.
- Sheltered: open to airborne salts but not rain washed.
- Exposed: open to airborne salts and rain wetting.

Metal building components in these micro-environments are affected differently by climatic factors such as wind-driven rain, temperature, UV irradiation and also salt deposition and therefore require different levels of protection to achieve the durability expected. See BRANZ Facts: Metal corrosion in New Zealand buildings #3 for more details.

BRANZ has tested the condition and corrosivity of micro-environments on a number of buildings across the country, including one on the BRANZ Judgeford campus approximately 5 km from a saltwater estuary and an Auckland building within 500 metres of the harbour.

- On the BRANZ campus building, higher

positions – more sheltered from wind-driven rain – generally collected more salt deposits than lower positions on the same wall. This did not automatically mean a faster corrosion of metals in sheltered positions, however. Nails embedded in H3.2 CCA-treated timber blocks installed in the exposed position showed significantly more corrosion than the nails in the sheltered position.
- On the Auckland building, the sheltered position collected approximately 3–8 times more salt deposits than the exposed position, supporting the understanding that the sheltered areas see much less rain washing and thus more salt particles remain in place. Despite this, the corrosion rate in the sheltered position was lower than that in the exposed position for each wall. Sometimes the rate was almost half, although for the north wall, the corrosion rates at these two positions were broadly similar. As with the BRANZ campus building, nails embedded in H3.2 CCA-treated timber blocks in exposed positions also had rates of corrosion considerably higher than those in sheltered positions.

BRANZ is continuing corrosion research into micro-environments on other buildings in other New Zealand regions. The findings so far suggest that, in areas with weak marine influences, the presence of salt alone does not automatically increase the risk of corrosion. Higher moisture levels and longer wet periods in exposed areas most likely see higher levels of corrosion.

BRANZ is also investigating the conditions and corrosivity of micro-environments on a building in a severe marine environment.

How different metals react

Looking at corrosion in coastal locations, BRANZ has found significant differences in the corrosion risks of different types of metals:

- **Mild steel** is much more vulnerable to corrosion than other types of steel. Mild steel without effective surface protection is not normally used where it will be exposed to coastal environments. Its corrosion products tend to form into porous layers that are prone to cracking and can even flake off from the underlying steel.
- **Galvanised steel** has a zinc coating for enhanced corrosion protection when compared with mild steel. Zinc can form protective layers to completely cover the surface, resulting in corrosion that proceeds at a greatly reduced rate. When exposed to marine environments, chloride-containing particles can deposit to initiate localised corrosion or pitting. This could lead to local breakdown of the protective layers. However, corrosion is not as great as might be expected. Atmospheric corrosion of zinc is influenced by the concentration of airborne salt. A linear relationship between the corrosion rate of zinc and the chloride deposition rate has been demonstrated within some studies.
- **Stainless steels** contain chromium and are much more resistant to corrosion in coastal environments than mild steel or galvanised steel. This significantly increased corrosion resistance is due to the passive film spontaneously formed on the stainless steel surface. This thin film is composed primarily of chromium-rich oxide and/or oxyhydroxides. When exposed to marine environments, this protective film could be partly damaged by the deposition of chlorides, leading to localised corrosion or pitting. Grade 316, a typical austenitic stainless steel with approximately 2–3% (by weight) molybdenum, is more resistant to pitting and crevice corrosion in coastal environments than grade 304.
- **Aluminium** exhibits good corrosion resistance when exposed to most natural environments. This is because its high affinity for oxygen allows the rapid formation of an adherent, continuous and corrosion-resistant oxide layer onto its surface. Its corrosion often takes the form of pitting rather than a uniform surface change when exposed to adverse environments such as marine environments. Anodisation is widely used to improve its corrosion resistance. Long-term testing confirms that well sealed anodised coatings on aluminium can provide good protection to the underlying metal in marine environments.
- **Copper** generally has high corrosion resistance in most natural environments. This is because its corrosion products can build up to provide a reasonably good physical barrier. Sodium chloride (NaCl) from sea salt particles can accelerate the breakdown of the naturally formed and protective copper oxide through the formation of copper chloride complexes, especially at high concentration of chlorides and high ambient relative humidity. Below a certain threshold for atmospheric salinity, (approximately 20 mg/m^2/day of chlorides), copper in coastal buildings behaves as it does in rural buildings. Typical corrosion rates of unprotected copper in marine environments have been reported around 1 μm/year, although the initial rate could be higher.
- **Zinc** is used largely as a protective coating for steel components such as fixings. When zinc is effectively protecting the steel substrate, it undergoes corrosion and will be consumed gradually over time. Its corrosion rate can be high in severe marine environments due to the negative influences of chloride deposition on the composition and micro-structure of the growing corrosion product layers.

