# IMPLICATIONS FOR STRUCTURAL RELIABILITY AS INDICATED BY IN-SERVICE OBSERVATIONS OF TIMBER DURABILITY

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## SUMMARY

The NZ Building Code highlights the need for designers to consider structural durability. Its present prescriptive approach to durability design inhibits innovation and extrapolation. A design procedure for durability considerations is being developed in Australia but it requires models which relate structural performance of building materials to environmental conditions. Some such models already exist for the resistance of timber to insect or fungal attack, and for adhesives, but need to be developed further to be useful for design by the Australian procedure.

## INTRODUCTION

### Building Code requirements

***Forest Research*** maintains records of the continuing service performance of selected structures including houses, bridges, fence lines, transmission line poles, log houses, retaining walls, building poles and piles, and horticultural supports. The primary objective is to monitor them for decay, corrosion, insect attack and weathering so they serve as a measure of the efficacy of various timber preservative and surface coating treatments. The New Zealand Building Code, (NZBC), (BIA 1992), brings in the requirement that buildings need to be designed for a specified service life. Generally this is 50 years although a client can specify a longer or shorter service life. For most structural materials the service life will be at least 50 years but the point about the NZBC is that it requires the issue of durability to be addressed by the designer. The requirement is expressed as “Building materials, components and construction methods shall be sufficiently durable to ensure that the building, without reconstruction or major renovation, satisfies the other functional requirements of the building”. A problem with this definition is that it is not quantified. Is a chance of failure of 1 in 1000, 1 in 10,000 acceptable? How does maintenance influence that probability? It is expected, of course, that a building will receive some maintenance, although it is conceivable that a design requirement is that it is to receive no maintenance. Clearly such things as house piles or framing have a no maintenance requirement, whereas boron treated weatherboards do, if timber treated to TPC Specifications is the durability solution. MP 3640, clause 9.1.2 (Standards NZ) states “Exterior cladding and associated trim may be included in Hazard Class 1 provided that it is additionally and continuously protected by a well-maintained three coat paint system”.

### Design for durability

Design for structural reliability in timber construction is sufficiently well developed that computational design procedures can be defined and even codified except that the impact of material durability on structural reliability is not included. Usually, design for durability is omitted, and the control of performance is undertaken by complying with good building practice, for which there are many excellent texts and standards, (BRANZ). Thus proven experience becomes the principal guide for the designer but it takes a long time to develop standards and evaluate innovations by this method. Innovation is thereby inhibited too. Reliance on durability standards for design tends to ignore the impact that changes in building practice, such as increasing air-tightness of buildings, thermal insulation and acceptance of the use of untreated timber may have. One solution to foster innovation, although perhaps far from satisfactory, is to require “fitness for purpose” producer statements from material suppliers, builders and designers. This somewhat bureaucratic approach which may be taken by building officials shifts the onus of ensuring compliance onto some specific individual or company. The producer statement will usually specify how a material or component is to be installed, maintained and used which mean that the liability passes to the builder for correct installation, to the owner of the building for correct maintenance and the occupier of the building for correct use.

### Prediction models

An alternative to relying on experience is to base design procedures on the use of prediction models. A benefit obtained from the application of prediction models is that they can be used in design to target a specific performance, and to predict the effects of changes in operative conditions. An example of this is knowledge of the rate of change in strength of an adhesive under given conditions of temperature, moisture content, and stress (Walford 1994). Another would be a knowledge of the rate of corrosion of fasteners given the ambient conditions. Leicester et al (1998) describe a major national project on this topic funded by the Forestry and Wood Products Research Development Corporation of Australia. This project aims to define relationships between structural durability, specific durability hazards, the extent of attack, time, and the environmental conditions.

The object of this paper is to examine such evidence that ***Forest Research*** has for establishing the above relationships for hazards and environmental conditions encountered in New Zealand.

