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Implications of the New Zealand Building Code durability requirements

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The durability of materials and components used in buildings has been studied worldwide for a long time. In the building process, there has always been an implicit reliance that the finished building will be durable, able to carry out its function for a long time. The New Zealand Building Code, which came into force on 1 January 1993, has mandatory requirements for building durability which apply across the whole code. This has thrown the question of durabiiity into sharp focus, and the consequences of this are explored in this paper.

Keywords: building durability; New Zealand Building Code; weathering

The durability of buildings and their components has been and continues to be extensively investigated. Soronis[1] has recently given a summary of current thinking and scientific approaches to durability issues. The recent introduction of the new New Zealand Building Code (NZBC) and Approved Documents[2] on 1 January 1993 has had a far reaching effect on the New Zealand building industry. The NZBC is a performance-based code principally concerned with health and safety issues for building occupants. However, Section B2 of the Approved Documents Durability, is mandatory and applies across all other sections of the code[2,3]. Some degree of durability has always been assumed or implicit in the supply and use of building materials and components. In New Zealand, there are now explicit requirements – in the form of defined minimum lifetimes – for all parts of buildings. All building materials and components are required to perform their intended health, safety and amenity functions, and retain those functions, with maintenance, for their stated lives. The code requirements are spelt out in *Table 1*, and examples of components required to have 5 or 15 year durabilities are given in *Table 2*. The critical point to note is the requirement for structural components, or those components for which access and maintenance is difficult. These must have a durability of at least 50 years, or some other nominated lesser lifetime. This means that they must meet or exceed their original code-required performance criteria for all of this lifetime, with only routine maintenance.

The durability assessment of building materials and components, whilst based on sound scientific and engineering principles, also requires experience and intuition. It requires a good understanding of the way materials react to different exposure and use conditions, the attempted reproduction of those conditions or parts of them, and a knowledge of the way buildings are put together and used. In the end an assessment relies very heavily on the skill and experience of the person making it.

Performance verification

Approved Document B2 allows two methods of verification of durability performance. These are:

- history of use, or
- laboratory assessment plus expert interpretation of the laboratory results.

For all but traditional materials, such as wood, brick, concrete, glass or steel, and in particular for the structural use of components which require a 50 year durability, historical information just simply is not available. It is a matter of finding some laboratory-based method, with perhaps a field study on 'real' buildings as well, to arrive at a conclusion. Even where the durability requirement of B2 is less stringent, such as 15 years for exterior claddings, marketing considerations may dictate the obtaining of as long a durability statement as possible. The manufacturers and suppliers of building products and components now must supply durability information to end users and building owners.

The first thing to do is to assemble as much relevant information as possible. There are several things to concentrate on in doing this. Consider the case of a building product:

(a) What is the product used for? In particular, what is the scope of use(s), are there limitations on installation methods, exposure, particular uses, abuses, contact with other materials, runoff, etc.?
(b) In its use(s) how will the product fail, or what changes or deterioration mean that its useful life is finished?

Table 1 NZBC Clause B2 Durability Performance Requirements[2]

B2.3 From the time a code compliance certificate is issued, building elements shall with only normal maintenance continue to satisfy the performances of this code for the lesser of the specified intended life of the building, if any, or:

(a) For the structure, including building elements such as floors and walls which provide structural stability: the life of the building being not less than 50 years.
(b) For services to which access is difficult, and for hidden fixings of the external envelope and attached structures of a building: the life of the building being not less than 50 years.
(c) For other fixings of the building envelope and attached structures, the building envelope, lining supports and other building elements having moderate ease of access but which are difficult to replace: 15 years.
(d) For linings, renewable protective coatings, fittings and other building elements to which there is ready access: 5 years.

