# Non-structural elements: structural provisions and a holistic approach

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## Abstract

This discussion paper looks at the Structural Provisions of the National Construction Code of Australia as they apply to non-structural elements in Class 2 to 9 buildings. Commentary provides a short history, state regulator communications, market adjustments, current enforcement efforts and possible shortcomings of manufacturer systems. Recommendations are presented to correct specific challenges.

**Keywords:** Non-structural elements, Non-structural components, Parts & Components, NCC, structural provisions, seismic design, seismic restraint, non-compliance, deemed-to-satisfy, prefabrication

## 1. Introduction

The Australian National Construction Code 2019 (NCC) Part A2.4 states: *'It is important that a holistic approach is used when determining the appropriate Performance Requirements'* (ABCB 2019).

### 1.1. Structural Provisions

This paper explores Structural Provisions (NCC Part B1) applicable specifically to the seismic restraint of building services, and the design of non-loadbearing walls, and the challenges for holistic integration with other NCC Performance Requirements. The following Sections of Australia Standards form the primary basis of the exploration:

- AS/NZS1170.0 Section 2.2 Ultimate Limit States + App. C1 Table – accommodate minimum deflection 20mm of soffit above.
- AS/NZS1170.2 Section 2.1 – Determining wind actions upon structures and elements of structure or buildings (specifically inter-storey drift)
- AS1170.4 Section 5.2.2 Tying structure together – *'all parts…tied together both in horizontal and vertical planes so that forces…and other parts and components, are carried to the foundation'.*

- AS1170.4 Section 5.2.4 Walls – *'shall be anchored to the roof and restrained at all floors that provide horizontal support for the wall. Walls shall be designed for in-plane and out-of-plane forces'*
- AS1170.4 Section 8.1 *'Non-structural parts and components, and their fastenings… shall be designed for horizontal and vertical forces… and accommodate the design inter-storey drift'*

### 1.2.Structural Provisions and material requirements

For non-loadbearing walls, this paper introduces the material specific design and installation standards. The pitfalls of testing each solution in isolation is the secondary exploration.

- AS/NZS4600 Section 4.4
  - (a) *'Both ends of the studs shall be braced to restrain rotation… The sheeting shall be connected to the top and bottom members of the wall assembly to enhance the restraint provided to the stud and stabilize the overall assembly.', and;*
  - (b) *'If sheeting is used for stability of the wall studs, the sheeting shall retain its capacity and stiffness for the expected service life of the wall…'*
- AS/NZS2589 Section 4.4.3.1.3 Perimeter Fixings: *'..for perimeter fastening, fasteners shall be spaced not less that 10mm or more than 16mm from the edges and ends of the gypsum plasterboard…'.*
- AS/NZS2589 Section 3.5 Substrates Note 2: *'Suitability of gypsum linings to act as a bracing diaphragm should not be assumed unless verified by tests or rational design methods.'*
- AS5146.3 Section 3.1 Racking Resistance (applicable only to Reinforced Autoclaved Aerated Concrete) – *'All racking resistance shall be provided by the supporting structure in such a manner that ensure in-plane racking loads are not conveyed to the Reinforced AAC members'.*

### 1.3.Holistic approach of Structural Provisions & Fire Resistance

For non-loadbearing fire walls, this paper goes beyond Structural Provisions to explore NCC Part C requirements under Fire Resistance for Compartmentalisation and Separation and questions the ability for any non-loadbearing wall solution to meet the Deemed-to-Satisfy and/or Performance Solution requirements as the tertiary exploration for AS/NZS1530.4 – Fire resistance tests for elements of construction

## 2. Background

This paper began as a summary of the industry solutions failing to meet best-practice solutions for AS1170.4 based upon discussions with the standard committee and industry experts. In time, the topic grew to incorporate the other structural provisions, and their importance to Fire Resistance.