## SPECIFIC PREDICTION MODELS

Specific models are needed to describe the rate of strength loss from given hazards under given conditions. The usual hazards to be considered are insect attack, fungal attack, and corrosion of fasteners.

### Borer attack

A study (Walford, 1977, unpublished) on rimu used in the hangars built at Whenuapai aerodrome in 1945, revealed a relationship between loss in bending, tension, compression and bolted joint strength, modulus of elasticity, and the density of exit holes on the surface of 75x100 mm members as shown in Figure 1. From this it can be deduced that if conditions favour borer infestation then a loss of strength of up to 50% can be expected in 30 years. Another study (Gaunt & McNab, 1995, unpublished) showed losses in compression strength of 12% in radiata and 17% in rimu that had been in a structure for about 40 years. If these data are combined with information about the likelihood of attack, the particular species, temperature and moisture conditions, then it should be possible to estimate the risk of structural failure from this cause. The risk can be eliminated entirely by treating the timber with insecticidal preservatives and the cost of doing this can be weighed against the product of the probability of failure and the cost of failure.

### Fungal attack

Typical data (NZFOA, 1992) from tests of preservative treated timber in ground contact is given in Figure 2. The stakes are 20x20 mm in cross section and are pushed into soil to a depth of 200 mm. They are periodically inspected and a condition index calculated.

