# Fifteen Years of Performance-Based Design in New Zealand

**A.H. Buchanan, B.L. Deam, M. Fragiacomo**
**Department of Civil Engineering, University of Canterbury**
**Christchurch, New Zealand**

**Tony Gibson**
**Consulting Engineer, Gibson Consultants Civil/Fire/Structural**
**Auckland, New Zealand**

**Hugh Morris**
**Senior Tutor, Department of Civil and Environmental Engineering**
**The University of Auckland, New Zealand**

## Summary

The paper gives an overview of performance-based design in New Zealand with particular reference to fire, seismic, and durability design of timber structures. The performance-based code came into force 15 years ago when it superseded the previous prescriptive codes. Major changes were introduced, particularly in fire engineering, where every specific limitation, such as that on the maximum number of storeys for timber buildings, was removed. The compliance of each design with the performance requirements may be demonstrated using either of an approved verification method (specified calculations), an acceptable solution (prescriptive requirements), or an alternative solution (special one-off design). This new regime allowed more freedom in design and the use of new construction systems, but with the simultaneous deregulation of the building industry, a reduction in quality followed, with poor details and sloppy construction leading to a number of problems such as "leaky buildings". For this reason, more stringent regulations were recently introduced, with a much more rigorous system of quality control.

## 1. Introduction

New Zealand is a small country with only 4 million people. The Building Act 1991 introduced a major change in the legislative framework for building controls in New Zealand, with the introduction of a national building code for the first time. The new controls became mandatory in 1993. For some participants (such as structural engineers) not much changed because the new legislation allowed the continuing use of existing documents and existing calculation methods to meet the new performance requirements. On the other hand, very big changes occurred in fire design, where the old prescriptive code was superseded by new Approved Documents, and the opportunity of fire design from first principles was introduced.

## 2. Prescriptive codes vs performance-based codes

The previous New Zealand legislation was piecemeal. Most regulations were prescriptive documents with language which sounded like *"Do this, do that, don't ask any questions"*. The new legislation is performance based, so that it allows any solution provided that compliance with the performance requirements can be demonstrated. Prescriptive codes are concerned with "*how the building is built"* whereas performance codes are concerned with "*how the building behaves"*.

# 3. New Zealand legislation since 1990

## 3.1 Building Act

The Building Act 1991 set out a new "light-handed" legislative framework for building controls in New Zealand. It required design in accordance with the Building Regulations and the Building Code in a performance-based structure, controlled by the Building Industry Authority (BIA).

Following the emergence of poor practice in some areas (notably weathertightness), a more stringent regime was introduced in the Building Act 2004 [1]. The BIA was dissolved and the new Department of Building and Housing was established, with the objective of restoring public confidence in the building industry. However, this did not change the basic 1991 performance-based structure.

The 2004 Act has created an environment where innovative solutions are significantly more difficult to introduce, but not impossible. A higher level of proof in design, as well as much higher standards of drawing and detailing are now required. A key feature is that code compliance must be demonstrated by compliance with the consent documentation rather than directly with the building code as had been previously the case. Well designed and detailed innovative buildings will still find acceptance in the market-place.

## 3.2 Building Regulations

The Building Regulations 1992 are those regulations called up by the Building Act 2004. The First Schedule to the Building Regulations is known as the New Zealand Building Code [1].

## 3.3 Building Code

In accordance with the Building Act, the New Zealand Building Code requirements summarised above can be achieved in any one of three different ways:

1. Verification Method
2. Acceptable Solution
3. Alternative Solution

A *Verification Method* is an approved calculation method, generally consisting of well established codes of practice for design. Many of these codes have existed much longer than the Building Act, so are called up with or without modifications.

The *Acceptable Solution* is a "cookbook" of prescriptive measures which are a "deemed to satisfy" solution to the requirements of the Building Code.

For special designs which do not fit the above two options, the Building Act allows an *Alternative Solution* to be offered. This solution may be accepted by the Territorial Authority (TA) if they are persuaded on "reasonable grounds" that the solution meets the requirements of the Building Code.

