BUILDING
INNOVATION
PARTNERSHIP

Design, Construction and Seismic Performance of Non-Structural Elements

Strategic Position Paper - Summary Document

Quake Centre
Delivering Industry Solutions

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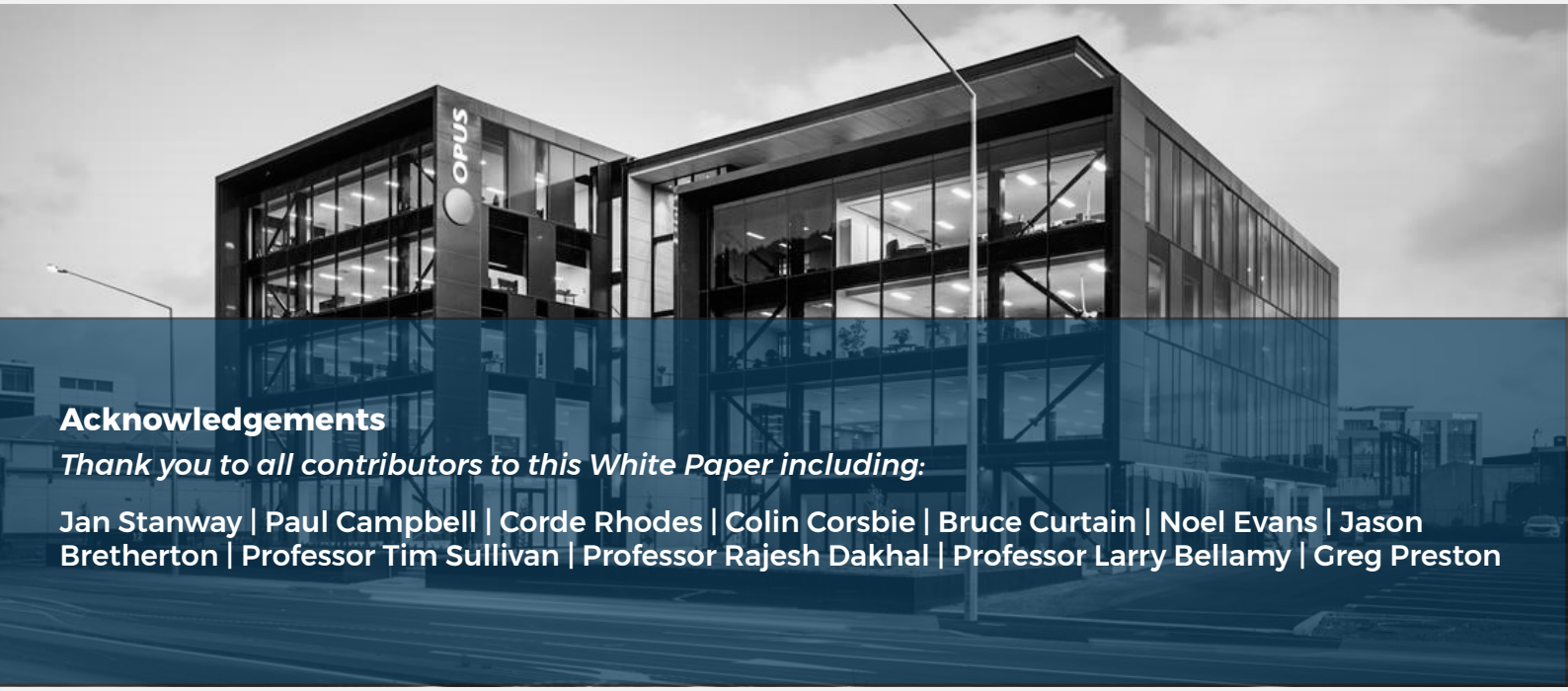

Acknowledgements

Thank you to all contributors to this White Paper including:

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Foreword by Lindsay Crossen

Historically, a large effort and many resources have gone into improving our understanding of the seismic performance of the primary structure of buildings and development of improved methods of design and construction of buildings. This has resulted in modern buildings being much safer and resilient than was historically the case. Whilst this is a good thing, the seismic and general performance of non-structural elements in buildings has received much less historical attention. This is despite the fact non-structural components can make up eighty percent or more of the total asset value of a new building.

