Corrosion over the building envelope

The risk of corrosion is different on different parts of the building envelope. Understanding this and specifying the appropriate metals and protective measures for the different locations will help ensure buildings and building materials have significantly greater durability and longer service lives.

WHEN CONSIDERING the different levels of risk of corrosion to metallic building materials, geographical location often comes to mind first. Everyone understands that coastal areas with sea salt on the breeze and geothermal areas with sulphur-containing gases have a higher risk of corrosion than rural areas.

There is also significant risk difference around the building envelope, however, largely due to whether a location is washed by rain and/or subject to salt deposits. The New Zealand Building Code and construction standards take this into account.

NZS 3604:2011 *Timber-framed buildings* addresses durability, defining three main micro-environments over the building envelope:

- Closed – a dry internal location not subject to airborne salts or rain wetting. Inside the roof space is an example.
- Sheltered – open to airborne salts but not rain washed. In general terms, these are the areas above a 45º line from the lower edge of a projecting weathertight structure such as a floor, roof or deck (see Figure 1).
- Exposed – open to airborne salts and rain wetting. In general terms, these are the areas below a 45º line from the lower edge of a projecting weathertight structure.

Tables 4.1, 4.2 and 4.3 in NZS 3604:2011 set out the requirements for steel fixings and fastenings in the different environments. Hot-dip galvanised steel may be acceptable for a sheltered location while an exposed location requires grade 304 stainless steel, for example. In sheltered locations, steel brackets require galvanising of 390 g/m^2, while 600 g/m^2 is required in exposed locations.

Micro-environments

While existing requirements in NZS 3604:2011 and elsewhere acknowledge the presence of different environments around a building, BRANZ has been researching the topic in greater detail, including buildings in coastal, rural, industrial and geothermal environments. The work has involved measuring sun, rain, wind and wind-blown sea salt in different positions on the building envelope and the corrosion of mild steel plates and mild steel nails in H3.2 CCA-treated timber blocks.

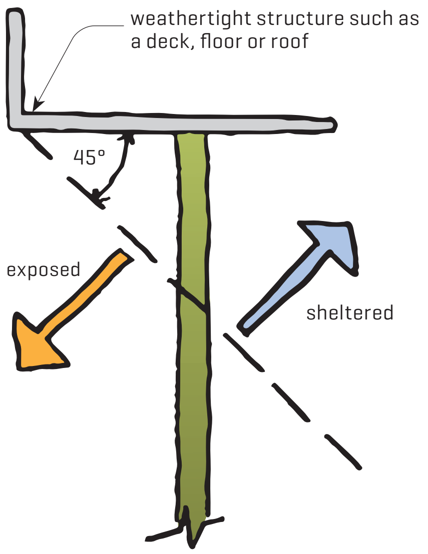

Figure 1. The definitions of sheltered and exposed as given in NZS 3604:2011.

Results confirm that these micro-environments can be very different from each other and also from the surrounding atmospheric environment, providing different levels of corrosion risk.

The influences that micro-environments have on material performance include:

- severity of the atmospheric environment (rural, marine, industrial, geothermal)
- type and concentration of pollutants (sea salt, sulphur-containing gases such as hydrogen sulphide and sulphur dioxide)
- geometry and orientation of the building
- in-service configuration of the materials (vertical, horizontal, tilted).

Moisture is required for corrosion. Measuring where wind-driven rain lands on a building is key to understanding corrosion risks. Rainwater entering gaps on a material surface may accelerate degradation. Rain washing may remove some loose corrosion products, exposing fresh material surfaces to further attack. On the other hand, rain could wash dust and salt off surfaces partly or completely depending on its quantity and frequency – particularly in marine environments where chloride-containing salt particles can contribute to corrosion – slowing down material degradation.

Figure 2. Measuring equipment installed on the BRANZ test building at Judgeford (semi-rural environment).

Test in a semi-rural environment

A test building in BRANZ's semi-rural Judgeford campus (approximately 5 km from a saltwater estuary) was used for one trial (Figure 2), with the following findings:

- As might be expected, the lower position on each wall generally received more wind-driven rain – up to 3–5 times more – than the higher position. Roof eaves restrained rain access to the area immediately below.
- Sheltered wall areas (which receive less rain washing) often collected the most salt, and higher positions on a wall collected more salt than lower positions.
- On the north wall, a steel plate sample fixed horizontally in the exposed position showed significantly greater corrosion than that in the sheltered position. With a sample fixed vertically, there was little difference. For a steel plate sample inclined at a 45º angle, the sheltered position showed a greater corrosion than the exposed position.
- On the south wall, all the exposed samples showed significantly greater corrosion than the sheltered samples.
- Corrosion rates of mild steel nails in H3.2 CCA-treated timber blocks installed at different locations on the building were also measured after 1 year's exposure. On both north and south walls, the nails in the exposed position showed significantly more corrosion than the nails in the sheltered position. Higher moisture levels were clearly the dominant factor.

Test in a maritime environment

A test building in Auckland, close to the Auckland Harbour Bridge and within 500 metres of seawater, showed these preliminary findings:

- The sheltered position under the eave or window awning collected approximately 3–8 times the amount of salt than the exposed position, supporting the understanding that the sheltered areas see much less rain washing and thus more salt remains in place.

