Durability evaluation framework for new building materials

From thermally modified timbers to self-healing coatings, new building materials have the potential to bring many benefits to construction - but how do we know that their durability will meet Building Code requirements? A BRANZ research project developed a framework to help.

Materials account for around 16-24% of residential building development costs in New Zealand. New materials can bring cost, performance and environmental benefits. Consider just a small sample of what is available such as:

- timber treated with new preservatives
- thermally modified timbers
- high-performance concretes
- thermal spray coatings
- self-healing coatings.

Before they are introduced into everyday construction, we need to determine that they will comply with Building Code durability requirements. The durability of materials is vital to understand:

- service life prediction and planning
- cost and time intervals of maintenance, repair and refurbishment
- climate change resilience
- whole-of-life embodied carbon.

A BRANZ study developed a generic framework to help - see BRANZ Study Report SR464 *Durability evaluation framework for new building materials*. This included two interconnected parts of:

- a structurally phased durability evaluation procedure
- a general approach for developing testing schemes using top-down and bottom-up approaches.

The study included the development of a weathering rig that can rotate from east to west following the sun, spray specific solutions and also control sample inclination angle. This rig will help evaluate durability and predict service life more closely, helping to better evaluate the durability of materials on buildings under simulated conditions and using accelerated means.

Building Code requirements

The performance-based New Zealand Building Code requires functional components used on a building to meet minimum durability requirements depending on their location, accessibility and importance of not less than 5, 15 or 50 years.

Acceptable Solutions can be used to demonstrate compliance, but these mostly cover building materials and construction methods with an established history of use in New Zealand.

Verification Method B2/VM1 offers generic guidance that proof of performance should be demonstrated by in-service history, laboratory testing or analogy with similar products or situations, but there are challenges in achieving this.

Other assurance options available to demonstrate how a specific building product will comply with Building Code durability requirements include:

- technical information - typically provided by the manufacturer/supplier
- independent assessments
- industry-based schemes - for example, there are schemes in New Zealand covering glass and ready-mixed concrete
- appraisals - a technical opinion of a building product or system's fitness for purpose
- product certification such as CodeMark.

There are some problems with introducing new materials:

- It is difficult to thoroughly investigate the durability of these materials and to establish their reference service lives by determining the factors that may affect their durability.

- The availability of numerous standards and test methods does not mean the durability of any building material and/or product can be assessed properly. Durability is defined by the complicated interactions between a material and its in-service environment.
- Lab-based accelerated methods are commonly used to produce data for durability evaluation and service life prediction. It is challenging to verify the correlation between accelerated testing results and real in-service performance.

Durability evaluation framework

The evaluation framework in this study provides guidance about the durability evaluation of new materials. It includes a structurally phased durability evaluation procedure (Figure 1) and a general approach for developing testing schemes using a material-component-environment paradigm.

These are supported by:

- a generic database of some examples of new building materials
- an evaluation tool with compilations of:
  - durability evaluation methods
  - materials specifications and durability evaluation standards
  - factors relevant to durability and durability evaluation
- an interpretation tool with:
  - a database of service lives of typical building materials and components
  - a compilation of service life prediction methods, models and/or tools.

Durability evaluation methods

Evaluating the durability of building materials is not an easy task.

Non-accelerated methods include field exposure tests where materials are exposed to natural atmospheric environments to determine the degradation behaviours and durability. A good example of this approach is atmospheric exposure used for service life prediction of metal-based materials and/or structures. Field tests can offer a good representation of actual service life and a baseline for durability evaluations with other techniques under simulated conditions. An obvious limitation of non-accelerated field exposure testing is that it may require several years to deliver data.