Many examples of failures of non-structural components in buildings were observed as a result of the Christchurch earthquakes of 2010-2011, Seddon earthquake in 2013, Kaikoura earthquake in 2016 and many other earthquakes around the world. This demonstrated that significant interruption to business and community occurs because of damaged or inoperable non-structural building elements. Depending upon severity, this can have a devastating effect on the national economy, in additional to the general well-being of a nation. This coupled with evidence the co-ordination and integration of the various forms of non-structural elements with each other, and the primary structure, is frequently less than needed to ensure efficient construction and asset management, strongly indicates the need for review and change. Whist this situation exists in many jurisdictions around the world, this paper focuses specifically on the relevance to New Zealand and the status of its design, construction, and regulations in relation to building structures.

This paper compiles a comprehensive review of the status of key challenges in the design, construction, and seismic performance of non-structural elements in buildings in NZ. It concludes with a series of seven wide ranging recommendations which if adopted, are expected to result in improved resilience, better built outcomes, and lower total out-turn costs. These outcomes would benefit asset owners, the building and construction industry and, importantly, the wider community of New Zealand with safer and resilient buildings.

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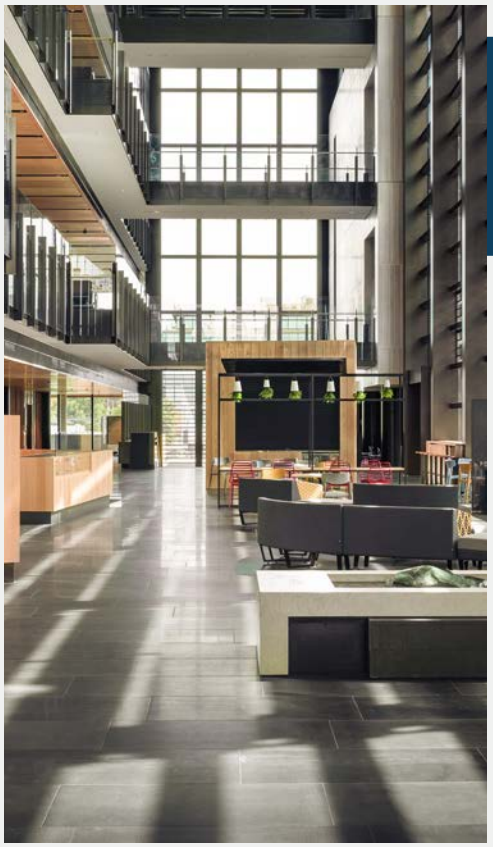
FOREWORD




