Review of the Building Code Structural Provisions

G.M. Lawrance, D.C Hopkins, D.P.H Cheong & M.C. Stannard

Ministry of Business, Innovation and Employment

2014 NZSEE
Conference

ABSTRACT: A review of Clause B1 (Structure) of the New Zealand Building Code is being undertaken to improve the clarity and consistency of structural performance expectations for new building work and obtain a better societal mandate for what we expect from our buildings. The Canterbury earthquake sequence and an earlier Building Code review between 2005 and 2008 have highlighted this need. This paper is a forerunner to a public discussion and consultation paper anticipated to be released later in 2014 and is presented here to promote discussion.

The proposed amendments to B1 expand the functional and performance requirements and introduce a risk-based performance system that is not aimed at changing the current design levels but to make them clearer.

It is proposed that building importance levels will now be defined in the Building Code rather than in AS/NZS 1170 as at present – building importance being relevant to more than just structural safety. It also introduces the concept of "tolerable impacts" in defining the objectives and requirements of the Building Code Clause B1. A new risk-informed performance matrix contains a series of Tolerable Impact Level statements (TILs). The TILs specify structural performance outcomes depending on the severity of the natural hazard event (earthquake, wind and snow) for buildings with different building importance levels and design lives. Taken together, the set of "tolerable impact statements" are expected to provide Standards writers with clear and consistent definitions of what is required of building structures - no matter what the material or structural type. It is intended that these amendments help the sector achieve more effective and efficient structural design and construction decision-making through better understanding of Clause B1's objectives and performance criteria.

1 INTRODUCTION

1.1 Why the Building Code needs to be amended

The New Zealand building control system has been performance-based since the introduction of the 1992 Building Regulations which reflected the Building Act passed in 1991. This is often referred to as 'outcome-based' law and regulation. Broadly speaking this means that it specifies what has to be achieved rather than how it will be achieved.

An earlier review of the Building Code indicated a need for more clarity. In particular, a lack of measurable performance requirements across the Building Code clauses has been an issue recognised for some time. The current Building Code uses qualitative terms such as requiring a low probability of loss of strength or loss of amenity but does not identify what this means. Therefore, requirements are currently largely qualitative and the level of performance can only be interpreted on a more quantitative basis by using the Building Code Verification Methods (VMs), e.g. B1/VM1, and Acceptable Solutions (ASs), e.g. B1/AS1, which cite building Standards. These Building Code supporting documents are not mandatory and potentially alternative solutions could be used. This leaves a question as to what performance requirements are required when anything other than a VM or

AS is used unless an equivalence principle is adopted. This is not consistent with a performance based system.

To date the Building Code's structural performance requirements have been provided within New Zealand Standards. Setting the level that we want our buildings to perform to is public policy and is not something that should be left to individual Standards committees. There can be and is variability between different Standards. Stronger direction on what we are aiming for when designing our buildings needs to be provided to the individual Standards committees. Commentators, particularly those in the industry, have therefore called for better descriptions of performance criteria and quantification of the requirements as far as is practicable. This view was reinforced by the Canterbury Earthquakes Royal Commission.

1.2 **What level should we be aiming for?**

The Royal Commission noted the general consensus amongst stakeholders that the central regulator should:

- develop building policy including determining the level of risk that society will tolerate and the regulatory requirements and the Standards needed for the design and construction of buildings;
- take a more active role in developing and reviewing acceptable solutions and verification methods (including cited Standards) and guidance material on the requirements of the system.

Current MBIE thinking, subject to consultation, is that there is insufficient societal demand to change the level of building performance. Reasons for this position are outlined below.

The generally satisfactory performance of contemporary buildings in the Canterbury earthquakes designed to current performance levels is one indicator. There were notable instances in Canterbury where this performance was not achieved but this was due to non-compliant design or construction and where there was an issue with specific design details, e.g. insufficient wall reinforcing confinement, diaphragm force prediction, etc. Post 1995 buildings generally performed satisfactorily.

There has been discussion as to whether damage prevention should be part of the Building Code. The Royal Commission has recommended further guidance be developed to promote low damage technologies, base isolation, PRESS systems, etc. This is on the MBIE programme to work with the professional societies to do this. While we would want to endorse and promote the use of such technologies, the Building Code sets the minimum level of performance that society expects. The Building Act has life safety and prevention of damage to other property objectives, but does not require protection against damage to the building itself. Serviceability state requirements do have an element of property protection and the proposed changes would make these more explicit. However, higher levels of property protection are seen as more of an individual choice by the owner than as a societal requirement. While overall community resilience is important and the collective cost to New Zealand in rebuilding major cities, e.g. $40B to rebuild Christchurch, impacts all, there are many other factors at play apart from Building Code requirements. Land use planning and insurance are just two major issues.