The Building Code of Australia 2010 (BCA) called up AS1170.4:2007 without exemptions, where previously Section 8 had been Optional. A delay to the building approval into 2010 for the new Royal Adelaide Hospital, saw AS1170.4 Section 8 being enforceable for the project. This resulted in major revisions by manufacturers of their products and the installation methods.

The SA DPTI experienced a great deal of market outrage at the requirements and this resulted in the creation of the following guidance notes to assist construction professionals to ensure compliance:

a. Seismic Design of Engineering Services (G172)
b. Seismic Design of Ceilings (G173)

Accordingly, the national specification not-for-profit organisation, Natspec, updated many of their specification documentation for subscriber use:

a. Natspec TECHnotes DES030 – Seismic Design Actions on non-structural components (April 2014)
b. 0171 General requirements worksection - 3.15 Seismic restraint of non-structural components (with option to 'complete/delete', based upon 'a structural engineer's advice' and referenced the SA DPTI G172)
c. General and 'branded' specifications included references such as: 'In accordance with AS1170.4'.

Between 2010 & 2016, a few major projects across Australia are known to have required 'seismic' ceilings and building restraints: the industry generally referred to these as 'Seismic Jobs'. The requirement to meet AS1170.4 section 8 seemed only to apply if the Building Certifier/Surveyor had a clear knowledge of the requirement, or the main contractor asked for it. The industry rule appeared to be, 'Don't mention seismic until the certifier/surveyor/client does'. Throughout this time, the majority of major project documentation and specifications for non-structural elements stated 'in accordance with AS1170.4'. Therefore, the requirements of AS1170.4 were part of the deliverable contract, while mandated by the NCC Vol 1 Part B Structural Provisions.

In 2016 the Northern Beaches Hospital Project (NSW) was alerted to the need to comply with AS1170.4 section 8. This project was a private hospital, although due to it's emergency department and NSW Health service agreement, it was also defined as a building of Importance Level 4 for seismic design requirements. This resulted in the NSW Health and the designated certifiers looking closely at the requirements, and the creation of the NSW Health document DGN_024. Based loosely upon the SA DPTI G172, this document was included in all NSW Health project documentation since, alerting much of the industry to the seismic design requirements under the NCC.

It was at this time (2016), a member of the VBA was alerted to a lack of consideration for AS1170.4 Section 8. The issue received no formal confirmation until 20/07/2018. 5 short sentences were included midway through a very long 'VBA Mail', with minimal information and a minor direction to designers. That direction continued to be simply a specification reference 'in accordance with AS1170.4', with little market attention and the status quo of 'Don't mention seismic'.

After a Non-Conforming Building Product Complaint in Queensland, the QBCC began investigations into the requirements for AS1170.4 Section 8. The market was given prior advice that industry audits were soon to occur, and was followed by a published notification on March 7, 2019. Within weeks, site audits wreaked havoc with installers of building services and internal fit-out. Installations had not been based upon a Specific Engineered Designs (SED) for seismic requirements. Constructors and sub-contractors turned to manufacturers for designs and Form 15 engineering certifications. A few engineers are rumoured to have been referred to the registration board for incorrect certifications, although no formal confirmation was published.

Following the QBCC published notification, the ABCB made a statement on 27/03/2019. This advice was issued to only one stream of it's subscriptions, missing this author and it appeared the WA & TAS departments for building regulation, who all required notice from the market itself.