RANGIORA FIRE STATION

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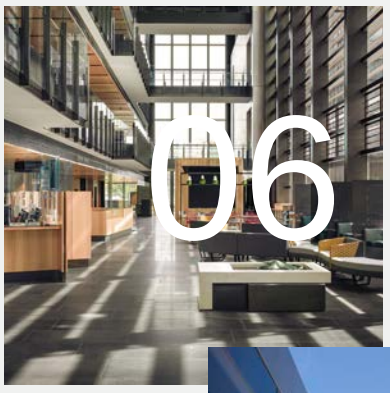
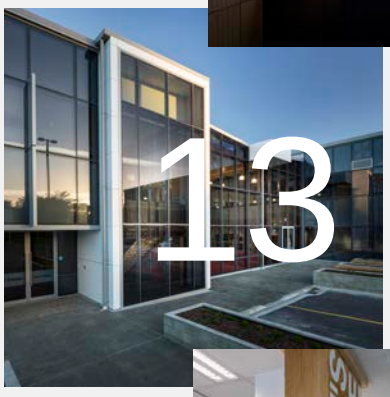
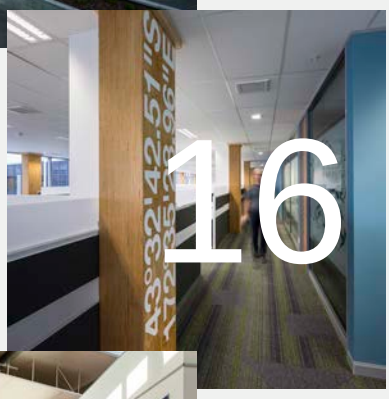
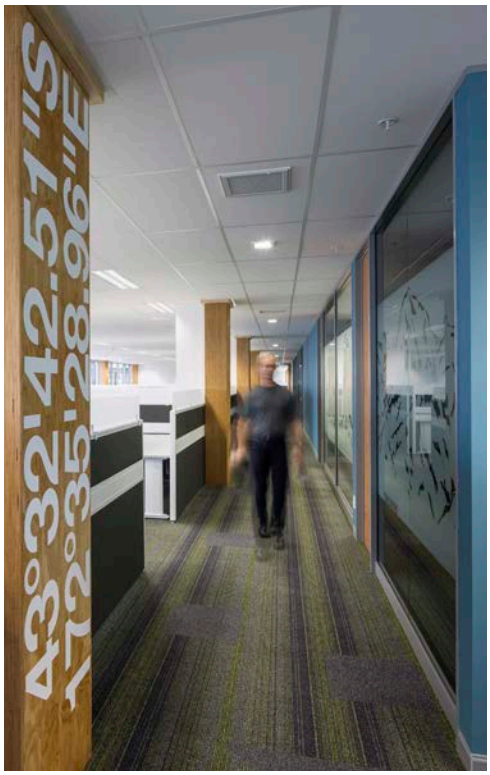
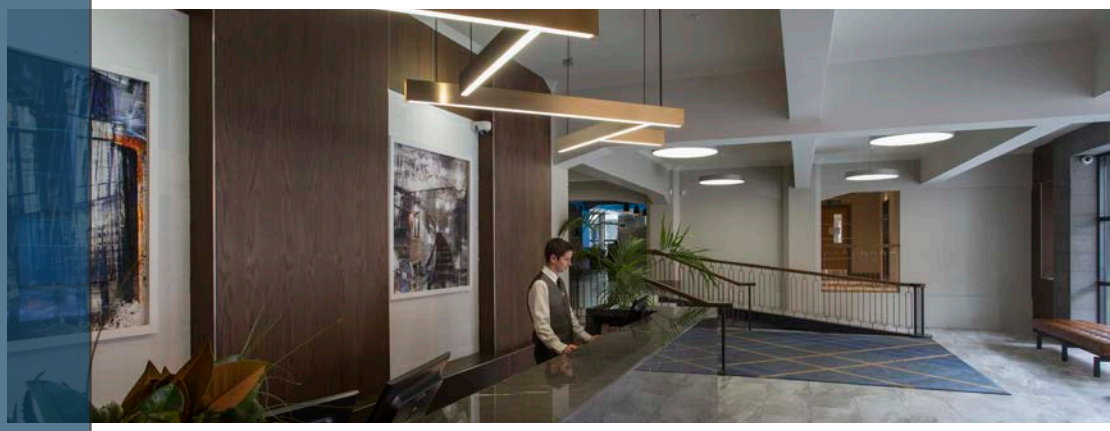