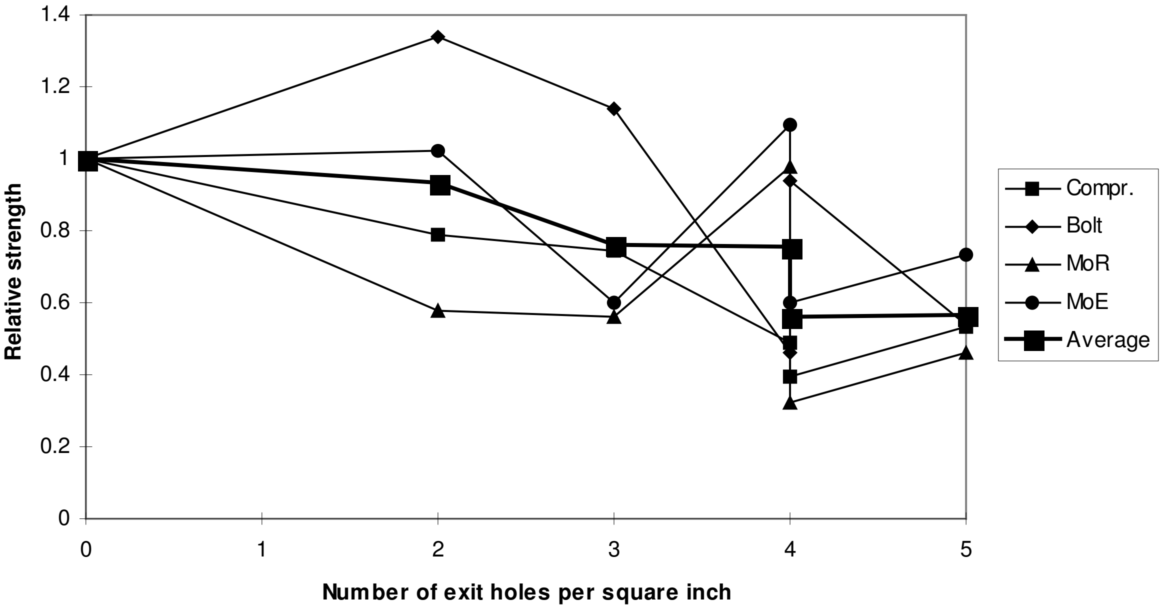

**Figure 1.** Effect on strength of borer attack in rimu.

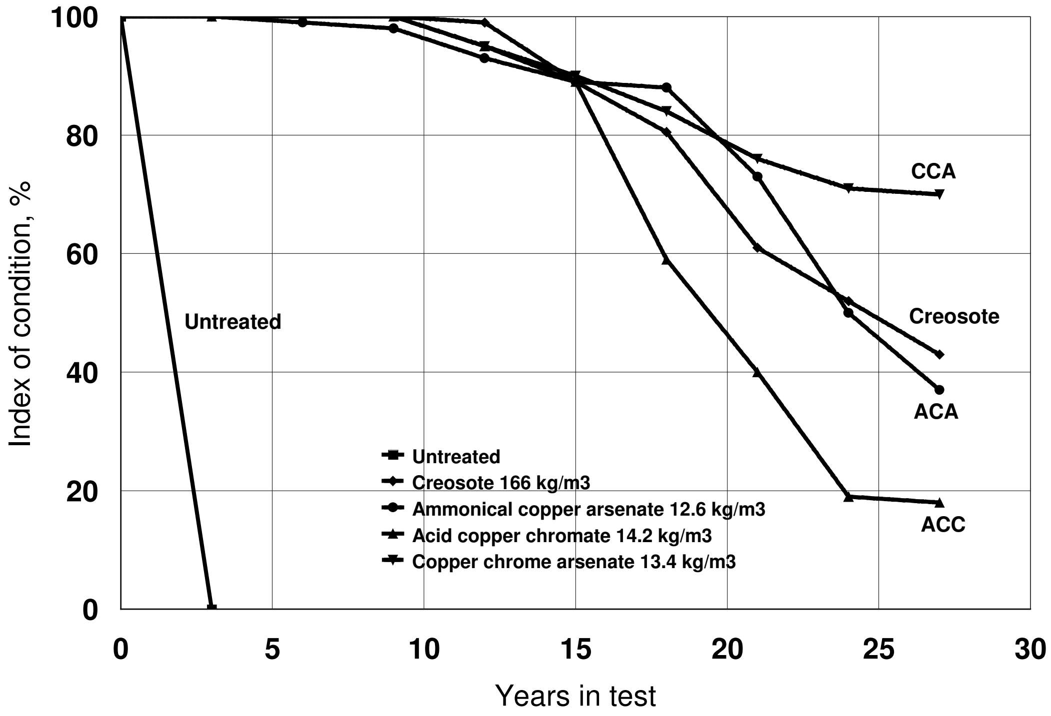

**Figure 2.** Performance of some preservatives in 20x20 mm radiata pine stakes in ground contact.

The condition index is calculated from the estimated percentage of sound cross section remaining over a large sample of stakes. It is seen that untreated timber completely rots through in three years, i.e. to a depth of 10 mm. Copper chrome arsenate (CCA) treated stakes have rotted to leave 70% of the cross section intact after 27 years, i.e. the depth of decay is 15% of 20 mm or 3 mm after 27 years. In a stake of 20x20 mm cross section this means a residual section modulus of 100 x $(0.7)^3$ = 34%. Extrapolating this to treated poles of 300 mm diameter, after 27 years the residual diameter would be 294 mm. Thus the section modulus would reduce to 100 x $(294/300)^3$ = 94% of the original. Figure 3 bears this out, comparing 30x30 mm stakes with 150 mm diameter posts. Rates of decay are similar but because of the larger dimensions of the posts, the percentage cross sectional loss is less. Thus estimates of the rate of strength loss due to decay can be made and explains why a service life in excess of 50 years is ascribed to treated radiata building poles.