# 4. Fire Safety

Fire safety in New Zealand buildings is controlled by the Building Act and the Building Code, as summarised by Buchanan [2]. The main performance requirements are:

1. Provision of safe egress for occupants.
2. Provision for safety of fire-fighters.
3. Prevention of fire spread to neighbouring properties.
4. Safeguarding the environment from the adverse effects of fire.

The Building Code does not address fire damage to the building's contents or fire damage to the building structure, as these are considered to be the concern only of the building owner.

## 4.1 Building Code; Clauses C1 to C4

The fire related clauses are in four sections, as follows:

- C1: Outbreak of Fire.
- C2: Means of Escape.
- C3: Spread of Fire.
- C4: Structural Stability During Fire;

Some of the requirements for each of these are listed in the Appendix.

## 4.2 The design process

### 4.2.1 Verification Method

No *Verification Method* has been approved for fire design.

### 4.2.2 Acceptable Solution

The *Acceptable Solution* C/AS1 in the Building Code Handbook and Approved Documents is used for design of most buildings for fire safety.

### 4.2.3 Alternative Solution

Wherever a designer wants to do something more innovative than the prescribed Acceptable Solution, an *alternative solution* is offered using specific fire engineering design. This requires a high level of education, and reference to the latest technical literature.

## 4.3 The Review Process

### 4.3.1 Local Councils (Territorial Authorities)

The approving authorities have had to change the way that they think about fire safety. After 1991 they had to develop a whole new approach to the problem of fire, and needed to re-educate themselves in order to be able to process the routine jobs and call in expert advice for the major jobs. Re-education within the approving authorities is particularly important because they shoulder the main burden of responsibility for fire safety in buildings.

Most larger cities appear to have accepted their responsibilities and have adapted to the changes, but there have been some wide differences in the quality of interpretation across the country which are being addressed by the New Zealand Fire Service and other agencies.

### 4.3.2 New Zealand Fire Service

Under the Building Act 2004 it became a requirement for Alternative Solutions to be referred to the New Zealand Fire Service (NZFS) for advice on means of escape and the safety of Fire Service personnel in the event of fire. This is undertaken by the Design Review Unit of the NZFS, who are required to provide a memorandum to the Territorial Authority on these matters. The final decision on approving building consent applications remains however with the Territorial Authority.

## 4.4 Outcomes

### 4.4.1 More Innovation

The new environment introduced in 1991 allowed much more innovation. It removed the arbitrary 2.5 storey height limitation for timber buildings, for example, as the criterion now is simply the level of safety. Many four to six storey timber framed apartment buildings have been built since the new code came into effect. However, the 2004 Act has changed the freedom with which innovative design can be used, not so much the finished product, but more of process, proof and detailing. A higher standard of design and quality control is now expected, and designers are required to respond accordingly.

#### 4.4.2 From Property Protection to Life Safety

There has been an altered emphasis in the new Building Code from property protection to life safety. The Building Code is not concerned with property protection in the owner's building, only with the protection of property belonging to "other people" such as neighbours. Responsible designers have to discuss property protection with the owner, who then has to consider the possible event of a fire, often resulting in discussions with the Fire Service and the owner's insurance company.

#### 4.4.3 From Passive to Active Protection

The new code environment resulted in a significant change in emphasis in many buildings, with less passive fire protection, lower fire resistance ratings and more active systems including smoke and heat detectors, and wider use of automatic sprinkler systems. Smoke detectors were rarely used in New Zealand before the new code was introduced, now they are used widely.

# 5. Earthquake Safety

The approach adopted for fire safety has also applied for seismic design of structures since 1991. This aspect of design is almost entirely focused entirely on safety, with little regard for preservation of the structure or its contents in the event of an earthquake. There are no insurance or other incentives for better than minimum performance, possibly because New Zealand has not had a significant earthquake near an urban centre since 1931. Building developers and owners in the private sector are very cost sensitive, so few will accept additional costs for improved seismic performance. Many buildings are constructed for property developers who are only interested in maximising the sale price (and profit). Recent emergency management legislation requires Local Councils to identify earthquake-risk buildings (defined as those likely to be less than 1/3 as strong as a new building) but the business community opposes this because of the loss of value when such buildings are publicly identified.