- The corrosion rate in the sheltered position was lower than that in the exposed position for each wall for both steel plate samples and mild steel nails in H3.2 CCA-treated timber blocks.
- Horizontal steel plates showed greater corrosion than plates installed at 45º and vertically, but the biggest difference was that the plates at 45º showed much higher corrosion (more than double in some cases) than those installed vertically.
- The environment on the building envelope appears to be less corrosive than the atmospheric environment surrounding the building.

More-recent field research was carried out on a building in a severe marine environment (see BRANZ Study Report SR457).

- In this severe marine environment (Waihau Bay in eastern Bay of Plenty), corrosivity was greater on the south and west walls of the test building (directly exposed to the marine environment) than the surrounding atmosphere. The corrosivity of the surrounding atmosphere was, in turn, greater than or approximately the same as the corrosivity on the north and east walls.
- On the Waihau Bay building, the sheltered positions on the north, south and west walls (the west wall faces the sea) collected approximately 2–4 times more deposits than the exposed positions.
- The mild steel samples on the north and east walls were corroding slower than those exposed to the atmosphere and facing towards north and east. The samples on the south wall were corroding faster than those exposed to the atmosphere and facing towards south. The highest difference can be approximately 4 times. On the west wall, the 45º inclined samples were corroding faster than those exposed to the atmosphere, the 90º inclined samples were corroding slightly slower than those exposed to the atmosphere.
- The corrosion rates of the mild steel samples on the building depended on the wall orientation. Corrosion rates observed on the south and west walls were similar and much greater than the walls to the east and north, which were also similar. The south and west walls had a much higher corrosivity than the north and east walls in both sheltered and exposed positions. The prevailing winds were from the west (sea) and east (farms on hill). The west and south walls would be exposed to the marine environment when considering the actual orientation of this building. The south wall surfaces received the highest salt deposits in both sheltered and exposed positions. This may contribute to the high corrosivity observed on the south wall. However, the high corrosivity on the west wall might not be well explained with salt deposition only.
- The corrosion rate of mild steel nails driven into H3.2 CCA-treated timber blocks in the sheltered position on the west (sea-facing) wall was approximately double the corrosion rates in the sheltered positions on the north, south and east walls.
- The nails in the timber blocks in the exposed position had a corrosion rate approximately double those in the sheltered position on the same wall. This is particularly true for the north, south and east walls. On the west wall, the nail corrosion rate in the sheltered position was similar to that in the exposed position.

Test in a geothermal environment

A test building in Rotorua near the geothermal area of Sulphur Bay showed these findings:

- The averaged concentrations of hydrogen sulphide (H_2S) and sulphur dioxide (SO_2) during a 3-week monitoring period were uniformly distributed around the test building, with no significant difference related to wall orientation, height or position (exposed or sheltered).
- A weak height effect was observed with metal corrosion raes on the building. The corrosion rate in a lower position (1 m above ground) could be approximately 1.2–1.4 times higher than that in a higher position (2.6 m above ground) on the same wall.
- Horizontal steel plates in the high sheltered position had approximately 10–19 times less corrosion than horizontal plates in other locations, while the corrosion on the 45º and vertical plates was approximately 2–3 times lower than other locations. This demonstrates yet again the protection that shelter (eaves) gives.
- In general, the micro-climates on this building were less corrosive than the surrounding atmospheric environment.

The southeast and northeast walls of the test building face towards Sulphur Bay, a large geothermal source. The wind could carry sulphur-containing gases from here to the test building. This may explain part of the findings around corrosion on different walls:

- The mild steel samples installed on the southeast and northeast walls, particularly those fixed at 45º and 90º inclines, had corrosion rates higher than those on the southwest wall.
- Mild steel nails driven into H3.2 CCA-treated timber blocks fully exposed to the atmosphere had a corrosion rate higher than those installed on the southwest wall (approximately 2.5 times). However, this corrosion rate was lower than those of the nails installed on the southeast wall (except the high exposed position) and northeast wall of the building.
- The corrosion rate of the nails installed in the low exposed position on the southeast wall was approximately 2 times higher than that of nails in the high exposed position. On the southwest and northeast walls, nail corrosion rate was not related to height.
- On the southwest wall, the nails installed in the sheltered position had a corrosion rate approximately 3 times lower than those installed in the exposed positions. This is similar to the observation with mild steel samples.

Maintenance

Maintenance is essential for acceptable building performance, durability and appearance. Acceptable Solution B2/AS1 says that basic maintenance tasks include:

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

The presence of different micro-environments around a building clearly has an impact on the maintenance required. While some surfaces may be regularly washed by rain, for example, others are not and require manual washing.

Obtain and follow the maintenance recommendations of product manufacturers and/or suppliers, looking particularly for what they recommend for different areas on the building envelope. 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

Micro-environments over a building envelope are created by local weather and climate conditions, the type and levels of atmospheric pollutants and the geometry and orientation of buildings. In many cases (but not all), the corrosivity in exposed positions is slightly higher than or similar to sheltered positions.

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 #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 Research Now: Positional corrosion #3 *Positional material deterioration over the building envelope of a coastal building*

BRANZ Research Now: Positional corrosion #4 *Positional material deterioration over the building envelope of a building in a geothermal area*

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 SR457 *Positional material deterioration over the building envelope*