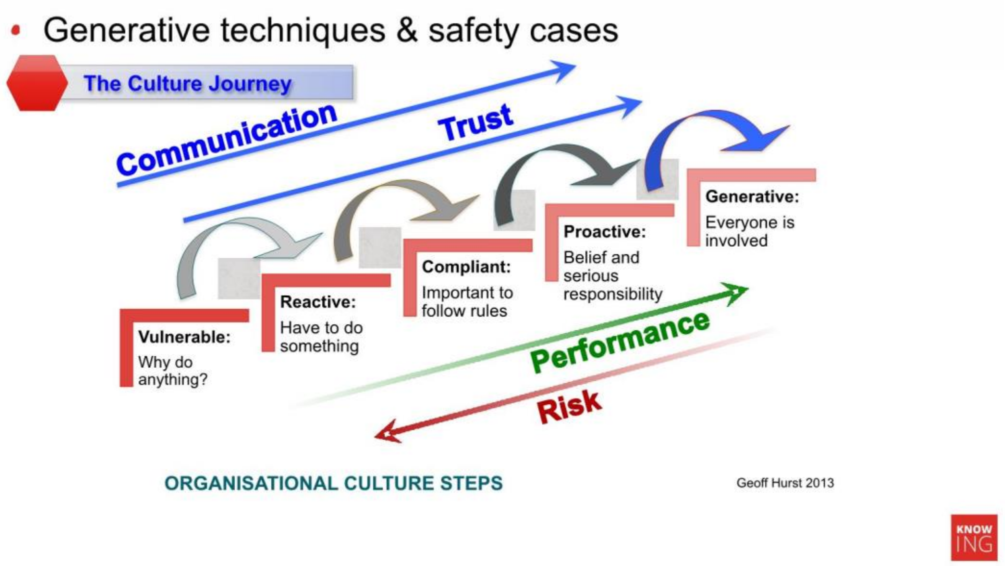
To date, no form of Structural Provision oversight (peer review) has been clearly expressed in any state. Testing facilities complete testing as requested, although a holistic review for compliance with the Structural Provisions is self-managed by wall manufacturers and restraint designers/suppliers.

Recently, 'cladding fires' have brought attention to the failures of multiple fire systems in buildings. The passive fire systems of firewalls and fire doors are still under investigation on multiple sites.

## 3. Market Adaptation to date

The majority of manufacturers are very well aware of the NCC Part B1 Structural Provisions. If a client advises their project is 'a seismic job', manufacturers respond with the standard expected locally. The engineering team know the requirements applied, although for the rest of projects the approach continues to be 'Sell people what they want, not what they need'.

Based upon 'The Culture Journey' (Hurst 2013) below, manufacturers choose for their clients to be 'Vulnerable' to risk of non-compliance, and upon being 'caught out' they become 'Reactive'. A small number of manufacturers attempted the 'Compliant' route to market by spruiking the compliance benefits of their products, only to be 'sent packing' by Project Management representatives not wanting additional cost, time or Being scrutinized for their project package.



For the many engineers and building practitioners external to seismic design, there is an underlying assumption of solutions being 'Compliant': that all companies want to perform as best they can. It appears that 'Best Performance' is maintaining or increasing sales, and compliance requires innovation, testing, behavioural changes: each costing a great deal and a major risk to sales.

The days of learning there's a requirement mid-project should be long gone for the majority of major projects, although Victoria, Tas, NT & WA still have 'Vulnerable' sub-contractors getting a first exposure now.

The following sections cover when seismic design is introduced to a project in NSW & QLD, and follows the 'Culture Journey' classifications.

### 3.1. Seismic 1.0 – Reactive @ Site installation

In the authors experience, the majority of 'seismic' projects in Australia still attempt 'seismic compliance' during construction. The contractor has now been informed/reminded prior to tendering, the installation team are installing basic elements and a 'seismic design is coming'. It is here that a seismic specialist is quickly engaged into a live construction project with multiple frustrated parties impatient for a solution and no budget allocated previously.

A subcontractor may have heard of the requirements previously, but avoided it multiple times on similar projects, but demand for seismic compliance has increased rapidly.

Experience is not complete knowledge, even the most experienced subcontractors can be challenged by greater demands for seismic restraint than previously experienced as the market is still learning the requirements due to gaps in the standard and explanatory documentation.