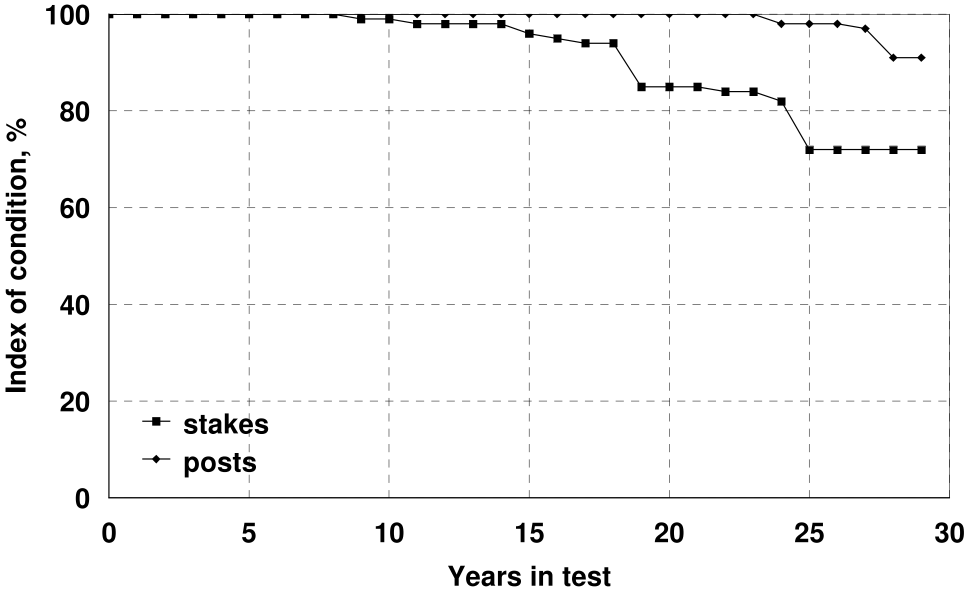

**Figure 3.** Rates of decay of 30x30 mm stakes and 150 mm diameter posts treated to H4 hazard class with CCA

It needs to be understood that some deterioration will inevitably occur in a building. The important point is to assess whether that will prevent the "other functional requirements of the building" from being satisfied and whether normal maintenance will effectively prevent, retard or rectify that deterioration. For some structures, untreated timber is preferred and for these, attack from insects and fungi is a concern. A survey of 16 log buildings in New Zealand (Page 1996, unpublished), showed that decrease in the "average soundness rating" for the buildings was extremely variable, ranging from zero to 2 % per year with an average rate of 0.3% per year which extrapolates to 15% in 50 years. Looking at the particular buildings, it was obvious that at least two would not give 50 years' service without major repairs. One was built of untreated radiata and the other from untreated Lawson cypress. In the latter case the problem stems from the non-durable sapwood that was left on the logs. The lesson here appears to be that logs with little or no sapwood should be used, or the sapwood should be treated. However, to refute that opinion, two other buildings made of the same two untreated species were considered to be sound. The remaining log buildings were of Douglas fir, Redwood, Larch, Western red cedar or CCA treated Corsican pine.

### Corrosion

An extensive study has been set up by Pokorny and Collins (1997) to determine the rate of loss of withdrawal strength in a variety of nails in a variety of exposures. Samples were tested after one year's exposure and further tests are planned for 10 and 15 years' exposure. Unfortunately no immediate, i.e. control, tests of withdrawal strength were done so the relative strength loss after one year cannot be determined. However, it is possible to compare the effects of various parameters. Four types of nails were tested as shown in Table 1. Two exposures were set up: exposed to direct wetting, and protected from direct wetting but otherwise subject to atmospheric moisture. Other variables were also included in the experimental design but are not included in the data in Table 1.:

- Influence of degree of fixation of the CCA preservative
- Flat-sawn and quarter-sawn ring orientation.
- Effect of additional protection with grease.
- Geothermal and marine locations.

Compared to the galvanised steel nails in the protected environment, the relative withdrawal strengths after one year are those given in Table 1.

**Table 1.** Types of nails used in exposure tests, and withdrawal strengths after one year's exposure in three environments, relative to the strength of protected galvanised nails.

| Type | Dimen-sion | Description | Overall | Exposed | Protected |
|---|---|---|---|---|---|
| Plain steel | 75x3.15 mm | Bright jolthead | 0.50 | 0.68 | 0.49 |
| Galvanised steel | 75x3.15 mm | Galvanised jolthead | 0.93 | 0.82 | 1.00 |
| Roofing nail | 60x4.25 mm | Galvanised, Nuway roofing nail | 0.86 | 0.84 | 0.88 |
| Stainless steel | 80x3.25 mm | Annular grooved, rosehead | 1.06 | 1.09 | 1.04 |

From this it can be deduced that after one year:

- The use of stainless steel gives very little advantage over galvanising.
- Bright steel nails have a strength reduction of twice that of the galvanised nails.
- Bright steel nails apparently fare better fully exposed than protected.