## 5.1 Building Code

Earthquake safety is one aspect of the Building Code, Section B1 – Structure, which aims to:

(a) Safeguard people from injury caused by structural failure,
(b) Safeguard people from loss of *amenity* caused by structural behaviour, and
(c) Protect *other property* from physical damage caused by structural failure

Some performance requirements are reproduced in the Appendix. The most significant engineering change introduced in the 1991 Building Code was the exclusive use of Limit State Design for all structures (i.e. working stress design (or allowable stress design) was no longer able to be used).

## 5.2 The Design Process

#### 5.2.1 Verification Method

The Verification Method B1/VM1, specifies two standards for the seismic design of timber structures. The structural design actions for earthquake were originally specified in NZS 4230:1992, which is in the process of being superseded by the recently published NZS 1170.5:2004. The verification method for designing timber structures is the Timber Structures Standard NZS3603:1993 plus amendments.

#### 5.2.2 Acceptable Solution

For timber structures, the only acceptable solution specified in B1/AS1 is NZS3604, which is used by architects, builders and engineers to design the seismic bracing elements within small light timber framed buildings such as houses.

#### 5.2.3 Alternative solution

Alternative solutions are only needed to be used for special cases that are not included within a Verification Method or Acceptable Solution (e.g. epoxied steel rods).

### 5.3 The Review Process

The introduction of performance-based codes reduced the amount of building control exercised by local city and regional Councils, with their previously comprehensive technical overview of building design and construction being replaced with a quality control process that figuratively ensured that all of the boxes had been ticked in the correct places. This was in part due to Councils wishing to minimise their exposure to liability wherever possible.

Independent privately owned inspection companies were encouraged by the 1991 Building Act. These flourished during the 1990's but weather-tightness problems (see later) eroded confidence in these professionals and their Public Liability insurance costs significantly increased. Many stopped working.

### 5.4 Outcomes

New Zealand had shown itself to be innovative in the field of earthquake design and construction long before the introduction of the 1991 Building Act so there was little additional innovation after this was introduced. It is likely that there was actually less innovation because performance based seismic design was already a mature discipline by the time the Building Act was introduced.

One significant advance was the 2001 publication of the Multistorey Timber Buildings Manual [3] which merged the earthquake design methodologies and material properties from several research publications into a single document, alongside fire and acoustic design information.

## 6. Durability

As listed below the same performance approach applies to durability, with the Building Act calling up the Building Code which again offers three different approaches to compliance. The main concern has been weathertightness of so-called "leaky buildings".

### 6.1 Building Code

Durability is covered in the New Zealand Building Code in Section B2 – Durability, and Section E2 – External Moisture The aim of the durability clause is to satisfy the other objectives of the Building Code without major renovation. It requires that materials, components and construction methods will allow the building to function for its *specified intended life* of not less than 50 years for structural and inaccessible elements. Accessible elements where failure can be detected such as exposed cladding, plumbing in a crawl space, interior linings and coatings may have a shorter specified life of 15 or 5 years.

### 6.2 The Design Process

#### 6.2.1 Verification Method

According to Verification Method B2/VM1 durability may be verified by proof of performance, using

- In-service history,
- Laboratory testing, or
- Comparable performance of similar building elements

Such factors as the local environment, intensity of use, material composition, the degradation mechanism are evaluated for an element within a specified system including fixings, flashings etc.

6.2.2 Acceptable Solution

In Acceptable Solution B2/AS1, New Zealand standards are approved for a variety of construction materials. For timber the main ones are *NZS 3604:1999 Timber Framed Buildings*, and *NZS 3602:2003 Timber and Wood-based Products for use in Building*. NZS 3602 includes the required level of chemical treatment for different levels of hazard, and is also is referenced for E2 External Moisture. *The Compliance Document for the New Zealand Building Code- Clause E2 - External Moisture,* a prescriptive solution for exterior detailing, was expanded from 28 pages in 2000 to 184 pages in 2005.

6.2.3 Alternative Solution

Alternative solutions are usually supported by expert opinion such as from BRANZ Ltd. (Previously known as the Building Research Association of New Zealand).

### 6.3 The Review Process

Territorial authorities went through a period of adjustment when the performance based approach was introduced in 1991 and again in 2004 following the leaky buildings problem, so that they now have greater levels of responsibility and work more closely with the Department of Building and Housing.