### 3.2. Seismic 2.0 – Thinking ahead

Presently there is pressure upon consultants designing Building Services to implement seismic restraint design (with locations and exemptions identified) into their pre-tender documentation. This would enable improved tendering through:

- greatly improve clearance integration for services and related object
- enable cost accuracy for restraints, and
- any work required to change design/substitute equipment, etc.

### 3.3. Seismic 3.0 – Hook time, Prefab rewards

Modular prefabrication ('Prefab') lends itself well to meeting the seismic restraint requirements, with multiple elements fixed together within a frame and then fixed into structures. From observations of overseas markets, prefab and relies upon offsite construction and a reduction in crane 'hook-time' utilisation. Prefabrication frames provide a structure (diaphragm) to affix the multiple components and replace the need for seismic restraints. This prefabricated modular from can be lowered or elevated into place and fixed appropriately to the main structure. This structure and the connections align with the intent of AS1170.4 and brings with it multiple macro and micro environmental benefits.

## 4. Building Services & AS1170.4

In the absence of the AS1170.4 Commentary covering Section 8, the construction industry is challenged to establish a cohesive understanding of the intent. Market forces have hijacked the outcome delivered to stakeholder management in the interests of outcomes for constructors/sub-contractors, and the certifier. The building owner/manager perceives the building to be compliant and safe, while the occupants become the vulnerable who work, live or play in the structure.

### 4.1. IL4 Special Study

AS1170.4 Table 2.2 Note 4 states *'In addition to above, a special study is required for importance level 4 structures to demonstrate they remain serviceable for immediate use following the design event for importance level 2 structures'* and based upon the NCC 2019, an IL2 Earthquake design event is 1 in 500 years.

Such special studies are uncommon, and if provided many seem insufficient in their direction for what are essential services for the facility to remain operational/functional, within any timeframe and unclear what uses must be maintained.

It is here that building inhabitants are made 'Vulnerable' by a lack of commentary for AS1170.4.

### 4.2. Wind v Seismic actions

'The resistance of a building or structure must be greater than the most critical action effect resulting from different combinations of actions….' (NCC 2019 Vol 1 Part B1.1)

In the northern states of Australia the most critical action is often wind design for structures. As a result, many construction industry people believe that they can ignore earthquake requirements for non-structural elements. This theory is reinforced by the Master Builders of QLD media release:
*Master Builders is pushing for changes to the Earthquake Standard, for example, modifying earthquake provisions in particular locations. We would like to see zones where the Earthquake Standard does not apply like the cyclonic wind design requirements.*

Yes, the critical action for the structure may be wind, although that does not negate designing the non-structural elements in accordance with AS1170.4 section 8, and the requirements of AS1170.2.

There is also a belief by many people that gravity based friction calculations can be used to avoid fixed mountings and/or restraining large equipment on structures. A commentary to AS1170.4 section 8 should address such an issue.

Many liquid filled vessels/equipment have lifting points designed only for dry lifting which are inadequate as commissioned anchor points during a design event.

### 4.3. Building Services exemptions

Section 8.1.4 (b) outlines that ‘Mechanical and electrical components… shall be designed in accordance with this section’. The section then outlines all of the systems and conditions in which seismic restraint are required. The section finishes with ‘(xvii) Ducts and piping distribution systems’ and then provides exemptions (xviii). Often these exemptions are considered to apply to every system listed above although:

- Exemptions only apply to IL2 & IL3 structures. IL4 (& IL5) structures require a Special Study.
- All systems and equipment listed above the exemptions do not receive exemptions.
- The exemptions only apply to ‘individually supported services’, not co-suspended items.

It is quite common for those delivering a project to apply the exemptions under 8.1.4 (b) (xviii) and apply them to every building service and the plant/equipment.

