Atmosphere and material durability

BRANZ research is expanding our knowledge of how multiple factors influence building material corrosion. This will lead to a new way of mapping corrosivity and allow the right materials to be specified for different environments.

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MATERIALS ARE CORE to buildings, contributing, for example, 16-24% of residential building development costs. They are required to meet the durability requirements of the New Zealand Building Code to address potential corrosion risks.

This poses huge challenges since corrosion is influenced by multiple factors and varies considerably across New Zealand's diverse and unique environments.

Material specification scheme

A scheme has been established to specify materials. It uses a two-tier approach - atmospheric corrosivity zone where the building will be built and micro-environment where the material will be used on the building. This has been adopted by E2/AS1 of the Building Code and NZS 3604:2011 *Timber-framed buildings*.

Implementation of this scheme relies on having in-depth knowledge of atmospheric environments and building micro-environments and trusted data of how materials perform when exposed to them. Are these always available to support construction so that buildings are affordable and resilient and have low climate impact?

Atmosphere is corrosive

The atmosphere supplies oxygen, water and nutrients to sustain life as well as protect life on our planet from extreme temperatures and excessive solar irradiation from the sun. It has negative impacts on materials and buildings through temperature, humidity, wind, rain, solar irradiation and other climate variables and weather patterns. This is exacerbated when the atmosphere is contaminated with, for example, corrosive particulate matter (PM) and sulphur or nitrogen oxides - for example, SO_2 and NO_x.

Most cities in New Zealand are coastal, and many buildings are within 5 km of the sea. Chloride-containing salt particles are generally believed to have a major influence on atmospheric corrosivity.

Mapping atmospheric corrosivity

How can the corrosivity of the atmosphere surrounding a building be determined? A quick answer would be referring to the atmospheric corrosivity map in NZS 3604:2011 Figure 4.2. This map divides New Zealand into three zones - B (ISO 9223 C2: Low), C (ISO 9223 C3: Medium) and D (ISO 9223 C4: High) - corresponding to the severity of exposure to wind-driven sea salt.

This map was based on the corrosion rate dataset of mild steel and galvanised steel collected across the country in the 1980s. It has been partially updated recently. There is evidence that the atmospheric corrosivity in some areas is changing due to some known or unknown reasons - for example, climate change.

A national monitoring network that can produce long-term environmental and material atmospheric corrosion data may help to provide a baseline to increase our understanding of this observation (Figure 1).

Micro-climate can increase corrosivity significantly

Micro-climatic conditions, for example, agricultural chemicals, geothermal gases and industrial emissions, can affect the corrosivity