Any change to the performance levels could, as a consequence, require considerably more engineering involvement in the assessment of earthquake-prone buildings. New legislation currently before Parliament reinforces the need to comply with at least 33% of 'new building standard' (NBS) and proposes a more active approach to upgrading earthquake-prone buildings. Assessment of all commercial buildings will be required within a five year timeframe. This puts a huge demand on engineering resources. As there are already many thousands of buildings that have been assessed, changing the 'new building standard' could potentially invalidate previous work.

1.3 **Other considerations**

Other aspects to consider in the review include:

- The code is pitched at new buildings. How does it apply for building work associated with existing buildings or other ‘buildings’ such as bridges and dams?

- Should there not be more emphasis on and integration of geotechnical aspects?
- Is the mix of functional requirements and performance requirements right?
- The Canterbury earthquake sequence pointed to a need to better define amenity and structural performance, particularly with respect to liquefaction.
- The Code aims to achieve an outcome for society in general, i.e. buildings collectively. Because of uncertainty and variability both on the demand and capacity side, specific outcomes cannot be guaranteed for any individual building. It is proposed that buildings will be designed with the expectation that for 99% of buildings the TILs will not be exceeded. This is subject to debate but the intention is to reflect current standards of reliability.

1.4 **Amendment options**

The amendment options considered and the main reason for pursuing or not pursuing these options are as follows:

1. The status quo option. Retain the existing Clause B1 and do nothing. This is not favoured as it does not address the industry and stakeholder’s call for more clarity and specificity.
2. As above but educate by way of seminars and guidance information to clarify the existing code. This option is not favoured because the education programme may not be entirely effective and over time the message will be lost leaving stakeholders no better off.
3. Introduce a prescriptive code. This option is not favoured because it stifles innovation and negates the generally accepted performance based philosophy behind the reforms of the 1991 building regulations.
4. Clarify the code clauses and specify a risk matrix (probability and consequence) for natural hazards in regulation based on the latest technical knowledge. This is the preferred option because it retains the current performance based philosophy, adds clarity and specificity to the requirements and would encourage (promote) rigour.
5. The preferred option above except that the risk matrix for natural hazards is contained in a guidance document. This is not favoured because, while it retains the current performance based philosophy and adds clarity and specificity to the requirements, it does not have the same regulatory force and would therefore not be as effective.

1.5 **Aims of Amendment**

The aims of a new code Clause B1, Structure, will be to maintain existing levels of performance, improve specificity and be capable of being practically applied. Where possible, quantification of the likelihood of major natural hazards, and better definition of the severity of impact that can be tolerated by society, will greatly assist in developing a more effective and efficient performance-based system of building control. The development of quantitative performance criteria is however constrained by two key issues:

- The limits of scientific knowledge on the likelihood of a range of major natural hazards and thus estimating demand on structures.
- A high level of uncertainty and variability exists in estimating the reliable capacity of structures and their material components.

Greater use of more measurable performance requirements in the Code itself may help foster greater levels of innovation by encouraging designers and consenting authorities to target the performance criteria and reduce their over-reliance on cited Standards as the default performance benchmark.

The proposed amendments are targeted specifically at new buildings. The TILs listed in Section 3 may need amending for other ‘buildings’ such as bridges and dams. Existing buildings are another challenge. It may be possible to develop tolerable impacts for the continuum of performance for existing buildings, from the earthquake-prone level to higher shaking levels. This is being considered as part of the review of the existing building assessment guidelines (refer 8.0 References).

Clause B1 is labelled "Structure". A fundamental aspect implicit in the structural performance of buildings is the geotechnical context. Too often geotechnical considerations are seen as an optional extra by structural engineers – to be considered if it appears (to them) that geotechnical aspects might be important. The fact is that they always are. Those involved in building "structural" design need to include geotechnical and site considerations from the outset. For example, in earthquake design, geotechnical and site considerations may significantly alter the likely response of the building to the earthquake shaking. In addition, the site vulnerability may render even the most robust structure at risk. Every opportunity will be taken in the new Clause to emphasise the need to consider geotechnical and site aspects integrally with structure.