### 4.4. Services clearances

The SA DPTI G172 states:
*‘Separation between services and between services and walls or services and ceilings is an important consideration in ensuring damage in an earthquake is minimised, whether services are braced or not. Such service clearances need to be allowed for in the design and shown on the tender drawings.’*

If the above is logical and should be common practice, then AS1170.4 is missing a relevant section similar to NZS4219. The multiple Seismic Design Specialists working on Australian projects utilise this in their design recommendations. Unfortunately, these requirements are applied to project documentation during installation (Seismic 1.0). This results in major adjustment of building service paths, challenges to integrate suspension heights, and in worse case, a major scope changes such as dropping ceiling heights for an increase in accommodating plenum space.

### 4.5. Other concerns

A great deal of other AS1170.4 concerns are being addressed by efforts of industry members, with concerns summarised below and requiring AS1170.4 Committee support.

- AS1170.4 s1.1 states *‘(c) tanks containing liquids*’ are *‘outside the scope of this standard’*, although the following standards directly reference AS1170.4 for this purpose: AS1940 (LPG), AS3735 (with any liquid) & AS/NZS4673 (with any liquid)

- Multiple projects are documented with Design Hazard Factors below 0.08 when Building Approval is post Feb 22nd 2018 or not yet issued. Another source of incorrect values are ‘soil reports’ which appear to be ‘cut and paste’ from previous documents.

- Tendering – needs seismic design, restraint material and additional labour to be itemised in costing or lack of level playing field.

- Manufacturers
    - ‘sell clients what they want, not what they need’ – insufficient design, non-compliant products, wrong application, etc, or the opposite;
    - excessive amount of restraints w free design: cluttering up the plenum and ensuring a behaviour of frustration/resistance to seismic compliance.

- Seismic and Wind Design Criteria generally not included in work packages/specs, and a strain to get hold of.

- Design computations – submission required with engineers certification with full transparency of assumptions.

- Fixings are generally ignored for compliance.

- Vibration systems – lateral restraint capacities ignored, and standardised weight tables which ignore Component Importance Factor influence.

- Structure capability – requirements of structure to adequately support the seismic and wind loads of NSE are not considered by structural engineers in initial design, and feedback not provided when the seismic design is completed. A major area for failure is consideration for lateral forces of fire water storage part way up multistorey buildings.

- Peer Review – no qualified review of submitted design computations.

- Inspections – hardly any verification of locations, materials utilised, and certification.

## 5. Non-loadbearing walls

The present non-loadbearing wall systems on the market in Australia are required to meet the standards as outlined in section 1.1 of this paper as required by the NCC Structural Provisions. In order to illustrate the challenges to industry to comply with these provisions, the following shall attempt to illustrate the ‘Vulnerable’ status of present market offerings when product and installations do not receive adequate scrutiny.

A desktop review of the most common wall systems and the many suppliers was made. The following generic wall systems were chosen for evaluation:

- Metal stud wall with plaster sheeting (MSP)
- Reinforced AAC (panel) wall systems (RAAC)
- Panelised wall system (PWS)

To meet AS1170.4 Sections 5.2.2 & 5.2.4, wall forces must be 'transferred to the foundations' and 'anchored to the roof'. Each of these wall systems utilised a 'top assembly' as anchors, identified as the following head tracks and angles:

- Deflection head track - utilised for MSP & PWS)
- Slotted-deflection head track - MSP
- Acoustic Deflection head track - MSP
- Slotted angle - RAAC

### 5.1.Top assembly assessment for Structural Provisions

Each top assembly is required to accommodate the following:

A. Creep – 20mm deflection
B. In-plane and out-of-plane forces
C. Inter-storey drift

All systems fail to meet B. & C. when any walls intersect: the vertical connections of the walls move in separate planes, thereby cycling through varying amounts of perpendicular impact and separation.