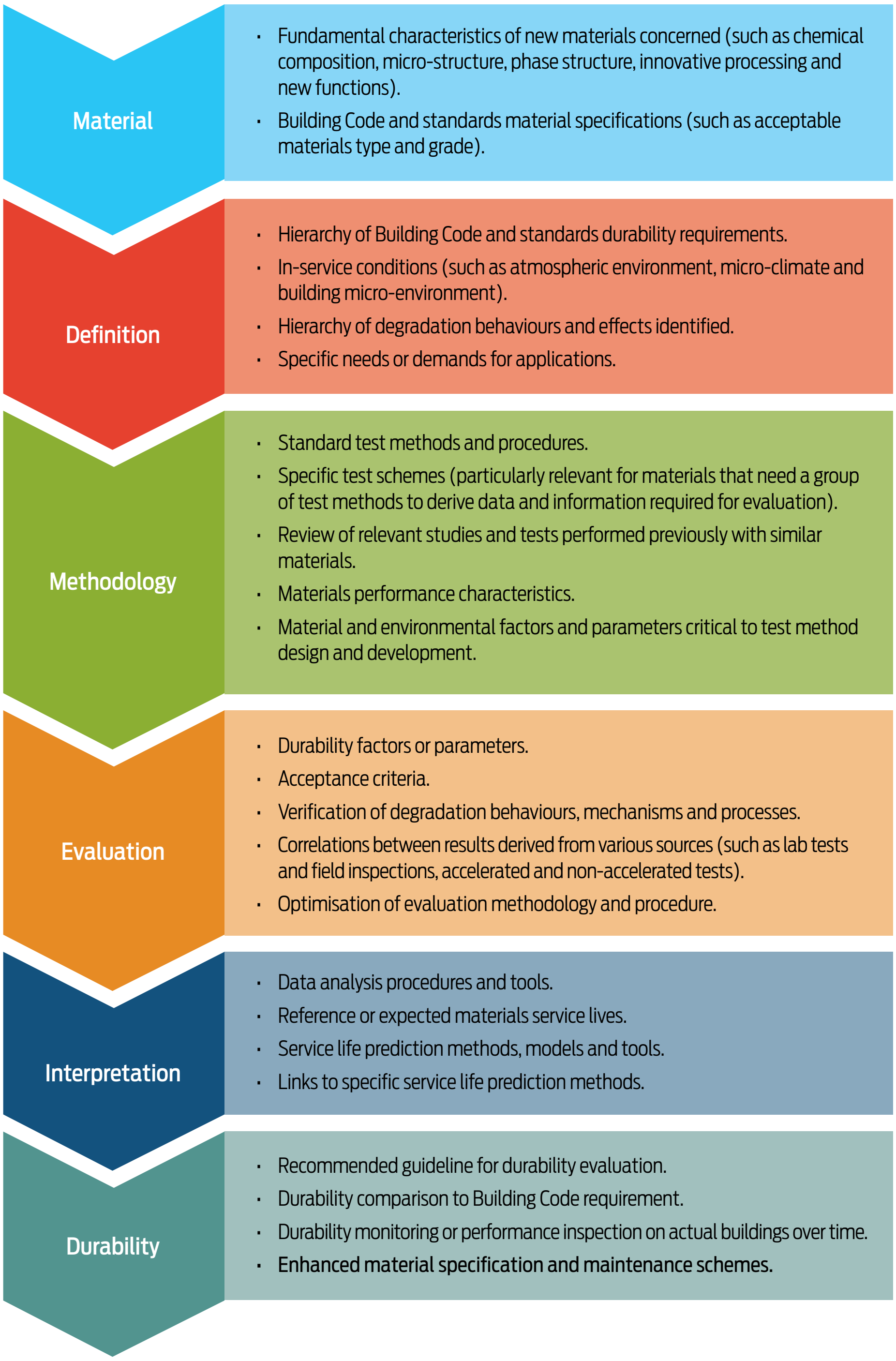

Figure 1. A structurally phased durability evaluation procedure.

Accelerated evaluation methods that can produce results in shorter timeframes are very valuable. Ideally, the results from accelerated tests should correlate, as closely as possible, with those from tests conducted under in-service or field exposure. However, an increase of acceleration will normally lead to a decrease in correlation. Typically, there is a threshold where the correlation remains reasonably good.

Two approaches are commonly combined and applied to accelerated testing:

- Time compression – a line-up of stresses observed in a real application but omitting periods where the stresses are known to be under a critical level, such as at night.
- Acceleration – increasing the magnitude of stress over the level of a real-time application. This can involve factors such as temperature or temperature cycling, and humidity.