Table 2 Examples of building elements required to have 5 and 15 year durabilities[2]

5 year durability	15 year durability
Wall and ceiling linings	Structural suspension systems for ceilings
Floor coverings in wet areas (bathrooms, laundries, etc.)	Internal wall and floor secondary elements (doors, windows, trapdoors)
Interior and exterior coatings used as protection against moisture	Internal stairs/ramps/balustrades
Exposed plumbing and electrical fittings	Waterproof linings in showers and around wet areas such as baths
Signs	Impervious barriers to protect adjoining occupancies
Hot-water cylinders	External wall (cladding/sheathing)
	External wall secondary elements (windows/doors)
	Roof (cladding/sheathing)
	Roof secondary elements (windows/skylights/doors)
	Services: high-temperature flues

(c) Is there already the same or a similar product on the market in New Zealand? If so, what is known about its performance and durability?
(d) Is any information available on the same or similar products from overseas? In particular, independent assessments such as Agrement Certificates are very useful. While there is risk in using overseas data directly, such information will show how a product may degrade, and which factors are critical in this.
(e) What is known about the generic performance of the class or type of product to which a particular product belongs? This information is preferably obtained from New Zealand experiences, but overseas information is also useful.

The information gathered allows an initial assessment of potential product performance, limitations, and likely failure modes. From these can be distilled out the factors causing failure, or ageing, of a particular product.

For example, consider a precast concrete flooring plank which has conventional steel reinforcing. The plank is used as permanent formwork in the suspended floor of a commercial building, and has a topping poured on top of it. The durability requirement is 50 years. We know from past experience that the failure mode is likely to be rusting of the reinforcement, and consequent spalling of the concrete. On the basis of historical knowledge we can control this by:

- concrete mix design,
- cover to the reinforcement,
- limiting exposure to sites away from the sea, and out of specified industrial environments.

If the reinforcement is changed from steel to pultruded polyester bars, the whole situation changes. The concern is no longer about steel corrosion and concrete spalling. The effect of alkaline concrete on polyester, and whether excessive deflection due to creep is likely to cause failure, must be considered instead.

Consider another example, this time from the housing area. Particleboard is used in New Zealand in the form of flooring to form a platform for the construction of the rest of the house. This means that as all the bottom plates of the wall framing are attached through the particleboard floors to the floor joists, the particleboard is structural and must last at least 50 years. Particleboard flooring used in New Zealand is usually bonded with urea-formaldehyde (UF) adhesives. Work reported overseas[4–7] indicates that UF adhesives can lose strength over time. We need therefore to try to quantify the amount of strength likely to be lost, estimate the structural consequences of such a strength loss, and the likely performance of a particular system.

This leads on to a particularly important point. *The information assembled using (a) to (e) above is a guideline to performance, and no more.* It will help in working out the parameters critical to product performance. *It is* *then necessary to show uniquely and unequivocally for a particular product or component what its performance is likely to be.*

Another very important point is that the product cannot simply be assessed in isolation. When it is used on any building it will be part of a component or system, and it must be assessed in the light of how it is used.

Finally, there is an implicit message for manufacturers and importers of building products in New Zealand. Because the establishment of a track record is so important, it is a very wise move to expose routinely some product to weathering or other in-use factors, in the same way it would be used in practice, and record the results. It is also very useful to get feedback from the field, through surveys, of the way products are performing. Whilst these are activities that manufacturers or importers can do themselves, the results are more credible if generated for them by independent agencies or assessors. Experience to date is that few manufacturers have done this, and there is little site testing data available.

Durability assessment methods

In the section above some basic parameters which affect performance have been established by obtaining information which probably does not give direct guidance to durability but suggests the critical factors to be assessed.

Durability assessment will often cover exposure to in-use factors other than the weather. It is useful, though, to use weathering considerations as an example of how durability considerations can be assessed. There are four basic contributors to the way building products weather; these are:

1 The macro environment – whereabouts in New Zealand a product is used, and the consequences for its performance; for metals, for example, close to the coast or inland.
2 The micro environment – whereabouts on a building a product is used. Again, for a metal, is it rain washed or not? For a joint sealant, is it exposed to sunlight (north exposure) or not (south exposure)? Is it subjected to contaminated runoff, such as alkaline water from concrete?
3 Workmanship – has the product been installed properly, with the right materials/components?
4 Maintenance – has the product been maintained in the correct way, with the correct materials, at the correct time intervals?

