BRANZ

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HOW MICRO-ENVIRONMENTS AFFECT MATERIAL PERFORMANCE

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- BRANZ is monitoring sun, rain, wind and wind-blown sea salt in different positions on a building envelope.
- These conditions help to create a variety of micro-environments over the building that can be very different from the surrounding atmospheric environment.
- This bulletin reports on the first monitoring of how micro-environments affect material performance on a BRANZ test building near Wellington.

1 INTRODUCTION

1.0.1 Building material performance depends partly on where materials are installed on the building envelope. NZS 3604:2011 *Timber-framed buildings* recognises this by setting different requirements for metal fixings in different building micro-environments, i.e. closed, sheltered and exposed.

1.0.2 Currently, little is known of the precise differences in these micro-environments and material degradation within them. BRANZ is conducting systematic research on several buildings in different climate zones in the North Island and South Island of New Zealand. This bulletin reports on the first monitoring done on a test building on the BRANZ campus at Judgeford, near Wellington.

1.0.3 Preliminary results available on this test building show that:

- micro-environments around the building envelope can be very different from each other and from the surrounding atmospheric environment
- degradation of material on the building is different from that directly exposed to the surrounding atmospheric environment and is heavily dependent on its position and orientation on the building.

2 TESTING AND THE TEST BUILDING

2.0.1 The test site is within BRANZ's Judgeford semi-rural campus, which is around 5 km from the nearest saltwater (an estuary) and protected by hills from the sea. This site's corrosivity classification is between zones B and C in the NZS 3604:2011 map, corresponding to 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*. The ambient temperature, relative humidity, rainfall, wind speed/direction and UVA irradiation of this site were monitored with a weather station.

2.0.2 The test building – a rectangular unoccupied house measuring 12.55 x 7.25 m – has light-green painted fibre-cement wall cladding and aluminium/zinc alloy-coated steel roofing on a pitched roof.

2.0.3 Several positions on the test building were selected for environmental and material degradation monitoring (Figure 1). These included three positions on north and south walls (described below) and two exposed positions of different heights on east and west walls:

- Under the 0.6 m wide eaves (the NZS 3604:2011 definition of 'sheltered').
- Fully exposed to the atmosphere.
- The sheltered/exposed boundary.

2.0.4 Two types of metallic samples were used to investigate position-dependent local corrosivity and material degradation on the test building after 1-year exposure:

- Mild steel coupons (approximately 120 x 80 x 1 mm) installed at 0° (horizontally), 45° and 90° (vertically) to the ground.
- Mild steel nails inserted into H3.2 chromated copper arsenate (CCA)-treated timber blocks (approximately 20 x 20 x 100 mm).

2.0.5 Reference mild steel coupons were installed away from the test building. They were also placed at 0°, 45° and 90° to the ground and oriented towards north, south, east and west. Reference nail samples were installed along the north-south direction with their heads facing north.

3 TEMPERATURE

3.0.1 Temperature affects material degradation. Rising temperatures tend to accelerate metal corrosion at a constant humidity. However, relative humidity typically falls as temperature rises, leading to less time when moisture sits on a metal surface and a complicated change in the overall corrosion rate.

3.0.2 Preliminary temperature results available on this test building show the following:

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

4 TIME OF WETNESS

4.0.1 Material degradation normally relies on the presence of a surface moisture layer. Gaseous or solid pollutants can dissolve into this moisture layer, contributing to accelerated degradation. Time of wetness – the period when a moisture layer could form on a material surface, particularly metal, under favourable environmental conditions – is a very important variable. It is normally calculated from when the temperature is above 0°C and humidity over 80%.

4.0.2 Preliminary time of wetness results available on this test building over a 1-year period (Table 1) show the following:

- Sheltered positions on the north and south walls

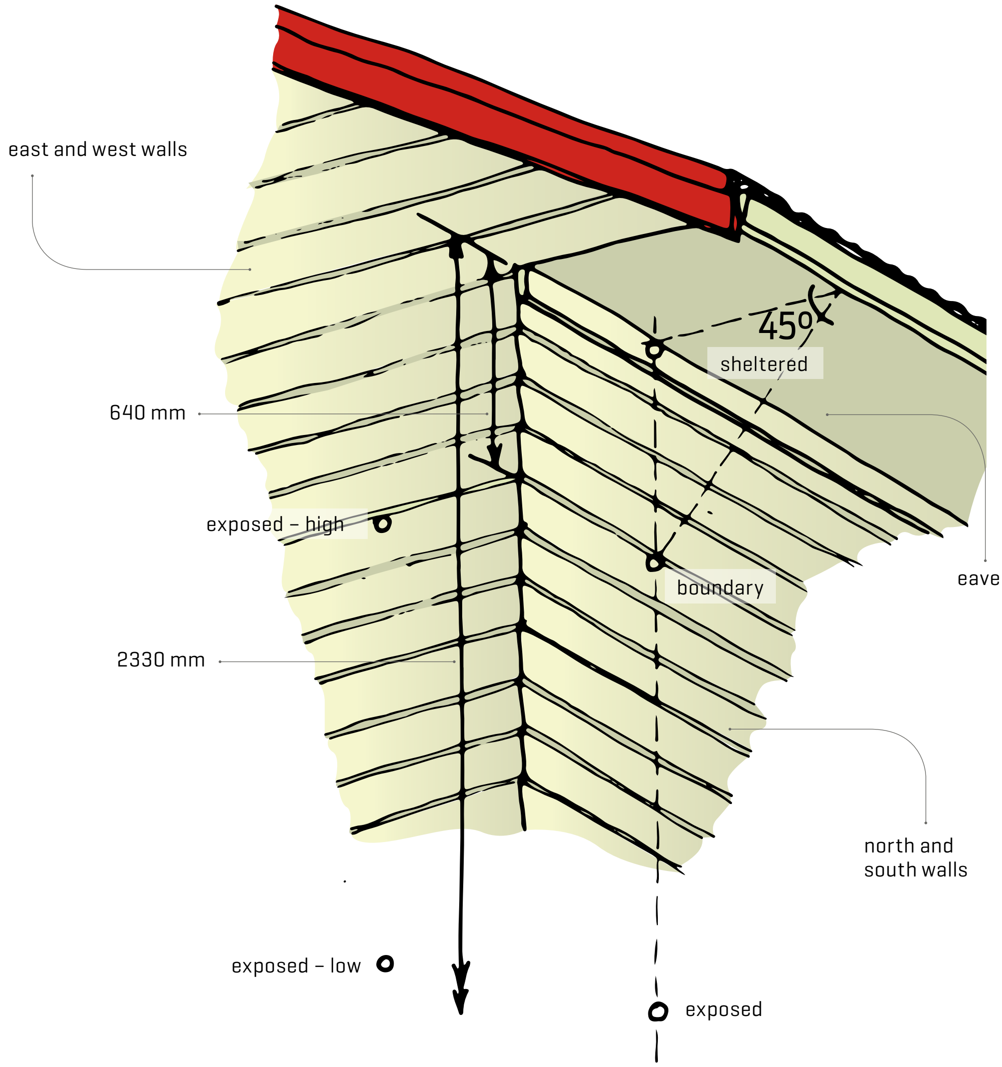

Figure 1. Monitoring positions on the building envelope. Only exposed positions at two heights were monitored on east and west walls.

were wet for much less time than the boundary and exposed positions. 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, with one exception – the south wall exposed position was wet for around 5,200 hours.
- The surrounding environment was wet for 5,339 hours, 850–2,150 more hours than the building envelope.

5 WIND-DRIVEN RAIN

5.0.1 Rain plays very important roles in material degradation. Rainwater entering gaps in a material surface may accelerate degradation. Rain washing could also, more or less, remove loose corrosion products, exposing fresh material surfaces to attack. On the other hand, rain could wash dust and salt off surfaces – particularly in marine environments where chloride-containing salt particles can contribute to corrosion – therefore slowing down material degradation.

5.0.2 Wind-driven rain is the rain that strikes a vertical surface. Its quantity and distribution over a building is affected by wind direction and speed, rainfall intensity, surrounding topography, building dimension/geometry and position on the building. It is the major source of moisture affecting building envelope performance and durability.

5.0.3 Wind-driven rain was monitored in two positions on each wall. Rain access to the sheltered positions on north and south walls was visually inspected during rainy days. Preliminary results available on this test building show the following:

- Rain collected on the building envelope was much less than the rainfall of the surrounding atmospheric environment – see Table 1, including note [2].
- The highest total amount of wind-driven rain, 297.8 mm, was measured in the exposed position on the north wall. The lowest amount, 2.6 mm, was in the high exposed position on the west wall.
- On each wall, the lower position received more wind-driven rain – up to 3–5 times more – than the higher position. The exception was the south wall, where both positions were similar.
- The boundary position on the north wall recorded 94.4 mm of wind-driven rain. This was about 3 times lower than the 297.8 mm at the lower, fully exposed position. Therefore, eaves appeared to restrain rain access to the area below.

- The total amount of wind-driven rain generally decreased from north to east to south to west. The predominant north-northwest (NNW) wind explains why the north wall received more rain.

6 SALT DEPOSITION

6.0.1 Marine-sourced salts can promote material degradation through several ways:

- Hygroscopic salts, such as sodium chloride and magnesium chloride, can absorb moisture from the air, therefore promoting metal corrosion at much lower relative humidity levels than normal.
- Chlorides can participate in the corrosion process, leading to the formation of unstable corrosion product layers with lower protection.

6.0.2 Salt deposits on stainless steel plates installed at 0°, 45° and 90° on the test building and at an exposure site about 100 m away were measured monthly on fine days.

6.0.3 Preliminary salt deposition results available on the test building show the following:

- Sheltered areas on north and south walls collected the most salt.
- Higher positions collected more salt than lower positions on the same wall.
- Almost all positions low on the wall and fully exposed to the weather had similar deposits at each installation angle. These quantities were similar to those on the reference surfaces.
- East and west walls had similar deposits.