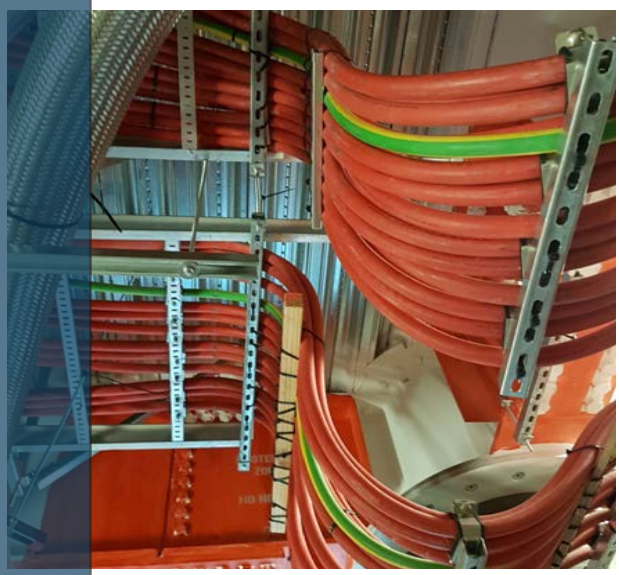




Introduction







The building sector contributes around $35B* to the New Zealand economy and represents some 20% of GDP. It employs around 250,000* workers who collectively have a responsibility to build the cities and towns that we, as a nation, need to prosper now and in the future.

We live in a seismically active region of the world. Recent experience of the performance of our buildings in both the Canterbury and Kaikōura earthquakes has delivered stark lessons on seismic resilience. Most of our buildings, with a few noticeable exceptions, performed as our Codes intended them to do, with the primary purpose to safeguard people from injury caused by structural failure. However, many buildings had minor structural damage but were unable to be reused and re-occupied due to damage and failure of non-structural elements. In these instances, the damage to non-structural elements caused major disruptions to businesses and our communities.

The performance of our buildings has caused many to pause and consider if current design and construction practices are delivering the buildings that meets the needs of our communities. Our buildings need to not only protect the lives of people in and around them in extreme infrequent earthquakes, but, in order to meet the expectations of our communities, they should also have the resilience to enable continued functional use of the buildings following earthquakes that occur more frequently. This challenge is an opportunity to define what a productive, resilient, healthy, sustainable and liveable building, that appropriately responds to Ruamoko (the god of earthquakes, volcanoes and seasons), might look like.

* MBIE publication "Future demand for construction workers, 2nd Edition, July 2017"

Unless we take clear, coordinated action together now, our credibility and future are at risk. Taking action will challenge the industry to work together with a common goal of enhancing building resilience.

Communities, iwi, government, owners, tenants and insurers, all have a vital role to play in setting the performance requirements for our buildings we, as a nation, want for the future. The government, designers and, contractors then have to adopt these performance requirements and ensure they are met.

"Do we have the right balance between designing to preserve life in extreme, infrequent, events versus designing for lesser more frequent events that enable continued functional use of the buildings in a way that meets the needs and expectations of our communities?"

Non-structural elements are all components of a building excluding the structure. This includes cladding, glazing, ceilings, partitions, cabling, lighting, equipment, air conditioning ducts, pumps, elevators and building contents.

The seismic performance of non-structural elements is at the heart of the challenge to improve the seismic resilience of New Zealand's Buildings.

The construction industry is challenged by risk avoidance. Standard contracts and procurement methodologies transfer risk from the asset owner to the construction teams. There appears to be a lack of appreciation by asset owners and project managers of the value of collectively managing the risk and responsibility for the design, coordination and construction of non-structural elements and their seismic restraints.

Research and recent experiences have identified that there are significant risks associated with the current approach to owning, tenanting, designing, constructing and regulating non-structural elements. There is also future risk of extensive damage to non-structural elements in the wider building stock in New Zealand when subjected to more frequent earthquake events (those events notionally above a moderate earthquake). Understanding the risks that face each project, building asset, owner and tenant has been poor. This has resulted in decisions to transfer risk onto the construction teams without fully understanding the significant wider implications to the construction industry and ultimately the seismic resilience of our buildings and communities.