To develop a model, these results will need to be reviewed after the 10 years samples are tested.

### Adhesives

Adhesives are gaining importance in structural timber components, whether in fingerjoints, glulam, panel products, LVL or in I-joists. A model predicting the durability of wall framing containing fingerjoints bonded with melamine-urea adhesive was developed by Walford (1994). Figure 3 shows the relationship between temperature, moisture content, and residual strength in the adhesive after 50 years' exposure.

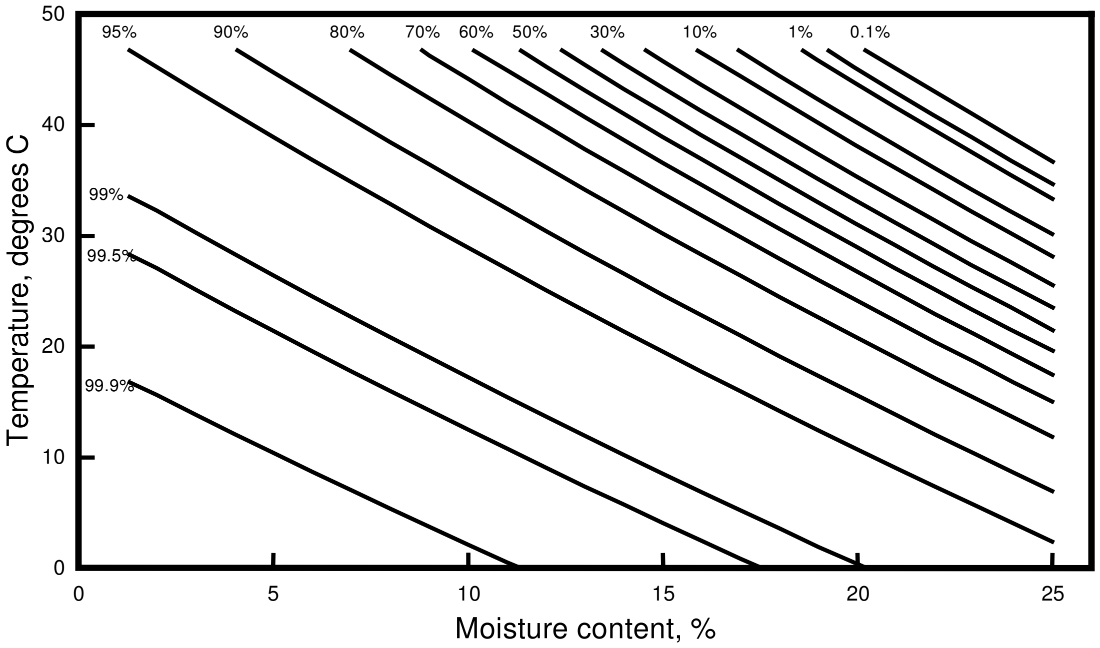

**Figure 3.** Predicted residual strength in fingerjoints made with MUF adhesive after 50 years exposure.

Although the assumptions made in the development of this prediction have yet to be validated for radiata pine, it does illustrate that models to predict the service life of adhesives are possible.

## CONCLUSIONS

- The NZ Building Code has highlighted the need for designers to address durability in a more structured way than the present prescriptive approach.
- A project is underway in Australia to develop models and design procedures for durability. By substituting models for New Zealand conditions, this procedure should be valid for New Zealand.
- Some specific models relating structural strength to environmental conditions already exist but considerable work needs to be done still.

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