# Positional material deterioration over the building envelope of a coastal building

BRANZ is researching how the corrosion of construction materials is affected by building micro-environments and where on a building the material is installed. This Research Now reports on a building very close to the marine influences of Auckland Harbour. Research Now: Positional corrosion #1 and #2 reported on research carried out on a test building on the BRANZ campus at Judgeford, near Porirua, while Research Now: Positional corrosion #4 covers a building in Rotorua's geothermal environment.

Early results from all these monitoring activities indicate that micro-environments around a building can differ significantly from each other and from the surrounding atmospheric environment. Gaining a better understanding of this should ultimately produce a better understanding of how, where and why materials degrade and how building durability can be improved.

Preliminary findings at the Auckland site show the following:

- The sheltered position under the eave or window awning consistently collected more salt than the exposed position by a wide margin.
- The corrosion rate at the sheltered position was lower than that at the exposed position on the south, east and west walls. On the north wall, corrosion rates at the sheltered and exposed positions were similar.
- Horizontal (0°) steel plates showed greater corrosion than plates installed at 45° and vertically (90°), but the biggest difference was that the plates at 45° 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.

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## Testing and the test building

The test building is located at 9 Princes Street, Northcote, Auckland. The building, close to the Auckland Harbour Bridge, is within 500 metres of seawater. Its atmospheric environment falls into zone D in the exposure zone map in NZS 3604:2011 *Timber-framed buildings* and C4 High in ISO 9223:2012 *Corrosion of metals and alloys - Corrosivity of atmospheres - Classification, determination and estimation*. The 1-year monitoring started in May 2017.

Monitoring was carried out at two positions on each wall (Figure 1):

- A low position fully exposed to the weather approximately 0.23 m from the bottom of the wall cladding on the north, south, east and west walls.
- A sheltered position under the eave of the north and south walls approximately 0.42 m from the top of the wall.
- A sheltered position under the window awning on the east and west walls.

Figure 1. Monitoring positions on the test building.

Three types of measurements were made:

- A salt contamination meter measured how much salt was deposited on the painted weatherboard wall cladding.
- Mild steel plates approximately 120 × 80 × 1 mm were installed horizontally (0°), vertically (90°) and at a 45° slope. Corrosion of each plate was measured through weight loss.
- Mild steel nails approximately 3.15 × 75 mm were nailed into H3.2 CCA-treated timber blocks to simulate fastener deterioration in timber wall cladding.

Two groups of reference samples were fully exposed to the atmospheric environment at the site:

- Mild steel plates identical to those on the test building were installed horizontally (0°), vertically (90°) and at 45° on four sides of a small rectangular rack that had the same orientation as the test building. These were used to investigate the potential orientation influences on metal atmospheric corrosion.
- Metal plates (~150 × 100 × 0.6-3.0 mm) of copper, mild steel and zinc were positioned to the north to classify atmospheric corrosivity of the test site according to ISO 9223:2012.

## Environmental conditions

- The highest hourly ambient temperature was around 26°C and the lowest around 5°C over the 1-year measurement period (May 2017 - May 2018).
- Time of wetness was approximately 3,251 hours. (This refers to the period when environmental conditions could allow a moisture layer to form on a surface, particularly metal.)
- Rainfall was 1,323 mm.
- The prevailing wind was from the west-southwest (WSW) and southwest.
- The maximum wind speed was around 24 m/s.

The first-year corrosion rates on the copper, mild steel and zinc indicate a relatively benign atmospheric environment, classified as C2 Low or C3 Medium in ISO 9223:2012. This corrosivity category is lower than that defined by the map of NZS 3604:2011. The height of the site and the shelter provided by the bridge and trees might be responsible for this relatively benign atmospheric corrosivity.

## Salt deposition on the test building

Salt deposition was measured in sheltered and exposed positions on the test building (Table 1). The sheltered position under the eave or window awning consistently collected more salt than the exposed position by a margin of 3-8 times. This supports the understanding that the sheltered area sees much less rain washing and thus more salt remains in place. (More salt was also recorded in sheltered positions during monitoring of a building on the BRANZ campus at Judgeford - see Research Now: Positional corrosion #1).

The south wall appeared to collect 1.5-2 times more salt than the other three walls, while the north, east and west walls collected broadly similar amounts. This orientation difference could be explained by the prevailing

WSW wind. The Harbour Bridge, a few metres to the west of the building, could be a source of dust and particulates from traffic to the south wall, which has a wide eave.

## Corrosion of mild steel plates on the test building

The first-year corrosion rates of mild steel plates on both the test building and the reference exposure rack are shown in Table 2.

Corrosion rates on the test building were generally lower than on the reference exposure rack, particularly for the vertical and horizontal samples. For the samples at 45°, corrosion rates were broadly similar.

The corrosion rate in the sheltered position was lower than that at 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.

In the sheltered positions, the north wall appeared to have the highest corrosivity and the other three walls had a similar corrosivity, but Table 1 shows that the sheltered position on the north wall did not collect more salt than the positions on other three walls. The higher corrosivity cannot be explained by more salt being deposited. Other factors such as time of wetness might contribute.

In the exposed positions, the east and south walls appeared to have a slightly higher corrosivity than the other two walls. This could be related to wind and air pollution. The prevailing WSW wind could bring more corrosive dust, particulates and salt to the south wall, while more rain driven to the exposed position leads to longer time of wetness. This could apply to the east wall as well, although this would be more associated with marine-sourced salt.

