Compatibility of aluminium and steel

Building materials are often paired - think of wood and metal - but this is not always trouble-free. In particular, when aluminium and stainless steel are used together, there may be corrosion problems.

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MATERIALS SUCH AS concretes, metals, polymers and timbers used in the construction industry are frequently mixed to deliver desirable aesthetic, structural and weathertightness functionalities.

Mixing materials matters

Sometimes, this mixed-material design can lead to compatibility issues, such as stained surfaces or accelerated degradation, particularly in highly corrosive environments.

One example is the accelerated corrosion of hot-dip galvanized nails when driven into wet timbers treated with certain copper-bearing preservatives.

Another is when two dissimilar materials not in direct contact with each other are subjected to water run-off such as water flowing from a prepainted steel surface that can induce premature failure of galvanized steel installed underneath it (Figure 1).

Figure 1: Water run-off from a prepainted steel surface can damage galvanised steel installed underneath.

Concerns when aluminium and stainless steel paired

Aluminium and stainless steel are a material pairing that often gets attention and that has long been used where long durability is essential to the integrity and performance of buildings.

In certain circumstances, depending on design or installation, this can lead to a high corrosion risk and, therefore, premature failure of the aluminium components. In other circumstances, no significant corrosion has been observed.

What happens and why?

The science behind this is galvanic corrosion. It is a process driven by the electrochemical potential difference between two dissimilar metals that are electrically connected with the presence of an electrolyte - for example, a water layer.

Aluminium is active and has an electrochemical potential ranging from -0.76 to -0.99 V in seawater.

Stainless steel – for example, grade 304, the most widely used stainless steel in New Zealand buildings – has a more positive potential than aluminium. When a passive thin chromium-rich oxide film forms on its surface, grade 304 has a potential ranging from -0.05 to -0.13 V. When this film is destroyed, the potential ranges from -0.45 to -0.57 V.

When these two materials are in contact, there is a potential difference larger than 0.2 V. Consequently, this can set up a galvanic corrosion cell and a corrosion risk for aluminium.

Other factors also matter

Galvanic corrosion can be severe under fully immersed conditions. In atmospheric environments, this will occur when the contact area is wet enough for long timeframes. These depend on local climatic conditions, including quantity and frequency of rain, evaporation rate and time of wetness.

In benign atmospheric environments, moisture condensation or rainwater with limited dissolution of corrosive media can bridge the contact between these materials. However, galvanic corrosion is slow. In marine environments, salt particles can deposit around the contact to significantly increase the conductivity of the moisture and water layer, resulting in a greater risk of corrosion.

The relative surface areas of the two pairing metals are extremely important to the actual galvanic corrosion risk. In most natural environments, this risk can be significantly decreased if the more active metal has a much larger relative surface area to the less active metal.

Distance also plays its role. Galvanic corrosion under atmospheric conditions will generally be localised around the point of contact. It will decrease with distance away from the contact area.

Where the two can be used safely

Aluminium and stainless steel can be used together safely in exposure zones B and C as defined by the atmospheric corrosivity map in NZS 3604:2011 *Timber-framed buildings*.

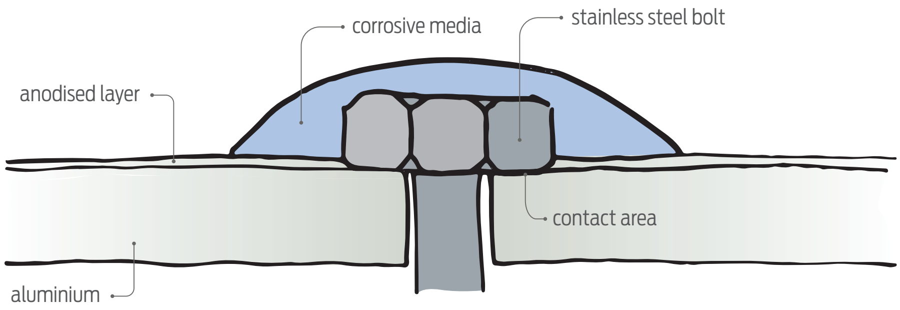

Figure 2: Contact between stainless steel fastener and partially damaged anodised aluminium sheet.