### 6.4 Outcomes

In the main the performance based approach was successful but poor practice crept in due to concurrent deregulation of the building industry and introduction of the non-prescriptive code. A problem started to become evident in the mid 1990s with poor detailing and poor construction, mostly with monolithic sheet claddings. By 1999 there were serious calls for improved practice [4]. Water penetrated the cladding of balcony structures and poorly sealed building envelopes of a large number of residential units, and without adequate wall ventilation this caused decay of the framing and serious structural risk.

In 1995 an amendment was made to the New Zealand Standard for timber treatment (referenced in Acceptable Solution B2/AS1 in 1998) allowing untreated kiln-dried timber in dry conditions. For buildings with poor weathertightness, this resulted in severe and rapid timber decay of timber framing where water was trapped against the timber in a relatively warm environment. Within two years a number of significant durability failures resulted in a public outcry and repair estimates of between NZ$120M to NZ$1.8Billion [4]. While this was quickly dubbed “leaky buildings” in the news media it was often incorrectly attributed to the use of untreated pinus radiata timber framing timber.

This problem led to a legal procedure for resolving disputes (Weathertight Homes Resolution Services Act 2002), changes to the Building Act in 2004, a major change to the government regulating bodies and a requirement for all carpenters to be certified. A new conservatism in weather detailing has become the norm for exterior claddings, with a requirement for chemical treatment of pinus radiata.

## 7. Conclusions

Fifteen years of a performance-based building code regime has allowed a lot of design innovation in the New Zealand building industry. It has also resulted in some problems including different levels of enforcement across the country, and poor workmanship, especially where local building inspection has been insufficient to ensure the expected quality of design or on-site workmanship from the small number of poorly qualified designers or sloppy builders who cause problems.

## 8. References


[1] Building Code Handbook and Approved Documents. Department of Building and Housing, Wellington, New Zealand. www.dbh.govt.nz

[2] Buchanan A.H. 1994. Fire Engineering for a Performance Based Code. *Fire Safety Journal* Vol. 23, No.1, pp. 1-16.

[3] Beattie, G.J., Buchanan, A.H., Gaunt, D. and Soja, E. 2001. Multi-storey Timber Buildings Manual Carter Hold Harvey Wood Products, Fletcher Challenge Forests Ltd, James Hardie Building Products Ltd and Winstone Wallboards Ltd.

[4] Parliamentary Library - information briefing service for members of parliament, Leaky buildings, Background Note 2002/10 06 November 2002 www.clerk.parliament.govt.nz/content/1207/02-10LeakyBuildings.pdf


## 9. Appendix

**Selected clauses from the New Zealand Building Code,** from www.building.dbh.govt.nz**.**
Words in *italics* are defined terms.

**Clause B1 – STRUCTURE**
**OBJECTIVE**
**B1.1** The objective of this provision is to:
(a) Safeguard people from injury caused by structural failure,
(b) Safeguard people from loss of *amenity* caused by structural behaviour, and
(c) Protect *other property* from physical damage caused by structural failure.

**FUNCTIONAL REQUIREMENT**
**B1.2** *Buildings, building elements* and *sitework* shall withstand the combination of loads that they are likely to experience during *construction* or *alteration* and throughout their lives.

**PERFORMANCE**
**B1.3.1** *Buildings, building elements* and *sitework* shall have a low probability of rupturing, becoming unstable, losing equilibrium, or collapsing during *construction* or *alteration* and throughout their lives.
**B1.3.2** *Buildings, building elements* and *sitework* shall have a low probability of causing loss of *amenity* through undue deformation, vibratory response, degradation, or other physical characteristics throughout their lives, or during *construction* or *alteration* when the *building* is in use.
**B1.3.3** Account shall be taken of all physical conditions likely to affect the stability of *buildings, building elements* and *sitework,* including:
(a) Self-weight, (b) Imposed gravity loads arising from use, (c) Temperature, (d) Earth pressure, (e) Water and other liquids, (f) Earthquake, (g) Snow, (h) Wind, (i) *Fire,* (j) Impact, (k) Explosion, (l) Reversing or fluctuating effects, (m) Differential movement, (n) Vegetation, (o) Adverse effects due to insufficient separation from other *buildings*, (p) Influence of equipment, services, non-structural elements and contents, (q) Time dependent effects including creep and shrinkage, and (r) Removal of support.
**B1.3.4** Due allowance shall be made for:
(a) The consequences of failure, (b) The intended use of the *building*, (c) Effects of uncertainties resulting from *construction* activities, or the sequence in which *construction* activities occur, (d) Variation in the properties of materials and the characteristics of the site, and (e) Accuracy limitations inherent in the methods used to predict the stability of *buildings*.
**B1.3.5** The demolition of *buildings* shall be carried out in a way that avoids the likelihood of premature collapse.
**B1.3.6** *Sitework,* where necessary, shall be carried out to:
(a) Provide stability for *construction* on the site, and (b) Avoid the likelihood of damage to *other property*.
**B1.3.7** Any *sitework* and associated supports shall take account of the effects of:
(a) Changes in ground water level, (b) Water, weather and vegetation, and (c) Ground loss and slumping.