Metal building products designed for coastal environments are often alloys and often coated. For example, one widely used steel profiled metal roofing product made for coastal environments has a 45% zinc/55% aluminium alloy coating, a corrosion-resistant primer and a baked-on multi-coating paint system. When corrosion takes place, it normally begins in the zinc-rich region of the alloy coating and creates a physical barrier against further attack. Aluminium-zinc alloy coatings generally have much higher corrosion resistance, therefore longer durability, over hot-dip galvanised zinc coatings of similar thickness in marine environments.

Coastal corrosion of steel in concrete

Moisture and sea salt can increase the risk of corrosion of reinforcing steel in concrete exposed to marine environments. This is most likely to be a problem with poorer-quality concrete or where there is less concrete cover to the steel. The moisture and sea salt work their way in through porous concrete or tiny cracks. Because rust occupies three times more space than the steel it forms from, the increasing volume created as steel rusts can lead concrete to spall or flake off. In extreme cases, entire concrete structural elements can fail. Corrosion of concrete reinforcing steel is a common cause of poor concrete durability in New Zealand.

One solution to this is more concrete cover to the reinforcing and better-quality concrete. 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.

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 to aggressive environments.

Another solution for enhanced durability is using reinforcement with higher resistance to chloride-induced attack. This typically includes hot-dip galvanised steel and/or stainless steel that can minimise the risk of steel corrosion and concrete spalling and make a cost-effective contribution to the durability of the concrete.

The importance of maintenance

Maintenance is essential for acceptable building performance, durability and appearance. Coastal environments close to breaking surf beaches require more frequent maintenance than benign rural environments.

Regularly checking the condition of buildings and building elements is the first step. Beyond this, Acceptable Solution B2/AS1 says that basic maintenance tasks include:

- washing down surfaces regularly, particularly exterior building elements subject to wind-driven salt spray
- recoating protective finishes
- replacing corroded metallic building elements
- replacing sealant and seals.

Obtain and follow the maintenance recommendations of product manufacturers and/or suppliers. For example, a large New Zealand manufacturer of sheet steel claddings says that, for its wall claddings, unwashed and high-risk areas require manual washing every 3 months in the most severe environments and 6 months or annually in other environments.

Conclusion

Chlorides from sea salt are the main pollutant affecting corrosion in New Zealand, and winds can deposit chloride particles on buildings more than 20 kilometres inland. Design and specification of buildings in coastal areas requires close attention to the level of corrosion risk and the specification of materials and their protective measures. Table 4.1 of NZS 3604:2011 requires that, in exposure zone D, all structural fixings (excluding nails and screws) in sheltered and exposed locations are stainless steel (minimum grade 304).

Buildings in severe marine environments, such as closer to breaking surf beaches, require more frequent maintenance, in particular, washing to remove salt deposits.

More-recent BRANZ field research from 2016–2018 (BRANZ Study Report SR458) again assessed first-year metal atmospheric corrosion rates at coastal sites. Comparing these results against the results of tests done in the 1980s showed significant increases in corrosion rates over the period for mild steel and even more so for zinc.

- At Whakatāne Airport, corrosion rates had increased 66% for mild steel and 86% for zinc.
- At Waihī Beach, corrosion rates had increased 32% for mild steel and 48% for zinc.

Assessment of this more-recent research also suggests that, in coastal areas from Te Puke to Whakatāne and from Ōpōtiki to Waihau Bay, the zone C boundary on the exposure zone map in NZS 3604:2011 should be moved slightly further inland. An updated atmospheric corrosivity map suggested for the Bay of Plenty region appears as Figure 9 in BRANZ Study Report SR458.

Further reading

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 Facts: Metal corrosion in New Zealand buildings #4 *Corrosion of metal in timber and concrete*

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*

BRANZ Study Report SR458 *Atmospheric corrosivity of the Bay of Plenty region.*