2 PROPOSED CODE AMENDMENTS

The proposed amendments to Clause B1 of the Building Code are intended to better define building performance requirements for a range of natural hazard events through a range of probabilities of occurrence.

In essence, "tolerable impacts" are defined according to the nature and probability of occurrence of each event and the importance category of the building. The concept is developed from international precedents, particularly the American ICC Performance Based Code. Attempts to provide greater clarity and quantification of building performance requirements involve two main considerations:

- Definition of the intensities of hazard events to be used in structural design or assessment.
- Definition of the tolerable impacts of any chosen hazard event on building performance.

The first essentially defines the demand on a building structure, while the second defines the aspects related to the capacity of the building to perform.

New Zealand's risk profile from the natural hazards is significant in world terms, particularly for earthquake. Scientific research by GNS Science, NIWA and others over many years has provided an ability to estimate the likely occurrence of natural hazard events for earthquake, wind, snow and flooding. This work forms the basis of current structural design. Seismic hazard factors in NZS 1170, for example, are determined on the basis of the intensity of ground shaking at a given location that is estimated to have a probability of occurrence of 10% in 50 years. The New Zealand scientific community is highly regarded and their work provides a reasonable basis for defining building performance – and one which is in line with international approaches.

It is important to recognise that the science provides only an estimate of probability and that this is constantly being reviewed and updated in light of the latest local and international research. Thus the value used for 500-year earthquake shaking intensity at a particular location may change with new knowledge.

Nevertheless, the various probabilities used in structural design (and proposed in the new amendment to the Code) provide suitable benchmarks against which to describe building performance requirements. Regardless of the uncertainties involved in estimating the hazard corresponding to a given probability, it is possible to define aspects of building performance that the community will tolerate in 50-year, 100-year, 500-year, 1000-year and 2500-year "events".

Thus the focus of the proposed amendments is on better defining the "tolerable impacts" rather than on better defining the hazard event characteristics. The proposed approach maps the expected and 'tolerated' building response to a natural hazard event, depending on the importance of the building to the community or Building Importance Level (BIL) and the frequency of occurrence of the event.

For natural hazards other than earthquake, wind or snow, the proposal is to maintain the status quo position by requiring a low probability of strength and amenity loss and to manage this by reference to the same tolerable impacts for earthquake, snow and wind that apply at the various design levels. The proposed risk-based performance framework for Code Clause B1 – Structure is designed to more clearly manage risk within these limitations. The likely performance outcomes of applying the current design Standards have been considered and developed into a comprehensive set of TILS according to building importance level and event probability.

The fundamental changes proposed are thus to:

- Elevate the risk matrix for the natural hazards of earthquake, wind and snow from AS/NZS 1170 Part 0 to the Building Code.
- Expand the risk matrix to include high-level TILs for conventional buildings.
- Elevate BILs to the Building Code – by combining with Clause A3 Fire.
- Amend objective/functional/performance requirements.
- Deal with other natural hazards – by maintaining the status quo position of meeting functional and performance requirements and the TILs.
- Deal with other building types such as bridges, dams and tanks by maintaining the status quo position by meeting functional and performance requirements and a variation on TIL descriptions.
- Simplify performance requirement descriptions, adding clarity without losing the message.

3 RISK MATRIX AND TOLERABLE IMPACT LEVELS

The risk matrix proposal for the common natural hazards is shown in Figure 1. The hazard levels for earthquake, wind and snow together with the design working life and the category or importance level of the building can be matched to specific tolerable impact levels. These levels are described after the table and it is proposed that these tolerable impact descriptions are included in the Building Code.

For example by following the risk matrix it can be seen that a BIL 2 building with a design working life of 50 years when designed for earthquake shaking with an annual probability of exceedance of 1/500 would be designed and detailed so that the impacts on the building were not expected to exceed Tolerable Impact Level (TIL) 4.

The APE's in black are for earthquake and wind. The APEs in red are for snow events.

It is not intended that designers will need to check specifically for performance at each level. Current design practice of considering the serviceability limit state (SLS) and the ultimate limit state (ULS) should remain appropriate when using the Verification Method as a means of compliance, but designers will need to be aware of the full range of performance expectations. It is intended that the full range will be considered by Standards committees when producing 'means of compliance' documents. This makes much more explicit the assumption implicit in some Standards that buildings continue to perform beyond the ULS design earthquake.