In exposure zone D where marine influences are severe, it would be wise to avoid direct contact between these materials. However, if the stainless steel element is small compared to the aluminium and their exposure to seawater or salt-laden moist air is minimal, the corrosion of aluminium will only marginally increase. An example of this is the use of stainless steel bolts, screws or rivets in aluminium window frames.

Where they cannot be used safely

A significantly increased corrosion risk for aluminium due to its contact with stainless steel may present:

- in areas where moisture or rainwater can be retained or trapped permanently or for long periods of time
- at the assembly points of roof or wall claddings exposed to substantially humid and aggressive atmospheric environments – for example, coastal or heavily polluted industrial areas.

When anodised aluminium sheets or panels are fixed with stainless steel fasteners, the thin anodised layer could be partially damaged – for example, by the formation of small cracks.

A small area of aluminium substrate would then be exposed and could be in

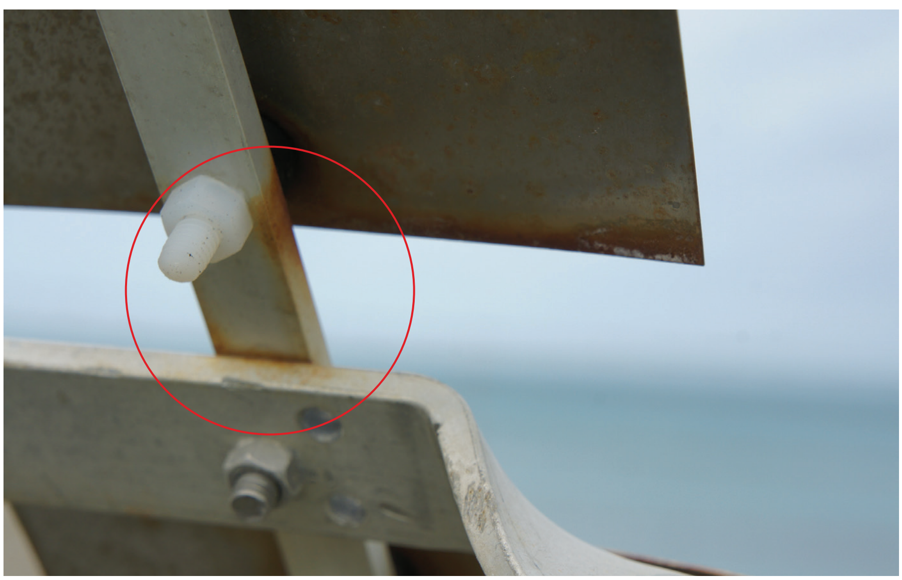

Figure 3. Stains on aluminium due to water run-off from a corroding stainless steel (grade 304) surface in a severe marine environment.

contact with stainless steel (Figure 2). This may cause localised increased galvanic corrosion of the aluminium in highly corrosive environments.

In very severe marine environments, stainless steels (for example, grade 304) may still corrode. Water run-off may result in unpleasant staining or superficial corrosion on the aluminium components installed below (Figure 3).

Preventing galvanic corrosion

Galvanic corrosion requires the following three conditions to be met at the same time:

- Different types of metals.
- Presence of an electrolyte at their contact areas.
- Electrical continuity between the two metals.

The best way to prevent galvanic corrosion is to avoid using dissimilar metals. If this cannot be achieved, consider these approaches:

- Design to minimise the retention of moisture and water and deposition of dust, salt particles or particulate matters around the contact area.
- Use durable, non-conductive spacers or washers of appropriate thickness to break the conducting path. A polymeric paint on aluminium may not always provide electrical isolation during the expected lifespan of this arrangement since it can deteriorate under the influences of heat, light or chemicals. It can also be mechanically damaged by other components such as fasteners.
- Apply durable polymeric coatings to isolate the whole joint area from the environment. This approach is popular in the building and construction industry for isolation between fasteners and roofing steel sheets.

Available guidance

Material compatibility should be considered during the design, construction and maintenance stages of building. General guidance on building material compatibility can be found in:

- E2/AS1 Table 21 *Compatibility of materials in contact* and Table 22 *Compatibility of materials subject to run-off*
- BRANZ Bulletin 519 *Fasteners selection*
- *NZ Metal Roof and Wall Cladding Code of Practice* v3.0 Table 4.10.3C *Material compatibility*.