The impacts of natural elements on different parts of the building envelope

BRANZ is researching the impact of natural elements such as sun, rain, wind and wind-blown sea salt on different positions on a building. Early results show that micro-environments around a building can be very different from each other and from the surrounding environment. Understanding this can lead to a better understanding of material degradation and ultimately to improved building durability.

How building materials perform depends partly on where they are installed on the building envelope. NZS 3604:2011 *Timber-framed buildings* sets different requirements for fixings in sheltered and exposed positions, for example. But while the general concept of varying exposure risks is accepted, there is a limited understanding of the precise differences in micro-environments around a building.

Temperature

Temperature can affect material degradation in complex ways. Rising temperatures tend to accelerate corrosion at a constant humidity. Relative humidity typically falls as temperature rises, however, leading to a shorter time when moisture sits on a material and a complicated change in the overall corrosion rate.

Results from a test building on the BRANZ campus show the following:

- Temperatures on the surfaces of the building envelope had larger variations than the ambient temperature:
  - During winter, north and east walls had the largest variations.
  - During summer, west and east walls had the largest variations.
  - The south wall showed smaller variations than the other walls.
- The lowest wall surface temperatures, typically around -0.9-0.2°C, were similar to the lowest value of the surrounding environment.

Testing and the test building

A small test building on the BRANZ campus at Judgeford is the source of data for this project. The site is semi-rural, 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 rectangular building 12.55 x 7.25 m has a pitched roof of aluminium/zinc alloy-coated steel. The wall cladding is fibre-cement weatherboard. Monitoring instruments and testing samples were installed in three positions/micro-environments on the north and south walls (Figure 1):

- Sheltered locations under the eaves (following the NZS 3604:2011 definition of 'sheltered').
- Fully exposed to the atmosphere.
- The sheltered/exposed boundary.

The east and west walls were monitored in two exposed positions but not the sheltered positions.

To give a baseline for comparison, a weather station nearby recorded ambient temperature, relative humidity, rainfall, wind speed and direction and UVA irradiation.

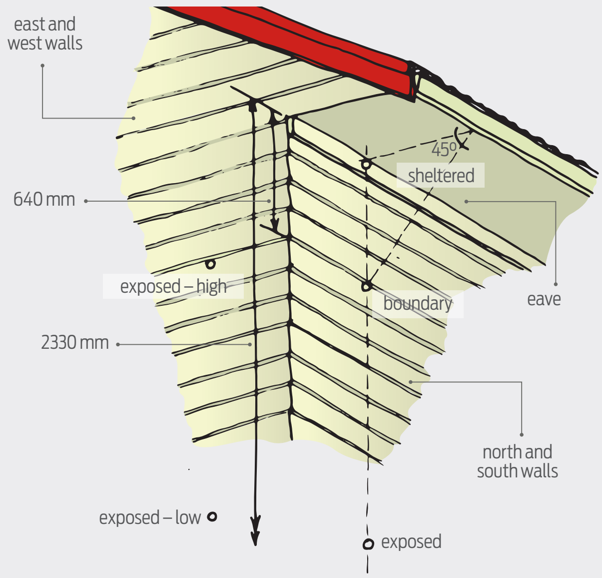

Figure 1. Monitoring positions on the building envelope. Only exposed positions at two heights were monitored on east and west walls.

- Maximum hourly wall surface temperatures could be 2-4 times higher than the ambient temperature. The maximums over 1 year were 62.8°C, 33.6°C, 67.4°C and 62.0°C for the north, south, east and west walls. The highest ambient temperature was 27.4°C.
- On the north wall, temperatures (and variations) at the exposed and boundary positions were similar and higher than the temperature at the sheltered position in winter. In summer, the temperature at the sheltered position would normally sit between those of the exposed and boundary positions.
- On the south wall, seasonal variations of daily temperatures at the three monitoring positions were similar. However, the exposed position appeared to always have the lowest temperature values.

Time of wetness

Material degradation relies heavily on the presence of a moisture layer on a surface. Gaseous and/or solid pollutants can dissolve in this moisture, accelerating degradation processes and reactions. Time of wetness, therefore, is an important variable to consider in the atmospheric corrosion of metals and alloys. It refers to the period during which a moisture layer could be formed on a material surface, particularly metal, under favourable environmental conditions.

The period of time the wall surfaces were likely to be wet was calculated based on when the temperature was higher than 0°C and humidity was over 80%. The measurements showed the following:

- Sheltered positions on the north and south walls were wet for much less time than the boundary and exposed positions (Table 1). The biggest difference was around 1,300-1,400 hours.
- The boundary and exposed positions were wet for similar periods, around 4,200-4,700 hours. (There was one exception - the exposed position on the south wall was wet for around 5,200 hours.)
- The figure for the surrounding environment was 5,339 hours or 850-2,150 hours more than the building envelope.

Building surface temperatures can be much higher than the ambient temperature, and a temperature increase normally decreases relative humidity. This could partly explain the shorter periods building surfaces were wet compared to the surrounding atmosphere.

Wind-driven rain

Wind-driven rain is normally defined as the amount of rain that strikes a vertical surface. Its quantity and distribution over the building is affected by wind direction and speed, rainfall intensity, building dimension/geometry, location on the building envelope and surrounding topography.

It is the major source of moisture that significantly affects the performance and durability of the building envelope.

On the one hand, rainwater entering gaps in a material surface or building element may accelerate material degradation by supplying continued wetness. Regular washing of the surface could also partially remove loose corrosion products, exposing fresh material surfaces to further attack.