There was comparatively little orientation difference on the corrosion of the samples installed on the reference exposure rack. The airflow here may have been strong enough to disperse pollutants uniformly around this small rack in a way that did not happen with the larger test building.

As expected, corrosion of the reference rack steel plates was greatest on the horizontal steel plates (where moisture or rainwater may sit) than the ones installed at 45°, with the least amount of corrosion on the ones that were vertical (where rain would drain off). The biggest difference between positions was that the corrosion rates on the horizontal steel could be more than double the rate of the steel installed at 45°.

Table 1. Salt deposition on the test building.

| WALL | POSITION | SALT DEPOSITION (µG/CM²) | | | | |
|---|---|---|---|---|---|---|
| | | AUG 2017 | DEC 2017 | FEB 2018 | MAY 2018 | TOTAL |
| North | Sheltered | 9.0–10.0 | 8.8–10.1 | 8.2–8.5 | 5.6–5.6 | 31.6–34.2 |
| | Exposed | 0.9–1.0 | 2.7–3.2 | 0.7–0.8 | 1.0–1.1 | 5.3–6.1 |
| South | Sheltered | 18.5–21.5 | 10.6–11.1 | 15.0–15.1 | 11.4–12.2 | 55.5–59.9 |
| | Exposed | 3.8–4.5 | 1.8–2.5 | 3.6–4.0 | 5.6–7.4 | 14.8–18.4 |
| East | Sheltered | 15.2–18.0 | 4.6–5.3 | 5.6–6.1 | 9.3–10.2 | 34.7–39.6 |
| | Exposed | 0.9–0.9 | 2.1–2.2 | 0.8–0.9 | 1.1–1.2 | 4.9–5.2 |
| West | Sheltered | 16.3–19.4 | 2.8–3.5 | 3.9–4.1 | 4.9–5.2 | 27.9–32.2 |
| | Exposed | 0.8–0.8 | 1.4–1.6 | 1.3–1.6 | 0 | 3.5–4.0 |

Table 2. Corrosion rates of mild steel plates after 1 year (g/m²/year).

| WALL | POSITION | PLATE ON TEST BUILDING | | | | PLATE EXPOSED TO THE WEATHER | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 0° (S) | 0° (G) | 45° | 90° | 0° (S) | 0° (G) | 45° | 90° |
| North | Sheltered | 210 | 129 | 188 | 132 | 346 | 293 | 147 | 120 |
| | Exposed | 181 | 142 | 171 | 125 | | | | |
| South | Sheltered | 157 | 56 | 143 | 77 | 330 | 369 | 166 | 144 |
| | Exposed | 281 | 124 | 209 | 116 | | | | |
| East | Sheltered | 155 | 89 | 147 | 86 | 322 | 316 | 167 | 145 |
| | Exposed | 333 | 170 | 193 | 101 | | | | |
| West | Sheltered | 148 | 63 | 125 | 53 | 330 | 440 | 172 | 140 |
| | Exposed | 223 | 120 | 167 | 77 | | | | |

S: skyward surface, G: groundward surface.

These results were very different for the steel plates installed on the test building. The biggest difference in corrosion was between the steel plates at 45° and those installed vertically (90°). The corrosion rates on the plates at the angle were much higher - more than double in some cases. (This finding was also recorded during monitoring of a building on the BRANZ campus - see Research Now: Positional corrosion #2).

Where exposed steel was facing the ground, the corrosion rates were much lower than the others except those installed at 90° (vertically).

## Corrosion of mild steel nails in timber

The first-year corrosion rates of mild steel nails in H3.2 CCA-treated timber blocks are shown in Table 3.

The nails in timber blocks fully exposed to the weather had a corrosion rate significantly higher than those installed in the exposed positions on the test building. The nails in exposed positions also had rates of corrosion considerably higher than those in sheltered positions. (Both of these findings were also recorded during monitoring of a building on the BRANZ campus - see Research Now: Positional corrosion #2).

Table 3. Corrosion rates of mild steel nails in H3.2 CCA-treated timber blocks after 1 year (g/m²/year).

| WALL | POSITION | NAIL IN TIMBER ON THE TEST BUILDING | NAIL IN TIMBER EXPOSED TO THE WEATHER |
|---|---|---|---|
| North | Sheltered | 11.9 ± 4.2 | 75.2 ± 29.1 |
| | Exposed | 32.6 ± 11.1 | |
| South | Sheltered | 5.6 ± 1.8 | |
| | Exposed | 27.4 ± 8.1 | |
| East | Sheltered | 11.9 ± 2.4 | |
| | Exposed | 47.2 ± 28.8 | |
| West | Sheltered | 8.3 ± 1.2 | |
| | Exposed | 41.4 ± 16.3 | |

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.

## Conclusion

- Corrosion rates on the test building were generally lower than on the reference exposure rack fully exposed to the weather, suggesting that the environment on the building envelope is slightly different from the atmospheric environment surrounding the building.
- The sheltered position under the eave or window awning collected 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.
- In general, the corrosion rate in the sheltered position was lower than that in the exposed position for each wall for both the steel plates and the mild steel nails in H3.2 CCA-treated timber blocks.
- As expected, corrosion of the steel plates on the building was greatest on the horizontal steel plates (where moisture and/or rainwater may sit). The biggest difference in corrosion rates was between the plates at the angle and those vertical, with the plates at 45° showing higher corrosion (more than double in some cases) than those installed vertically.

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

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