One example is an accelerated method developed overseas to estimate the lifetime of aluminium reflectors in a solar power system (Figure 2). The research included outdoor exposure and indoor accelerated testing in a laboratory. The accelerated testing programme included controlled salt spray, UV/humidity, damp heat, humidity freeze, condensation and thermal cycling with condensation.

No single accelerated test reproduced all the degradation mechanisms, but all could be observed within the total range of accelerated testing samples. For example, with micro-pitting, 164 hours of exposure in the UV/humidity test was found to be equivalent to 5 years of outdoor exposure.

Figure 3. The weathering rig developed for the study.

Service life prediction

Predicting the service life of a material or component is at the heart of ensuring that buildings will meet Building Code requirements and the demands of occupiers and owners. It is complex since there are many factors involved. While some methodologies have been developed to produce data through accelerated or non-accelerated tests in laboratory or field assessments as just described, others are based on the inspection of existing buildings.

BRANZ Study Report SR464 summarises the methods, tools and models commonly used for the service life prediction of construction materials given in publicly available literature. It divides service life into three categories:

- Physical or technical service life - deterioration through degradation and natural ageing.
- Functional service life - service level expectations and user demands.
- Economic service life - the period between a component's installation and its replacement.

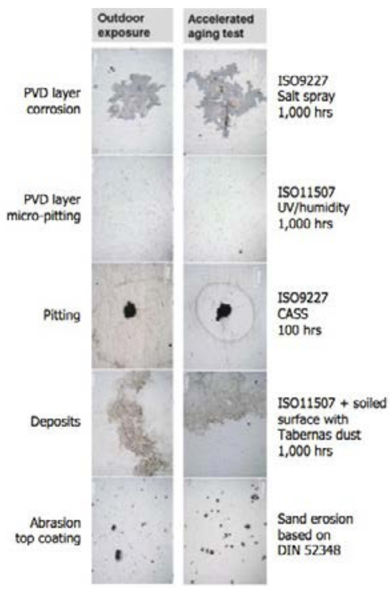

Figure 2, Outdoor exposure versus accelerated ageing test of aluminium reflectors.

Source: Wette, J., Sutter, F. & Fernández-García, A. (2016). *Correlating outdoor exposure with accelerated aging tests for aluminium solar reflectors.* AIP Conference Proceedings, 1734, 090003.

There are many different methods that can be used, from assessments based on real-life assessments or lab tests of degradation to use of fuzzy logic and artificial neural networks.

The service life data found in literature can vary significantly. A good scientific understanding of material degradation mechanisms and the methodologies used to derive the relevant data must be achieved so that data and information can be used appropriately.

BRANZ Study Report SR464 discusses the environmental degradation of metals, timbers, concretes and polymers and summarises the service lives of typical building materials, components and protective coating systems based on data collected from the literature.

Specialised weathering rig

Materials or components are normally installed on a building at a certain angle to the horizontal. This affects how long water remains sitting on the surface, the extent to which rainwater washes the surface, the amount of exposure from solar radiation and the extent to which solids such as sea salt or dirt can be deposited. These all impact on material weathering and performance.

Outdoor field exposure testing can provide important data in this area, but this can be limited if exposure is static and at a fixed angle.

This study built a weathering rig that can rotate from east to west following the sun, spray specific solutions and control sample inclination angle (Figure 3). This is a different approach from the use of artificial or hypothetical simulations and therefore evaluates durability and predicts service life more closely. A number of experiments are being designed to use this specialised weathering rig. It is expected that this may help better evaluate the durability of materials on buildings under simulated conditions and using accelerated means.

In addition to the work described so far, BRANZ Study Report SR464 also contains an in-depth analysis and review of data, methods, models and standards used all over the world to evaluate material properties, performance and durability for service life prediction. Appendix A outlines test standards for many different types of materials. Appendix B covers service life expectation.

More information

BRANZ Study Report SR464 *Durability evaluation framework for new building materials* - www.branz.co.nz/pubs/research-reports/sr464