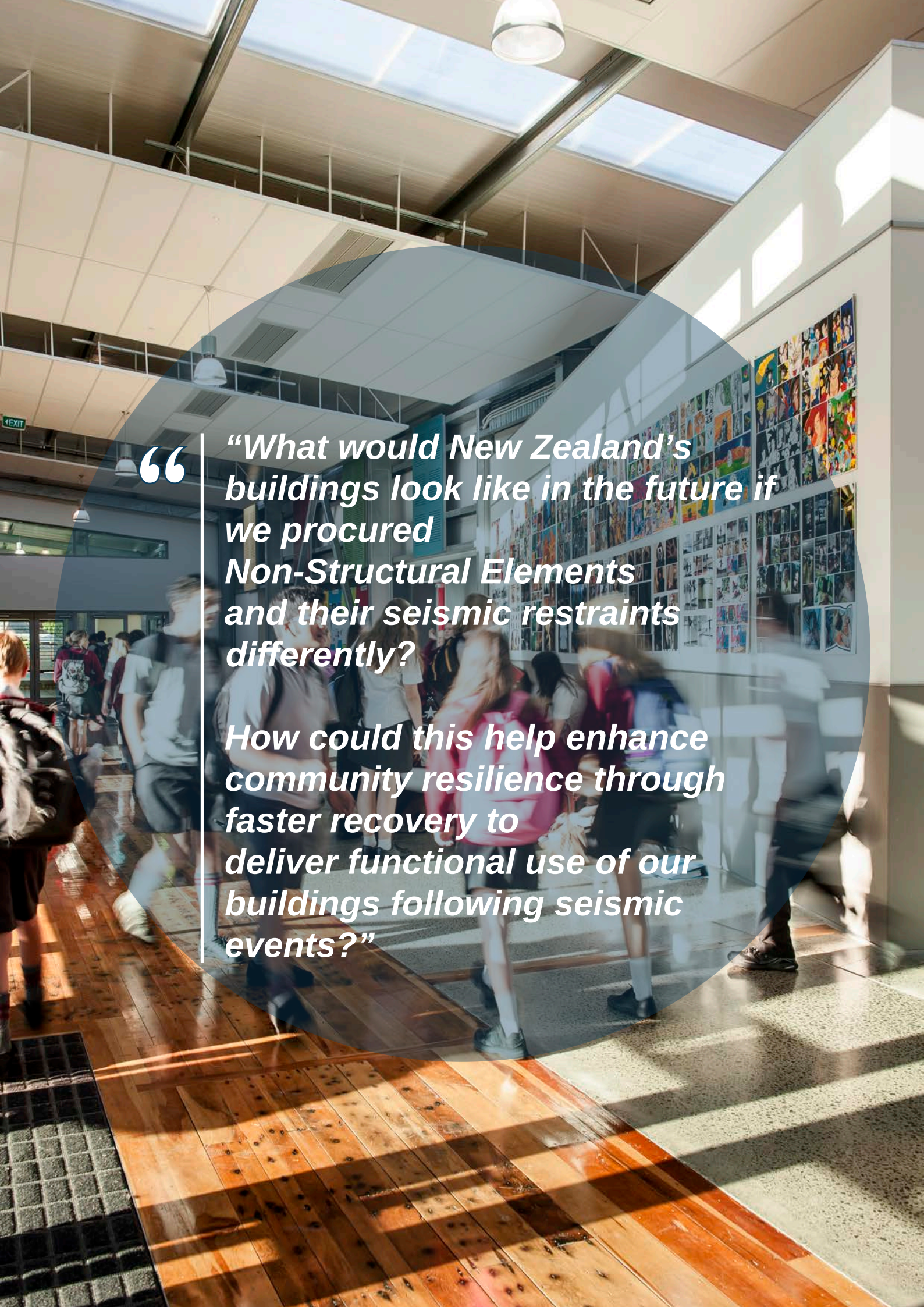
There is a clear connection between the issues causing pain in the industry with the significant damage and poor performance of non-structural elements in recent seismic events. The most common procurement model, lowest price conforming, transfers risk down the chain, often to the contractor and sub-contractors, who are least able to manage the risks. The procurement models push consultants and contractors to find ways to reduce their costs, which in many cases, results in an inferior outcome for the building owner. Product substitutions are common in the industry. Product substitutions do not always go through an approval process and can result in inferior products installed that are not identified due to a lack of independent review of non-structural element installations. In cases where product substitutions are offered for approval, anecdotal evidence is that either the substitution is offered with no cost, or as a cost saving, however approvers do not always understand the wider implications of knock on effects for other sub-trades, resulting in coordination issues, code compliance issues, increased costs and delays in the construction programme.