Laboratory-based durability assessment methods – weathering machines, for example – are only useful in providing information on (l), a little of (2) and a little of (4). Field assessment, on actual buildings, is the only way to generate the rest. As far as possible, any durability assessment must consider the system or installation containing the product, not just simply be an evaluation of the product itself. There is an excellent example of this in a recent Building Industry Authority newsletter[8]. Consider the piping components of a plumbing system. If the system is surface mounted on the internal wall of a building, then access for inspection and replacement is easy, and the durability requirement is 5 years. If the system is buried in the ground, then access for inspection and replacement is moderately easy, and the requirement is 15 years. If the system is buried under a concrete ground floor slab, access and replacement is difficult, and the requirement is 50 years. That is, the same plumbing system, but with different installations and different durability requirements.

Keeping to weathering as an example of durability assessment, the following methods are available.

Natural weathering

The simplest method of getting durability information, say on weathering, is to expose product samples on racks at 45° to the horizontal, facing the equator. This takes a long time, decades in some cases, and so usually is not practical. Also, often only small samples of product, typically 300 × 300 mm, are exposed. This limits the amount of 'real-life' information which can be reproduced.

Artificial weathering or degradation – 'off the shelf' methods

The main weathering influence on paints, plastics and rubbers is popularly believed to be UV radiation from the sun. UV is only one factor; heat and moisture are also very important. The effects of weathering on polymers – paints, plastics and rubbers – can be accelerated using artificial weathering machines such as xenon arc artificial weathering machines, or QUV cabinets (see, for example, Wypych[9]). These machines use combinations of heat, water spray, and normal or UV light as the factors which degrade organic polymers, and speed up the process. They are still slow; 5000 hours or up to 1 year of exposure may be necessary. At the end of this time an expert opinion is necessary to make sure what has happened in the machine is indeed typical of what occurs in natural weathering. Standard test methods are ASTM G26[10] and G53[11]. The sample size is small (e.g. 225 × 65 mm), and hence unrepresentative.

Testing of paints or plastics by simple exposure to short-wave UV light is useless, and likely to be misleading, since the radiation energy is too high, and only one factor is being assessed.

General guidelines to the likely weathering performance of plastics and rubbers in New Zealand are given in Reference 12, which also gives a fuller description of degradation factors and artificial weathering methods.

When it comes to metallic building products, a different set of degradation factors applies. Metals such as steel corrode through atmospheric oxidation; steel, galvanized steel and aluminium also corrode as a result of sea salt deposition, and from the effects of gases such as SO_2 or H_2S, or from other causes[13–15]. The most common method of assessment for metallic building products, including factory-coated products such as galvanized steel, is salt spray cabinet exposure. Metal samples, usually as small coupons (e.g. 225 × 65 mm), are exposed to a 5% salt fog for up to a month[16]. Unfortunately salt fog cabinet tests on their own are notoriously unreliable[17], and a better approach has been to combine salt spray and xenon arc testing[18]. Guidelines to the likely performance of metallic building products exposed to weathering in New Zealand are available[13–15].

As well as degradation caused by weathering, many other factors can be reproduced by standard tests. Building papers, for example, are not exposed to the weather, and ageing can be simulated simply by heat treatment[19]. Where failure is likely to be caused by impact (e.g. interior wall linings, doors) suitable tests can be found, such as ASTM E695[20], as can tests for things like the abrasion of flooring caused by people walking on it[21]. However, in all cases expert opinion must be sought as to whether the test methods proposed will provide a realistic assessment. Are the degrading factors appropriate for the product being assessed? For example, xenon arc accelerated weathering tests have been carried out on fibre-reinforced cement sheet. This is totally inappropriate, since UV light does not degrade cement-based materials. While heat and moisture are known to affect cementitious materials in real life, the heat and moisture regimes used in such tests will produce little damage.

Artificial weathering or degradation – specifically designed methods

In many cases no standard methods are available, and methods must be developed from scratch. Usually there will be a number of factors which need to be assessed. The usual method is to try to assess the effect of one factor, and try to eliminate or hold constant any others for the duration of that test. For example, thin cement sheets reinforced with glass fibres (GRC) were developed in the UK in the early 1970s. The main concern there was loss of impact resistance caused by corrosion of the glass fibres by alkali from the cement. A classic study used heat (as hot water) to accelerate the corrosion process, combined with separate studies of natural weathering[22]. The picture becomes more complex if the glass fibres are replaced by wood-based ones, giving wood-fibre-reinforced cement sheet (WFRC). Degradation can now potentially be caused by alkali attack on the fibres, wetting and drying of the fibres causing the cement to crack, or bacteria and fungi eating the fibres. Each possibility was independently assessed[23] and eliminated. The main ageing process was cement carbonation, which was not harmful.

