How different micro-environments around a building envelope affect material corrosion

The performance of building materials such as metal fixings depends partly on where they are installed on the building envelope. BRANZ is researching the differences between micro-environments and the degradation of materials within them. The long-term goal is to provide comparative and comprehensive data that can help make our houses more durable.

Corrosion rates of mild steel samples

Many New Zealand buildings lie within 5 km of the sea, and sea salt is widely accepted as the primary factor accelerating corrosion. It is assumed that sheltered areas on a building collect more salt particles than exposed areas because rain doesn't wash the salt away. The common expectation is that metals in sheltered areas will corrode faster than those in exposed areas.

This research measured the first-year corrosion rates of mild-steel samples intsalled in different positions. The preliminary results available on this test building show the following (Table 1):

- In general, samples on the test building on the BRANZ campus showed a lower corrosion rate than samples fully exposed to the atmosphere.
- In almost every case for samples on the building, the horizontal samples showed the highest corrosion, followed by the 45° inclined samples and then the vertical samples. The biggest difference was between the 45° inclined samples and the vertical samples. The inclined samples could corrode at a rate 2-3 times higher than the vertical samples.
- On the south wall, for each of the samples, the exposed position showed significantly greater corrosion than the sheltered position.

Testing and the test building

The research is being carried out on a test house at the BRANZ campus at Judgeford, a semi-rural environment. It is around 5 km from the nearest saltwater (a tidal estuary) and protected by hills from the sea. Long-term monitoring indicates the corrosivity classification as:

- between the top of C2 and the bottom of C3 in ISO 9223: 2012 *Corrosion of metals and alloys - Corrosivity of atmospheres - Classification, determination and estimation*
- between zones B and C in NZS 3604:2011 *Timber-framed buildings*.

The small rectangular building has fibre-cement wall cladding and aluminium/zinc alloy-coated steel roofing on a pitched roof.

Micro-environmental conditions are monitored at three positions - sheltered (under the eaves), fully exposed and the sheltered/exposed boundary (Figure 1). Mild steel samples were installed horizontally, vertically and at 45° to the ground.

Corrosion at the different positions was assessed after 1 year and also measured against samples not on the building but exposed to the general atmospheric environment.

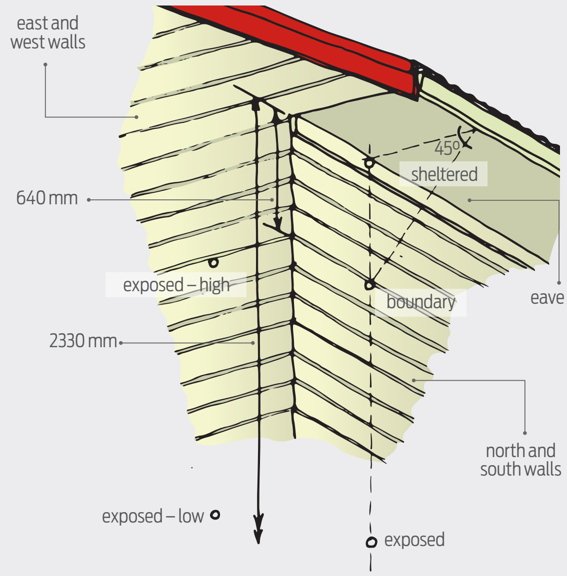

Figure 1. Monitoring positions on the building envelope. Only exposed positions at two heights were monitored on east and west walls.

- On the north wall, the horizontal sample in the exposed position showed significantly greater corrosion than that at the sheltered position. With the vertical sample, there was little difference. For the 45° inclined sample, the sheltered position showed greater corrosion than the exposed position.

Unexpectedly, the monitoring results indicate that the sheltered locations on buildings do not necessarily have a higher corrosivity.

Sheltered areas collect more salt deposits than exposed areas due to the lack of efficient rain-washing. This was supported by the monitoring of salt deposition and wind-driven rain reported in BRANZ Research Now: Positional corrosion #1 *The impacts of natural elements on different parts of the building envelope*. This seems to align with faster metal corrosion in sheltered building areas.

However, the actual material corrosion rates on the test building provided a counter argument, indicating that salt deposition is unlikely to be the key factor contributing to material degradation in an environment with weak marine influences.

Exposed positions on the test building had larger temperature variations and received larger amounts of rainwater than sheltered positions. The annual time of wetness of the sheltered areas was approximately 1,400 hours

Table 1. First-year corrosion rates of mild steel samples installed on test building and samples fully exposed to weather (g/m²/year).