Addressing the key issues as recommended by this paper (risk transfer, procurement, design, coordination, product substitutions, independent review and sign-off) will have significant co-benefits to the industry. Productivity of the construction industry will increase and consequently costs, and waste will decrease as the rework which plagues the industry decreases. With the right action taken now, this can be the step change improvement in building resilience that the car industry made when it went from seat belts to seat belts, airbags and crumple zones.

This Strategic Review White Paper acknowledges the current challenges facing the construction industry and the changes we collectively need to embrace to ensure buildings achieve not only the Functional and Performance Requirements required by building regulators, but also the expectations of asset owners and the wider community.

"Part One acknowledges the current challenges facing the construction industry, outlines our vision for how our industry will work in the future along with seven recommendations on how to get there.

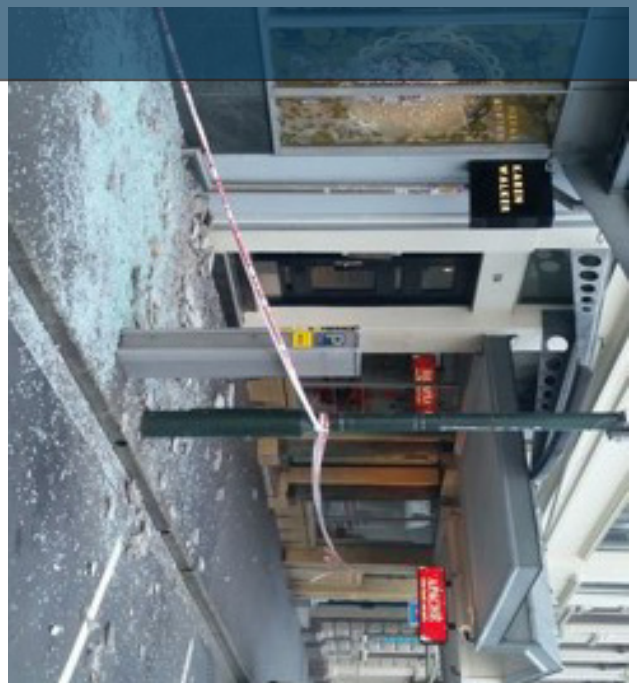
Part Two is a detailed look at issues that are currently facing the industry and steps required to move our industry towards our future vision."



“What would New Zealand’s buildings look like in the future if we procured Non-Structural Elements and their seismic restraints differently?

How could this help enhance community resilience through faster recovery to deliver functional use of our buildings following seismic events?”

Our Current Challenges



Current procurement methods (often lowest price conforming) have significant implications for construction teams, with additional risks assigned to the construction teams through the expectation to price, without tags, incomplete documentation where the detailed design and coordination for non-structural elements has not been undertaken. It often follows that when the construction teams complete the design and coordination of the non-structural elements that wider issues are uncovered. For example, it is not uncommon to find that there is insufficient room to install code compliant non-structural elements and seismic restraints within the space provided within the building envelope. Changes of this magnitude are too difficult to make during the construction phase and therefore lead to compromises.