Other issues for specific systems: failure to allow for different actions:

a. Slotted-deflection head track - no allowance for in-plane forces (shear) compromising stud and sheeting integrity through drag on fixings.

b. Deflection head track with studs fixed to top assembly – do not allow for:
    a. 20mm deflection, creating a load bearing wall.
    b. in-plane forces and inter-storey drift.

c. Acoustic Deflection head track – there is no evidence to support a 'cut flange' can handle out-of-plane forces. A head track is generally a continuous flange with a primary purpose of retaining the wall member within the flange and therefore remaining upright. By cutting the flange, the integrity of the system has been reduced dramatically. This product has been substituted for a generic deflection head-track without supporting evidence.

d. Slotted angle – does not allow enough for 20mm deflection, and in-plane forces during inter-storey drift.

A failure to accommodate the minimum Creep of 20mm ensures that the wall and it's openings become loadbearing elements. Openings may contain safety doors, essential barriers such as glass or provide building services penetrations. Similarly, in-plane and out-of-plane forces may damage or reduce the operational effectiveness of the openings, thus testing the integrity of the system.

As building services are often suspended from the soffit, they too drop 20mm under creep, resulting in loading upon the walls mounted on the floor below. Best industry practice, sees standard walls built to 100mm above the ceiling height, then a head track to enable creep and then continued with a plenum bulkhead fixed to the soffit . Effectively, a continuous system with two stacked walls which allow for deflection at their centre. This system a ensures the plenum bulk head and intersecting services encounter the same inter-storey drift and forces based upon the soffit above. Unfortunately, the previously explained head track failures remain, especially where walls intersect.

### 5.2. Structural Provisions and material requirements

As per section 1.2 of this paper, some wall systems have specific material design and installation standards to meet. This section applies those requirements to the generic wall types while identifying the challenges to illustrate performance.

- Deflection head track (MSP) – when are studs not fixed to top assembly, the plasterboard is utilised as bracing diaphragm for studs (AS/NZS4600 s4.4) but not fixed 10-16mm from top and bottom edges (AS/NZS2589 s4.4.3.1.3) as required.

- Slotted-deflection head track (MSP) – plasterboard integrity compromised through drag on fixings and sheets not fixed 10-16mm from top edges.

- Slotted angle (RAAC) – Does not 'ensure racking forces loads are not conveyed to the RAAC members (see AS5146.3 s3.1)'. These panels are adhered together, thus reducing movement, although the bottom angle is also slotted: which seems contradictory to 'ensuring racking loads are not conveyed but seemingly accommodated'

- Deflection head track (PWS) – no material standard appears to apply to non-RAAC PWS, although it is reasonable to assume a similar section to AS5146.3 s3.1 would be required in order to meet the requirements of AS/NZS1170.2 & AS1170.4.

These materials seem to have received limited testing as a holistic system, and selected as they meet selected building requirements in isolation. If the lifetime actions upon the building do not reflect the testing regime, then the performance requirements have not been met.

### 5.3. Holistic approach of Structural Provisions & Fire Resistance

Fire walls performance is defined by it's Fire Resistance Level (FRL): a grading period in minutes for three criteria (NCC 2019 Vol 1 Definitions):

1. Structural adequacy – meaning the ability of a structure to maintain its stability and loadbearing capacity;
2. Integrity – meaning the ability of a structure to resist the passage of flames and hot gases, and;
3. Insulation means the ability of a structure to maintain a temperature below specified limits on the surface not exposed to fire.

Based upon the review of the multiple wall systems to meet the structural provisions, we now apply these systems to fire applications. If the measure of a fire wall and door is its Fire Resistance Level, then the Structural Adequacy requirement will be compared to the Structural Provisions previously explored, and the Integrity compared to the material requirements.

As per NCC Vol 1 CP1, 'A building must have elements which will, to the degree necessary, maintain structural stability during a fire appropriate to:

(g) any active fire safety systems installed in the building;'

(k) the evacuation time.

Therefore, firewalls and fire doors are relied upon to provide the evacuation window of opportunity. If the firewalls and fire doors are compromised over time, then the building design has been approved based upon unrealistic performance for the service based upon inadequate testing methods. Resultantly, in a fire event the structural failure of any of the building elements could:

- lead to danger to building occupants, and;
- limit the ability of the fire brigade to control a fire.