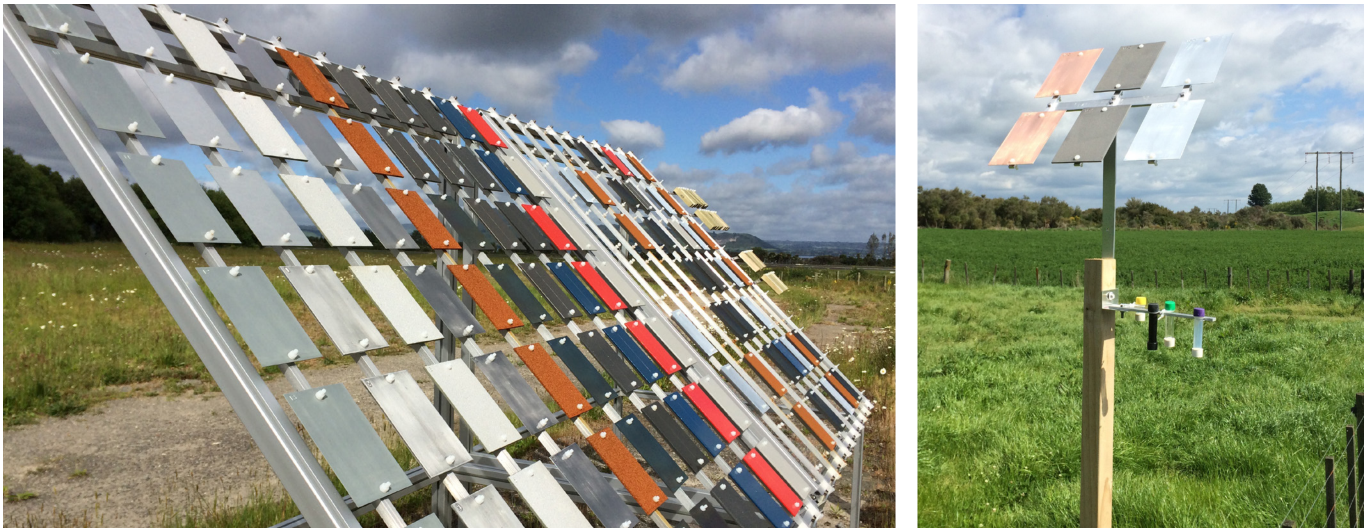

Figure 1: BRANZ national material environmental performance monitoring network.

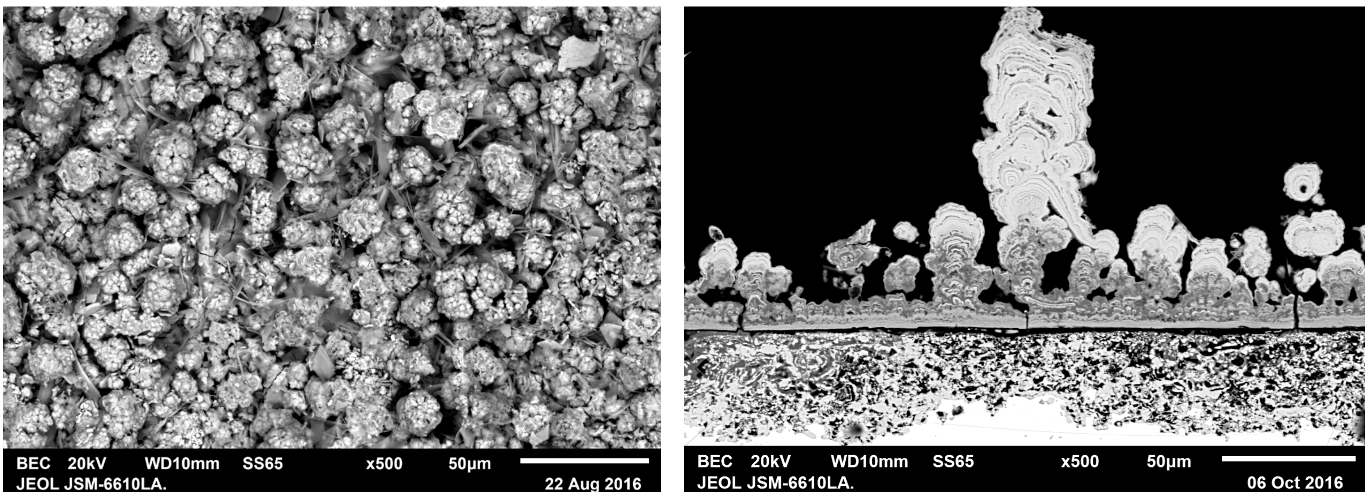

Figure 2: Surface (left) and cross-sectional (right) view of a corroded copper in a geothermal area.

of the surrounding atmosphere. Particularly, the high-temperature geothermal features commonly found in the Taupō Volcanic Zone have long been a concern.

The atmospheric corrosivity in areas approximately 500 m from an active geothermal feature could range up to ISO 9223 CX: Extreme with considerable variations. Metals (for example, steel, zinc and copper) could corrode at extremely high rates and with extraordinary behaviours that have not been observed in other natural environments (Figure 2). Note that the lower-limit steel corrosion rate in ISO 9223 CX is approximately 2.3 times higher than the upper-limit steel corrosion rate in NZS 3604:2011 zone D.

Furthermore, the background atmospheric corrosivity in the Taupō Volcanic Zone is likely to be higher than currently defined due to the synergistic effects of many small to medium-sized geothermal features.