**Clause B2—DURABILITY**
**OBJECTIVE**
**B2.1** The objective of this provision is to ensure that a *building* will throughout its life continue to satisfy the other objectives of this code.

**FUNCTIONAL REQUIREMENT**
**B2.2** *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 this code throughout the life of the *building.*

**PERFORMANCE**
**B2.3.1** *Building elements* must, with only normal maintenance, continue to satisfy the performance requirements of this code for the lesser of the *specified intended life* of the *building*, if stated, or:
(a) The life of the building, being not less than 50 years, if:
(i) Those *building elements* (including floors, walls, and fixings) provide structural stability to the *building*, or
(ii) Those *building elements* are difficult to access or replace, or
(iii) Failure of those *building elements* to comply with the *building code* would go undetected during both normal use and maintenance of the *building.*
(b) 15 years if:
(i) Those *building elements* (including the *building* envelope, exposed plumbing in the subfloor space, and in-built chimneys and flues) are moderately difficult to access or replace, or
(ii) Failure of those *building elements* to comply with the *building code* would go undetected during normal use of the *building*, but would be easily detected during normal maintenance.
(c) 5 years if:
(i) The *building elements* (including services, linings, renewable protective coatings, and *fixtures*) are easy to access and replace, and
(ii) Failure of those *building elements* to comply with the *building code* would be easily detected during normal use of the *building.*
**B2.3.2** Individual *building elements* which are components of a *building* system and are difficult to access or replace must either: (a) All have the same durability, or
(b) Be installed in a manner that permits the replacement of *building elements* of lesser durability without removing *building elements* that have greater durability and are not specifically designed for removal and replacement.

**Clause C2—MEANS OF ESCAPE**
**OBJECTIVE**
**C2.1** The objective of this provision is to:
(a) Safeguard people from injury or illness from a *fire* while escaping to a *safe place*, and
(b) Facilitate *fire* rescue operations.

**FUNCTIONAL REQUIREMENT**
**C2.2** *Buildings* shall be provided with *escape routes* which:
(a) Give people *adequate* time to reach a *safe place* without being overcome by the effects of *fire*, and
(b) Give fire service personnel *adequate* time to undertake rescue operations.

**PERFORMANCE**
**C2.3.1** The number of *open paths* available to each person escaping to an *exitway* or *final exit* shall be appropriate to:
(a) The *travel distance*, (b) The number of occupants, (c) The *fire hazard*, and (d) The *fire safety systems* installed.
**C2.3.2** The number of *exitways* or *final exits* available to each person shall be appropriate to:
(a) The *open path travel distance,* (b) The *building height*, (c) The number of occupants, (d) The *fire hazard,* and
(e) The *fire safety systems* installed in the *building.*
**C2.3.3** *Escape routes* shall be:
(a) Of *adequate* size for the number of occupants, (b) Free of obstruction in the direction of escape, (c) Of length appropriate to the mobility of the people using them, (d) Resistant to the spread of *fire* as required by Clause C3 ‘‘Spread of Fire’’, (e) Easy to find as required by Clause F8 ‘‘Signs’’, (f) Provided with *adequate* illumination as required by Clause F6 ‘‘Lighting for Emergency’’, and (g) Easy and safe to use as required by Clause D1.3.3 ‘‘Access Routes’’.