For any product, the methods selected to assess durability must be representative and realistic. Expert opinion must be used. Designing tests, and carrying them out, is a long and expensive process. The GRC durability assessment in the end took 10 years. The accelerated part of the WFRC work took 2 years. In both cases the accelerated work was backed up by natural weathering, the 'insurance' that in the end proved the artificial methods used were correct.

Examples

Some typical building products are listed in *Table 3*. With these are listed their failure modes, and hence the factors considered critical in making a durability assessment of them. Finally, appropriate test methods for each factor, where known, are given.

What is the significance of the information obtained?

Any durability assessment will give an indication of the factors important in causing product degradation and failure. It will also give an indication as to whether their effect will be fast or slow. *A durability assessment will not give a specific product lifetime in years to failure.*

This usually comes as a tremendous shock to a product manufacturer or importer, but the following comments will show why this is the case.

Degradation factors act together, not alone

The factors which cause degradation act all together on a product, not one at a time. This means that while the time frame over which a single factor will cause degra-

Table 3 Examples of building products and associated durability factors

Product	Failure mode	Factor causing failure	Test method
Exterior door	Weathering of coating (so substrate then degrades)	Sun, rain, heat	ASTM G26
	Impact	Human foot	ASTM E695
	Corrosion	Salt, pollution	ASTM B177
	Hardware fatigue (hinges, latch)	Human use	Cycles of opening and closing
	Adhesive failure	Water, heat	?
GRP cladding panel	Perforation (leaks)	Sun, rain, heat	ASTM G26
	Impact	Sharp body impact (vandalism)	?
	Corrosion of fixings attaching panel to building	Water, salt, pollution, etc.	ASTM B117 plus expert opinion on detailing of fittings
Nail plate	Corrosion	Water, salt, pollution	ASTM B117
	Corrosion	Treatment salts in timber (e.g. CCA)	?
	Fatigue	Cyclic stressing	?

dation can be estimated, the time frame for several acting together is much more difficult to assess. What is obtained is a general feeling as to whether degradation will be fast or slow, and any critical factors which could lead to very rapid failure.

All exposures are not equal
The four principal factors influencing durability were given above as:

1 Macro environment – where in New Zealand is the product exposed?
2 Micro environment – where on a building is the product exposed?
3 Workmanship – is installation correct, with the right materials?
4 Maintenance – has it been done properly, and at the right times?

All samples of a product are not equal
Manufacturing variations will mean that different product samples will behave differently. This effect is usually subtle, but can be catastrophic if critical aspects of the production process are not under control, for example the inclusion of UV stabilizers in polymeric products.

The same principles apply for any other factors causing ageing and degradation, apart from weathering. They mean that *for any particular building product, variations in manufacture, installation, conditions of use, and maintenance procedures will mean that the product will show a range of lifetimes* (see *Figure 1*). This is where the expert opinion comes in. The expert needs to know the general behaviour of generic – that is, types – of building products, for example exterior doors. For a specific product, it is then necessary to look at the laboratory test results for the degradation factors which have been assessed. These need to be examined in the light of the way the product is going to be used on a building, and the way it should be installed and maintained.

The expert examines the evidence, works out the most critical parameters, and arrives at a conclusion. This will be conservative, based not on worst-case considerations, but assuming extreme conditions. As the Building Code is written, the minimum lifetime figure should, in the absence of any case-law defining risk (see below), allow no failures. Where exposure, installation, workmanship and maintenance can result in an unacceptably short life if they are not done correctly, then the expert's durability opinion must state what must be done (or avoided) in these in order to achieve at least the specified minimum lifetime. These caveats must of course in turn be given by the manufacturer or importer in claiming specified levels of durability.

Risk, in terms of what is an acceptable level of failure of a product before its specified lifetime, has not yet been defined, and no doubt awaits the attentions of the legal fraternity. Certainly, in 20 years of investigating product problems and failures, BRANZ experience is that a 1% premature failure rate could be termed a disaster as far as the building industry is concerned. Our best educated guess for an acceptable rate currently is probably 0.005 or 0.01%.