The BRANZ test house at Judgeford, Porirua.

- Horizontal surfaces always collected more deposits (Table 1). However, the difference between the horizontal and vertical surface deposits was bigger if these surfaces were positioned on the test building – 2–6 times versus 1.1–1.9 times.

6.0.4 The increasing trend of surface deposition with height on the same wall seems tied to the trend of wind-driven rain. This provides more evidence that rain plays an important role in the accumulation of salt particles.

7 UVA IRRADIATION

7.0.1 Ultraviolet (UV) light can degrade a wide range of building materials, such as paints, sealants, adhesives and plastics. UV exposure on a building envelope is not uniform and can be affected by architectural features, construction materials, orientation and so on.

7.0.2 UVA irradiation (320–400 nm) was monitored in one position on each wall. Preliminary results available on the test building show the following:

- The daily average UVA irradiation intensity was the strongest on the north wall, followed by the east, west and south walls. The south wall consistently received the lowest UVA irradiation and showed the smallest seasonal variation.
- The highest UVA measurements were in the surrounding environment – around 1.5 times higher than on the north wall.
- Daily average UVA intensity is obviously stronger in summer than winter – up to 3 times higher.

8 CORROSION RATES OF MILD STEEL COUPONS

8.0.1 Many New Zealand buildings lie within 5 km of the sea, and sea salt can accelerate metal corrosion. It is generally assumed that sheltered areas on a building could collect more salt than exposed areas because rain doesn't wash it away. The expectation is that metals in sheltered areas will corrode faster.

8.0.2 The first-year corrosion rates of mild steel coupons (Table 2) available on this test building show the following:

- Samples on the building generally had a lower corrosion rate than those fully exposed to the atmosphere.
- In most cases, the horizontal samples on the building had the highest corrosion, followed by the 45° inclined samples and then the vertical samples. The biggest difference was between these last two – the 45° inclined samples could corrode 2–3 times faster than the vertical samples.
- On the north wall, the horizontal sample in the exposed position showed significantly greater corrosion than that in the sheltered position. With the vertical sample, there was little difference. For the 45° inclined sample, 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.

8.0.3 These observations indicate that sheltered positions on a building do not necessarily have a higher corrosivity towards materials, challenging normal assumption:

- Salt is unlikely to be the key factor contributing to material degradation in this environment with weak marine influences.
- The annual time of wetness in the sheltered areas was around 1,400 hours less than other areas. This significant decrease could be responsible for less material degradation despite more salt being deposited in these areas.

Table 1. Measurements of time of wetness, wind-driven rain and salt deposition on the test building.

Wall	Position	Time of wetness (hours)[1]	Wind-driven rain (mm)[2]	Salt deposition (g/m^2)		
				0°[4]	45°	90°
North	Sheltered	3,180	Not measured[3]	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:

[1] The atmosphere surrounding the test building was wet for 5,339 hours in this 1-year monitoring period.

[2] Rainfall for the site in this 1-year monitoring period was 1,589 mm.

[3] Extremely limited rain could only reach this position when the wind was very strong from the north.

[4] Installation angle relative to the ground.

Table 2. First-year corrosion rates of mild steel coupons installed on the test building and fully exposed to the weather (g/m²/year).

Wall	Position	Sample on building			Sample exposed to weather		
		0°	45°	90°	0°	45°	90°
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			

Mild steel coupons were installed in an exposed location away from the BRANZ test house.

Table 3. First-year corrosion rates of mild steel nails embedded in H3.2 CCA-treated timber blocks ($g/m^2/year$).

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	

9 CORROSION RATES OF MILD STEEL NAILS IN TIMBER

9.0.1 Corrosion rates of mild steel nails in H3.2 CCA-treated timber blocks installed on this test building were measured after 1-year exposure (Table 3). These preliminary results show the following:

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

9.0.2 Corrosion of fasteners is a result of the complicated interactions between atmospheric environment, timber, preservation chemical (if treated) and fastener material. Moisture is the root cause of 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.

9.0.3 Timber moisture content largely determines whether these processes can occur and be sustained to promote corrosion. Fastener corrosion in timber would be very limited below a moisture content of approximately 18%. A timber moisture content higher than 20% significantly increases corrosion risk.

9.0.4 Sheltered positions on this test building received little wind-driven rain. Moisture in timber here came mainly from and was 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 the prolonged periods that substantial corrosion requires.

9.0.5 Exposed positions received more rain (both in quantity and frequency). Timber had longer wetting periods and/or larger variations in moisture content, which could promote fastener corrosion in timber.

9.0.6 The contribution of salt deposition to fastener corrosion on this test building was comparatively low because:

- marine influence in this environment is weak and the total salt deposition is low
- a nail head directly exposed to the weather is much smaller when compared with a shaft embedded in timber.

10 MORE INFORMATION

NZS 3604:2011 *Timber-framed buildings*

Build 154. Nail micro-environments (pages 76–77)

Build 165. Position, position, position (pages 76–78)

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