To be competitive in a market driven by risk transfer and lowest cost, many subcontractors try to manage the cost risk by choosing the easiest and cheapest support points and reticulation routes without due consideration of the potential significant effects for other subcontractors or other elements of the building. An uncoordinated installation by one subcontractor can change a compliant installation from another subcontractor into a non-compliant one. Others are using the fact that there is no independent QA occurring, to use inferior products, both with or without approval, or not install the components and seismic restraint in accordance with the design documentation and required standards, as a means to reduce their costs and accordingly win work.

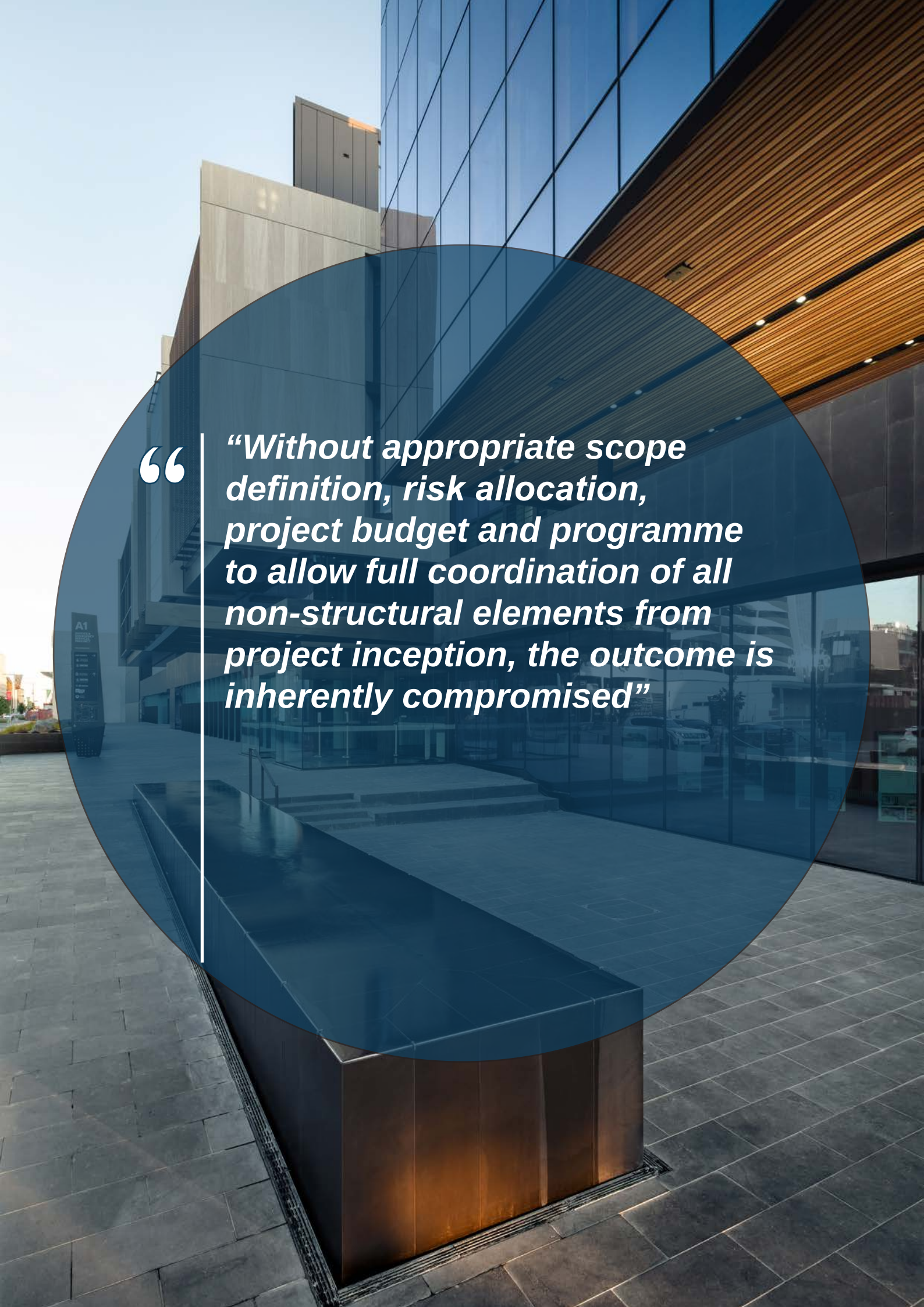
Currently, the design, coordination and construction of non-structural elements and their seismic restraints rely, in the most part, on self-regulation of the industry. Our research has indicated that self-regulation is not working, and we are falling well short of the seismic performance expected of non-structural elements in our code compliant building stock.