On the other hand, significant rainfall could remove accumulated salt deposits from surfaces. Rain-washing effects are particularly noticeable in marine environments where chloride-containing particles (sea salt) on surfaces can contribute to corrosion.

Wind-driven rain was monitored at two positions on each wall of the test building. (North and south wall sheltered positions were not included.)

- Much less rain was collected on the building envelope compared to the reference site (Table 1, including note b).
- The highest amount of annual wind-driven rain, 297.8 mm, was measured at the exposed position on the north wall. The lowest amount, 2.6 mm, was measured at the high exposed position on the west wall.

Table 1. Measurements of wet surface time, rain and salt deposition on the test building.

WALL	POSITION	TIME OF WETNESS (HOURS)[a]	WIND-DRIVEN RAIN (MM)[b]	SALT DEPOSITION (G/M²)		
				0º (HORIZONTAL)	45º	90º (VERTICAL)
North	Sheltered	3,180	Not measured[c]	1.015	0.547	0.166
	Boundary	4,442	94.4	0.442	0.251	0.077
	Exposed	4,151	297.8	0.292	0.193	0.053
South	Sheltered	3,727	0	0.700	0.522	0.123
	Boundary	4,394	19.6	0.623	0.407	0.105
	Exposed	5,195	19.4	0.288	0.241	0.085
East	Exposed – high	4,489	16.4	0.471	0.370	0.206
	Exposed – low	4,674	54.2	0.285	0.172	0.142
West	Exposed – high	4,247	2.6	0.469	0.381	0.189
	Exposed – low	4,483	14.0	0.273	0.198	0.084

Notes:
a. The atmosphere surrounding the test building was wet for 5,339 hours in this monitoring period.
b. Rainfall for the site in this 1-year monitoring period was 1,589 mm.
c. Extremely limited since rain could only reach this position when the wind was very strong from the north.

- On each wall, the lower position received a larger amount of rain than the higher position. The difference could be 3-5 times more. The exception is the south wall, where both positions had a similar amount of wind-driven rain.
- In general, the total amount of wind-driven rain decreased from north to east to south to west.

The predominant wind is from north-north-west (NNW), which probably explains why the north wall received more wind-driven rain.

The eaves on the north and south sides are about 600 mm wide. Only with very strong northerly winds could rain penetrate into the sheltered area on the north wall. Meanwhile, no wind-driven rain was observed in the sheltered area on the south wall. The boundary position on the north wall had a wind-driven rain recording of 94.4 mm. This is about three times lower than that at the lower, fully exposed position (297.8 mm). Eaves appear to provide some protection to the area.

Salt deposition

Deposits of salts that absorb moisture from the air, such as sodium chloride, can promote material degradation including metal corrosion at much lower relative humidity levels than normal.

Salt deposits were measured on stainless steel plates installed on the building

horizontally (0°), vertically (90°) and at 45° to the ground. Plates were also installed away from the building. Measuring was done monthly during fine days.

Initial findings are as follows:

- The horizontal surface always collected the largest amount of deposits (Table 1). The difference between the horizontal and vertical surface deposits was much larger if these surfaces were positioned on a building wall - 2-6 times versus 1.1-1.9 times.
- Surfaces at higher positions on a wall always collected more salt than surfaces at lower positions.
- The sheltered position on the north wall collected the most salt.
- Almost all positions low on the wall and fully exposed to weather had similar amounts of deposits for each sample angle. These quantities were similar to those on the reference surfaces.
- East and west walls had similar salt deposits.

The quantity of salt on the collection surface can be affected by the quantity of particles in the air, wind direction and speed, rain-washing and position on the building envelope.

For example, sheltered areas on north and south walls had extremely limited rain-washing. Over 1 year, surfaces in these areas collected more salts than others at the boundary or fully exposed positions.

In general, the increasing trend of surface deposition with height on the same wall seems to be tied to the trend of wind-driven rain. This is more evidence that the rain-washing effect plays an important role in the accumulation of salt particles. Wind alone can also have a cleaning effect - winds above a critical speed can blow dust and/or dry salt off material surfaces. The collection surfaces on the south wall may therefore retain more deposits.

UVA irradiation

Ultraviolet (UV) light can degrade building materials such as paints, sealants, adhesives and plastics. UV light may also interact with airborne chlorides and oxidising agents such as ozone to corrode susceptible metals.

UV exposure on a building envelope is not uniform and can be affected by architectural features, construction materials, orientation and so on.

UVA irradiation (320-400 nm) was continuously monitored at one position on each wall, with the following results:

- The daily average UVA irradiation intensity was different on each wall, following an order in intensity (most to least) of north, east, west and south walls. The highest UVA measurements were in the surrounding environment, approximately 1.5 times higher than that on the north wall.
- Daily average UVA intensity has an obvious seasonal variation - strong in summer and weak in winter. The maximum can be three times higher than the minimum.
- The south wall consistently received the lowest UVA irradiation and showed the smallest seasonal variation.

Conclusion

There can be very significant differences in the micro-environments around a building envelope and between the building and the surrounding environment. On the building itself, variations can be seen between walls of different orientations and between positions on a wall.

Quantifying micro-environment differences could ultimately:

- provide a stronger scientific foundation for a better understanding of materials performance on building envelopes
- provide more specific guidance on building maintenance
- help ensure that materials, components and structures meet or exceed New Zealand Building Code durability requirements.

Further reading

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*

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.