Each wall system failed to meet the Structural Provisions for actions during a buildings lifetime. Therefore, no firewall or fire door is able to maintain it's reliability with building movement. The FRL has not been tested for:

- the additional pre-loadbearing from creep to test the structural inadequacy.
- In-plane racking prior to fire testing

The Integrity of Firewalls (and fire doors) similarly, can't ensure performance with the material requirements. The structural provisions failures are likely to have caused damage to the compartmentalisation and the material requirements are not met either.

An additional material for consideration, is fire mastic utilised for sealing fire walls and doors. These products allow for minimal movement and are prone to shrinkage post-installation. Firewall testing is performed within a month of test wall assembly or less, although they are expected to perform similarly for a 50-year-life.

In short, no fire wall (and fire door) can be called a System if it fails the Structural, Material and Fire Resistance requirements of the NCC.

AS/NZS1530.4 – *Fire resistance tests for elements of construction* is not a siloed test for a 3x3m wall (and door) sample. It is to be a test of the system and it's lifetime application.

The author and others have engaged in discussion with multiple industry specialists from academic, structural and fire engineering, relevant standards and state regulators. Not one person could confirm the present fire walls met the required standards as a holistic system for NCC2019, or any previous version since the BCA 2010, and maybe beyond.

## 6. Recommendations

The following are provided for discussion and analysis to reduce the vulnerability of society to the physical dangers posed by the structures we live, work and congregate within.

### 6.1.National Building Products Review Panel

In keeping with the National Construction Code and Australian Standards, a National Product Review Panel to enable to provide:

- product accreditation
- publish product limitations
- investigate non-conforming products or non-compliant installations
- fund relative research for the benefit of safer buildings.

The first order of business should be firewall systems for internal and external applications. While replacing flammable cladding, we should be addressing the potential fire risk external walls pose for loss of compartmentalisation and internal kitchen fires reaching out to the cladding.

### 6.2.AS1170.4 Section 8 & Commentary

#### 6.2.1. Clearances and penetrations

The inclusion of : Subsection 8.1.5 – Building Services clearances and penetrations

#### 6.2.2. Illustrate best practice

AS1170.4 Commentary to include Section 8 Commentary, or a supporting Handbook (SA HB) or Technical Specification (SA TS) to clarify the best practice.

### 6.3.Structural testing scrutiny

Testing facilities continue to provide specific structural testing, although they should also comment on the holistic Structural Provisions and associated material requirements. If a manufacturer requests ‘out-of-plane testing’ for earthquake and wind forces upon a wall system with members fixed to the top assembly, the report should also state the testing is inconclusive for earthquake and wind scenarios without testing for in-plane forces, and that the system needs to be tested for creep of 20mm. Additional declarations would assist stating separate fire testing for both out-of-place and in-plane fire testing would also be required.

As an alternative to this, a structural engineering report should identify wall relevant standards to be met (as per this paper), and a holistic review prepared with certification and penalties for incomplete considerations.

## 5. Conclusions

Present market offerings require greater scrutiny for compliance with the relevant codes.

Manufacturers are complacent to meet the expectations of building certifiers/surveyors, are ‘Reactive’ to state regulators when their ‘Vulnerable’ inadequacies are identified, and ‘stop short’ of further progress when their outputs are considered ‘Compliant’.

Until there is a National Building Products Review Panel, Manufacturers will continue to promote compliance with the minimum standard, based upon the scrutiny publicly stated. Therefore, a Building Certifier/Surveyor is taken to be the minimum standard with their limited experience, and most state regulators lack the powers to investigate. Complacency of manufacturers makes society vulnerable with known Hazards, and until another major disastrous events occur, there is a lack of the Outrage required to perceive a major Risk and drive improvement.

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