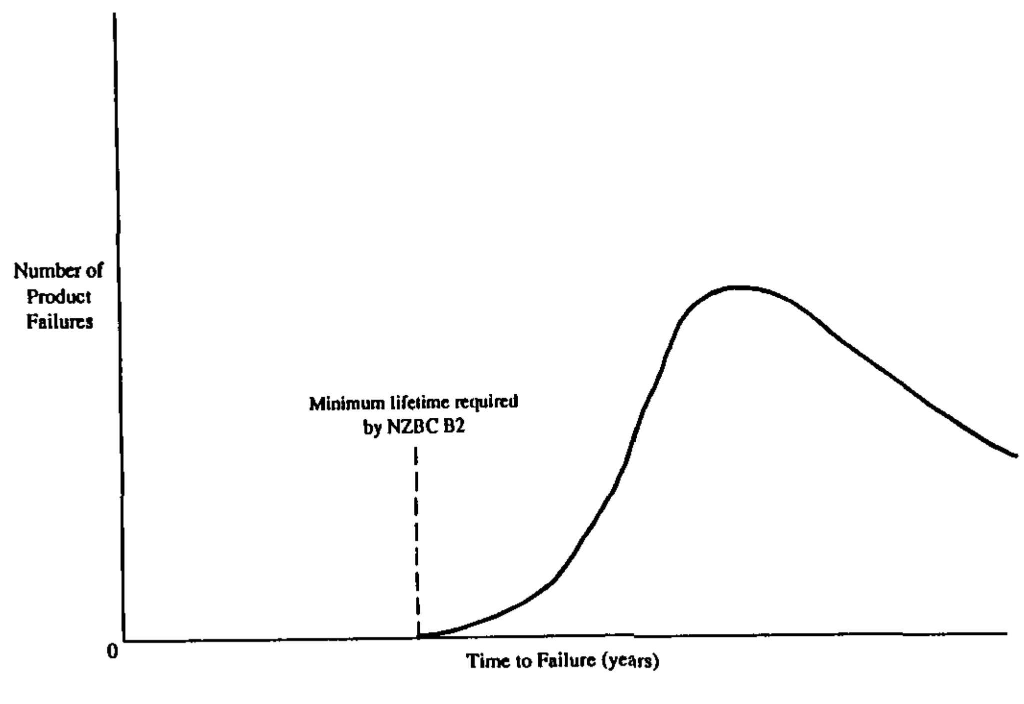

Figure 1 Building product lifetime range

Concluding comments

The introduction of the New Zealand Building Code and Approved Documents has placed a far greater emphasis and importance on being able to demonstrate the durability of building materials and components. Manufacturers and importers need to generate durability information for their products by routinely exposing products to in-use conditions (such as weathering), and by surveying the way their products are used and how they are performing.

Approved Document B2 of the NZBC allows durability information to be obtained either from history of use data, or laboratory tests followed by expert interpretation of the results. For the majority of building products there will be insufficient history of use for this to be the sole source of durability information. Laboratory assessment methods need to be carefully selected, so that they are appropriate for the in-use factors a building product will experience. While there are both 'off the shelf' and standard methods available, in some cases it will be necessary to develop suitable assessment methods. The methods used should as far as possible take account of the system in which the product is used, and not simply evaluate the product. Durability assessment, even by accelerated methods, can still take a long time. Expert interpretation of the results is necessary, preferably by an independent authority.

The durability information generated will not give a building product life in years to failure for all products. Factors causing product degradation act together, not singly, which is usually how they are assessed in the laboratory. Also, where a product is used in New Zealand, whereabouts on a building, how it is installed and how it is maintained will differ in each case, and all of these affect durability. The durability information obtained will be in the form of minimum product life, the period over which no failures can be expected.

An acceptable level of risk, i.e. a low level of product failure which is acceptable before the stated lifetime is reached, has not been established. The establishment of such a risk level is essential if the code is to work properly.

The assessment of the durability of a building product relies upon scientific measurements and observations. The selection of the methods used, and the interpretation of the results, are critical, and fall within the realm of the durability expert.

In terms of international developments in the assessment of the durability of building products and components, New Zealand is serving as something of a test bed with its Building Code requirements for durability. It has certainly placed durability under the spotlight, and developments both from the assessment and code compliance viewpoint are still in their infancy.

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