Building micro-environments important but poorly understood

The atmosphere can directly attack the materials that are fully exposed to it. Meanwhile, it can interact with structural components and functional features to create various micro-environments (closed, sheltered and exposed) on buildings (NZS 3604:2011 Figure 4.3).

These micro-environments may differ from the atmosphere. The current understanding of micro-environmental conditions, characteristics and influences on corrosivity and material durability is limited and not able to consistently support the material specification scheme.

BRANZ filling information gaps

BRANZ undertook quantitative monitoring on seven residential buildings in Auckland, Rotorua, Waihau Bay, Wellington, Greymouth, Christchurch and Lauder (Figure 3). General trends were revealed - see Table 1. ➤

Figure 3: Mapping corrosivity in micro-environments on buildings.

These observations imply that airborne contaminants will interact, through complex mechanisms, with atmospheric conditions to determine corrosivity on buildings. An improved understanding from systematic experiments will bring a new perspective for mapping corrosivity and help identify factors, parameters and processes key to material durability.

Challenges from the changing climate

The climate is changing, leading to changes in rainfall, wind patterns, surface temperature, sea level and frequency of extreme weather events such as air pollution episodes, flooding and storms. These could be further compounded with changes in urban and building design approaches, construction technologies and building typologies to create even more diverse and dynamic environmental conditions on buildings.

This can profoundly affect the corrosivity of the atmosphere and of the micro-environments on buildings, thus affecting material durability in unusual or unexpected ways.

On the other hand, materials and their durability have a significant role to play in combating climate change (Figure 4):

- Reduction in whole-of-life embodied carbon in buildings - material damage and losses can be significantly reduced by accurately predicting corrosivity and managing corrosion issues with more-informed choices of durable and efficient materials. This will reduce the overall carbon emissions associated with

Table 1

General condition trends for residential buildings

ENVIRONMENTAL CONDITION TRENDS					
Maximum surface temperature:	Building	>	Atmosphere		
Surface temperature variation:	Building	>	Atmosphere		
UVA irradiation:	Building	<	Atmosphere		
Wind-driven rain:	Sheltered building position	<	Exposed building position	<<	Atmosphere
Time of wetness:	Sheltered building position	<	Exposed building position	<	Atmosphere
Surface soluble deposits:	Sheltered building position	>	Exposed building position		
COMPARATIVE CORROSIVITY					
Areas with light to moderate marine influence:	Atmosphere	≥	Exposed building position	≥	Sheltered building position
Areas with severe marine influence:	Building wall directly exposed to marine	>	Atmosphere	>	Building wall not directly exposed to marine
Areas with geothermal influence:	Atmosphere	>	Exposed building position	>>	Sheltered building position