Annual Probabilities of Exceedance (APE) to be used for natural hazard effects				**Chance of occurrence in lifetime of building**	**Tolerable Impacts Level (TIL)**				
Design working Life (years)					**Building Importance Level (BIL)**				
Up to 1	**25**	**50**	**100**		**BIL1**	**BIL2**	**BIL3**	**BIL4**	**BIL5**
1/1000 **(1/250)**	**1/2500**	**1/5000**	**1/10000**	Extremely rare	TIL6	TIL6	TIL5	TIL5	TIL4
1/500	**1/1000** **(1/250)**	**1/2500** **(1/500)**	**1/5000**	Exceptionally unlikely	TIL6	TIL5	TIL5	TIL4	TIL3
1/250 **(1/100)**	**1/500** **(1/100)**	**1/1000** **(1/250)**	**1/2500** **(1/500)**	Extremely unlikely	TIL5	TIL5	TIL4	TIL3	TIL2
1/100 **(1/50)**	**1/250** **(1/50)**	**1/500** **(1/150)**	**1/1000** **(1/250)**	Very unlikely	TIL5	TIL4	TIL3	TIL2	TIL1
1/50	**1/100**	**1/250**	**1/500**	Unlikely	TIL5	TIL3	TIL2	TIL1	TIL0
1/25 **(1/25)**	**1/50** **(1/25)**	**1/100** **(1/50)**	**1/250** **(1/150)**	As likely as not	TIL4	TIL2	TIL1	TIL0	TIL0
1/10	**1/25**	**1/50**	**1/100**	Likely	TIL3	TIL1	TIL0	TIL0	TIL0
1/5	**1/10**	**1/25**	**1/50**	Very likely	TIL2	TIL0	TIL0	TIL0	TIL0

Figure 1. Risk Matrix

Tolerable Impact Levels (TILs)

The Tolerable Impact Levels (TIL 0 to 6) describe the structural performance expected of 99% of buildings (i.e. tolerable impacts) when they are subject to increasing levels of demand. Currently these are high level and focused on conventional buildings. The descriptions are as follows:

TIL0 – Insignificant – No deaths or injuries or loss of building functionality and amenity. No effects on structural integrity, stability or means of support. No effects on building contents or damage to other properties. Building remains fully accessible and no repairs are required.

TIL1 – Mild – No loss of life and no injuries. Building function fully maintained. Amenity partially lost for less than one day. No significant reduction in structural integrity, stability, or means of support. No significant damage to the building fabric including structural cracking, deflection or settlement that would affect the structural, fire or weathertightness performance of a building. Very limited damage to building contents. No damage to other properties.

TIL2 – Moderate – No loss of life. Few, if any, injuries. Building function and amenity partially lost for no more than a week. No significant impact on structural integrity, stability or means of support. Minor damage only to building fabric, including structural cracking, deflection or settlement, that would affect the structural, fire or weathertightness performance of a building. Damage to no more than 2% of secondary and non-structural elements. Limited damage to building contents. Little, if any, damage to other properties. Building is fully accessible and could be readily repaired within one month of repairs commencing.

TIL3 – High – No loss of life. Minor injuries to less than 10% of people exposed. Building function and amenity significantly affected for no more than two months. Limited (10%) damage to services repairable in no more than two months. Structural integrity, stability and means of support maintained. Some damage to key structural elements. Noticeable damage to structurally insignificant building fabric that may include cracking, deflection or settlement that does not affect the structural, fire or weathertightness performance of a building. Damage to no more than 5% of secondary and non-structural elements. Some building contents damaged. Little or no damage to other buildings. Very limited effects on building access routes. Damage readily repairable within a month of repairs commencing.

TIL4 – Severe – No loss of life. Minor injuries to no more than 20% of people exposed. Major injuries to 2% of people exposed. Building function and amenity widely affected and lost for up to a year. Extensive damage to services. Significant damage to building structure and building fabric including onset of permanent deformation in main structural elements. It is likely damage may affect the structural, fire or weathertightness performance of a building. No rupture or collapse of main structural elements. Damage to no more than 20% of secondary and non-structural elements. Significant damage to building contents. Unassisted evacuation of the building possible. Damage repairable within one year of repairs commencing.