WALL	POSITION	SAMPLE ON BUILDING			SAMPLE EXPOSED TO WEATHER		
		0° (HORIZONTAL)	45°	90° (VERTICAL)	0° (HORIZONTAL)	45°	90° (VERTICAL)
North	Sheltered	162	147	69	227	168	168
	Boundary	156	120	69			
	Exposed	245	107	65			
South	Sheltered	127	112	33	309	164	158
	Boundary	184	144	54			
	Exposed	220	170	81			
East	Exposed – high	151	153	80	264	154	139
	Exposed – low	150	128	92			
West	Exposed – high	178	166	80	208	165	154
	Exposed – low	193	154	88			

less than those of other areas. (Time of wetness is the period when a moisture layer could form on a metal surface, defined as when the temperature is higher than 0°C and the humidity is higher than 80%.) This significant decrease could lead to a remarkable reduction of material degradation despite more salt deposits being collected.

Corrosion rates of mild steel nails in timber

The exposure conditions of metal fasteners such as nails and screws are different from cladding materials because their shafts are embedded completely into cladding or framing materials with only the heads exposed.

Table 2 shows the corrosion rates of mild steel nails in H3.2 chromated copper arsenate (CCA)-treated timber blocks (approximately 20 × 20 × 100 mm) after 1 year's exposure. The reference samples were installed with their length along the north-south direction and the nail head facing north.

Table 2 shows the following:

- The nails in assemblies fully exposed to the atmosphere had a significantly higher corrosion rate than those on the test building.
- On the north and south walls, the nails in the exposed position showed significantly more corrosion than the nails in the sheltered position.

Table 2. First-year corrosion rates of mild steel nails embedded in H3.2 CCA-treated timber blocks (g/m²/year).

WALL	POSITION	NAIL-TIMBER ASSEMBLY ON BUILDING	NAIL-TIMBER ASSEMBLY EXPOSED TO WEATHER
North	Sheltered	8.0±1.8	45.2±23.4
	Boundary	11.1±3.0	
	Exposed	31.5±17.6	
South	Sheltered	7.2±0.1	
	Boundary	8.0±0.7	
	Exposed	13.9±8.8	
East	Exposed – high	14.7±4.8	
	Exposed – low	14.0±10.7	
West	Exposed – high	9.2±1.8	
	Exposed – low	18.3±14.2	

Moisture is the root cause for corrosion of metallic fasteners in timbers and timber structures. Moisture in timber is fundamental to:

- hydrolysis of acetyl to acetic acid
- ion and oxygen transfer along the length of an embedded fastener
- mobilisation and leaching of preservatives for the formation of free and corrosive ionic species, such as copper ions.

The actual moisture content in timber largely determines whether these processes can occur and be sustained to promote corrosion of metallic fasteners embedded in the timber. A moisture content of approximately 18% is generally accepted as the threshold below which corrosion in timber would be very limited. When the timber moisture content is higher than 20% due to exposure to rain or moist air, the risk of metal corrosion is significantly increased.

As revealed by this monitoring, sheltered positions on the north and south walls received extremely limited wind-driven rain. Moisture in these timber blocks is then sourced mainly from and determined by the equilibrium between humidity and temperature of the surrounding air. The probability of a moisture content higher than 20% would be low, especially for prolonged periods within which substantial corrosion could occur.

By contrast, timbers fully exposed to the atmosphere can receive more rain (both in quantity and frequency) and have long wetting periods and/or large variations in moisture content. This could significantly enhance corrosion of embedded metallic fasteners.

Considering all these points, the expected trend for corrosion of fasteners in timber would be that the greatest corrosion would be seen in exposed positions and the lowest corrosion in sheltered positions. This is exactly what the research found.

Conclusion

Micro-environments on building envelopes are a complicated function of:

- local weather and climate conditions
- concentration and type of atmospheric pollutants
- geometry and orientation of buildings.

Corrosion rates of metal samples on the test building varied by inclination angle and position. In almost every case, the horizontal samples showed the highest corrosion, followed by the 45° inclined samples and then the vertical samples. The inclined samples could corrode at a rate 2-3 times higher than the vertical samples.

On the north and south walls, the mild steel samples and nails showed more corrosion in exposed positions than sheltered positions.

The significantly lower wind-driven rain and time of wetness in sheltered areas may explain the reduced corrosion, even though more salt deposits were collected. The actual quantity of salt deposited was relatively low in this semi-rural environment, so its contribution to corrosion may be low.

Further reading

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

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*

Nailing micro-environments, *Build 154*, June/July 2016

Position, position, position, *Build 165*, April/May 2018

This Research Now describes a BRANZ research project in progress. More findings will be reported in due course and may modify the findings reported here.