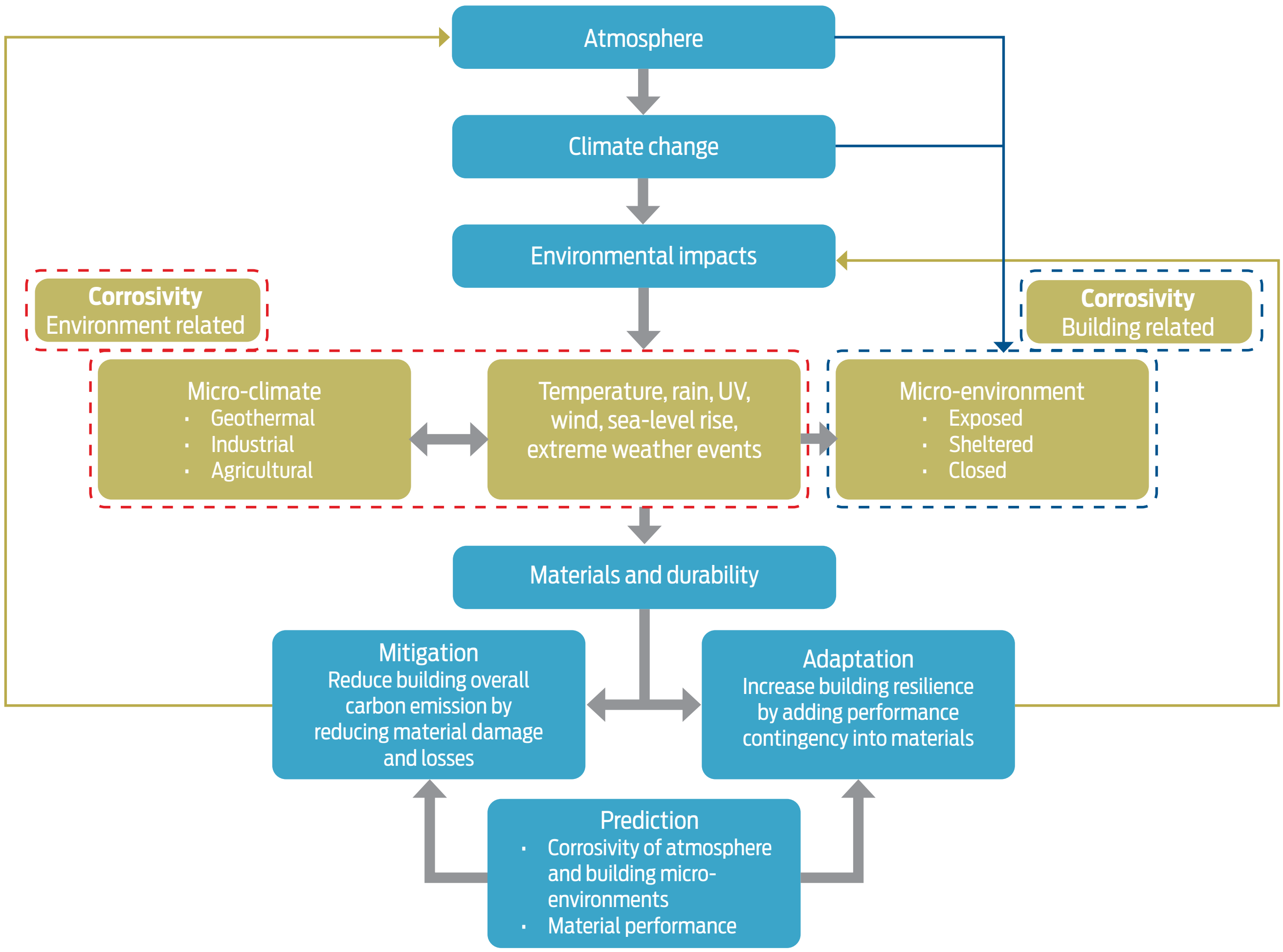

Figure 4: Interdependency of atmosphere, climate change, corrosivity and material durability.

those materials for maintenance and repair.

- Improvement of building resilience – appropriate performance contingencies can be predicted with climate change projections and embedded into materials. This will ensure buildings will be resilient to the likely future adverse effects of climate change scenarios.

Corrosion prediction is essential, but how?

How can these predictions be made to help inform decisions about the trade-off between material durability, climate resilience and carbon emission?

The interdependency, interaction and relevance of atmospheric, climatic and environmental factors must be investigated theoretically and experimentally to unveil their individual and collective influences on material environmental corrosion.

The science behind these manifestations will help identify the key factors contributing to corrosion and quantify the correlation functions. As such, universal prediction models can be built with a more mature use of data to provide new perspectives for informing the corrosivity of different and dynamic environments and specifying materials.

How can this science be delivered? There are many opportunities – for example, mechanism models using geographic information systems and data-related machine learning methods. Meanwhile, there are challenges and risks. Let us treat this as an open-ended question and keep the conversation going.

Get more information from BRANZ

More information can be found in the following BRANZ research reports available at www.branz.co.nz/pubs:

- SR288 *Update of New Zealand's atmospheric corrosivity map* (2013)
- SR325 *Update of New Zealand's atmospheric corrosivity map: Part 2* (2015)
- SR393 *Materials within geothermal environments* (2018)
- SR457 *Positional material deterioration over the building envelope* (due for release in 2021)
- SR458 *Atmospheric corrosivity of the Bay of Plenty region* (due for release in 2021).