TIL5 – Very severe – Some loss of life to no more than 1% of people exposed. Significant injuries to no more than 10% of people exposed. Minor injuries to no more than 40% of people exposed. Significant damage to structure and building fabric, including partial collapse of key structural elements. Egress routes do not collapse and escape is possible. Assisted evacuation severely restricted. Amenity / functionality lost for more than two years. Building services very extensively damaged. Damage to no more than 40% of secondary and non-structural elements. Repair may be uneconomic. Large proportion of building contents not recoverable. Minor damage to other property.

TIL6 – Extreme – Significant loss of life to no more than 5% of people exposed. Extensive injuries to 30% of people exposed. Minor injuries to 60% of people exposed. Many injuries serious. Structural integrity, stability and means of support significantly compromised resulting in collapse. Egress routes blocked making escape impossible for most. Evacuation possible with emergency service assistance. Extensive damage to building fabric and contents. Damage to no more than 80% of secondary and non-structural elements. Building function and amenity lost completely. Extensive damage to building services which is not repairable. Significant damage to other property. Total economic loss of building. Replacement needed.

4 STAKEHOLDERS

MBIE is engaging with the technical engineering societies to develop the amended B1 proposal. Public consultation is needed before any regulatory change can be proposed to Government and progressed through the parliamentary process. To date there have been technical workshops held. While it was recognised there was more work to do and some issues to iron out:

- There was unanimous support for the concept of a combined Structure and Fire Building Importance Level Table in the Building Code. However more work is required to test actual applications for structure and fire compatibility and more work to ensure Table descriptions reflect New Zealand demographics.

- There was more support than not for the Building Code to specify a continuum of tolerable impact levels (TILs) and at the level of detail proposed. Two specific concerns were the potential for more litigation as a result of damage associated with the design event and that existing buildings and other "buildings" would need separate TILs.
- There was no appetite for regulating property damage which reflects the current Building Act position, little support for a need to regulate soil/structure interaction and some support for dealing with primary, secondary and non-structural elements separately.

It is important to remember that this affects New Zealanders broadly and stakeholder engagement will not be confined to the engineering profession. Property owners, tenants, councils, other building professionals, and the public in general will have a say.

5 ISSUES

A number of issues have to be resolved using sector working groups. The new Building Code Clause B1 needs to cater for conventional commercial, industrial and residential buildings, as well as other 'buildings' covered by the Building Act such as towers, dams, bridges, tanks, wharfs, tunnels, mechanical systems and building elements. Other natural hazards such as tsunami or volcanoes are not covered now. Should they be?

The proposed combined structural and fire BIL table in Building Code Clause A3 needs to be rationalised for the New Zealand context and tested with stakeholders. The main issues besides alignment between fire and structure are with BIL4 around the designation of post disaster facilities and occupant numbers associated with BIL3.

6 PROCESS AND TIMING

Additional Code development and stakeholder engagement is to occur from now until mid year when it is anticipated a public discussion document can be issued for a two month consultation. After the submissions from this have been addressed and the government process including cabinet approval is complete it is expected that the amended Clause B1 will be promulgated in 2015 where it can transition with the existing Clause until the Verification Methods and Acceptable Solutions, including Structural Design Actions and the material Standards can be updated.

7 CONCLUSION

The intention of the Building Code Clause B1 review is to improve the clarity of outcome as a result of natural hazards and to confirm that current design performance levels are acceptable to society. This is to aid designers and Standards committees to better understand what is expected. Any change needs to be workable and not impose unreasonable burdens on designers so it will be important to get good engagement with the profession during the development and implementation stages.

Feedback and further discussion is needed on the major issues being addressed in this review. While improvements are being incorporated in Standards from the lessons from Canterbury, is the proposition acceptable that the overall level of performance expected from buildings essentially remains as it is currently? Is the proposal to incorporate explicit performance expectations currently in AS/NZS1170 Part 0 into the risk matrix as part of the Building Code, i.e. into the Regulations, appropriate? Are the Tolerable Impact statements worded such that there is a clearer understanding of outcome, both for designers and for building owners? MBIE is keen that the engineering profession engages in this discussion.

REFERENCES

The Building Regulations 1992 New Zealand Building Code – Clause B1 Structure, Clause A3 Building Importance Levels.

Australian/New Zealand Standard AS/NZS1170 Part 0: 2002 including Amendments 1 to 5. Structural Design Actions Part 0 General Principles.

NZSEE 2006, Assessment and Improvement of the Structural Performance of Buildings in Earthquake, including corrigenda 1 & 2.