In addition, university research has demonstrated significant gaps in technical knowledge both nationally and internationally especially with regard to how various non-structural elements respond to seismic accelerations and building drifts and how the various building components potentially damage other building components during seismic events.

The current issues facing the construction industry are not the fault of the contracting teams. Without appropriate scope definition, risk allocation, project budget and programme to allow full coordination of all non-structural elements from project inception, the outcome is inherently compromised.

The result is that many recently constructed buildings have Code Compliance Certificates, but the indications and research suggest that many of the non-structural elements in these buildings do not meet the requirements of the New Zealand Building Code.

“Self-regulation for the design, coordination and construction of non-structural elements is not working”



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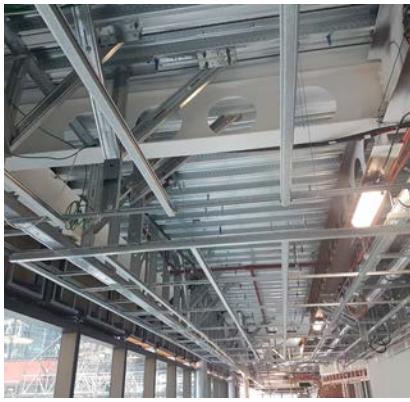
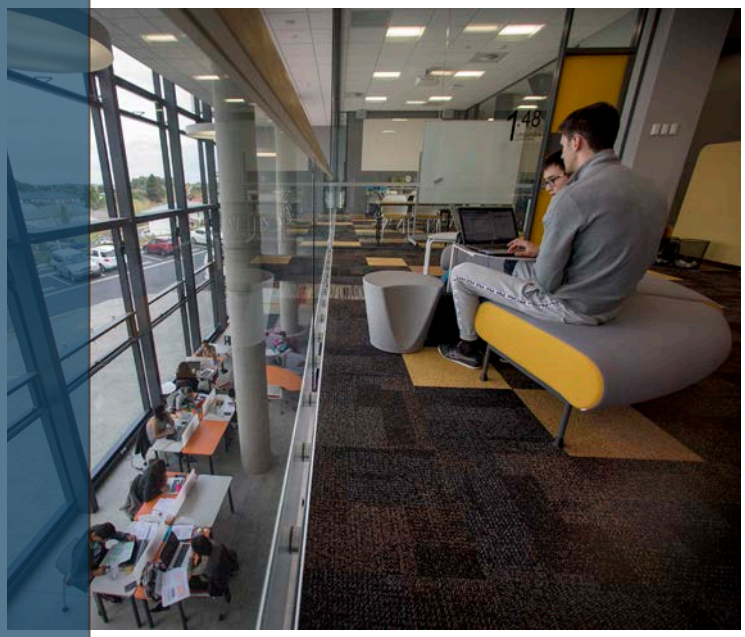




Our Vision

What could our industry look like when the seismic performance of non-structural elements is recognised as a key component to overall building and community resilience? What if we saw fair and appropriate risk allocation, clear responsibilities and fully coordinated design and construction? What would happen if we adopted enhanced design requirements for non-structural elements and procured non-structural elements and their seismic restraints differently?

In our vision, community resilience is enhanced through faster functional recovery of our buildings following seismic events, construction costs reduce and the construction industry sees a significant boost in productivity.

A system approach is embraced by the industry

The government (regulator), designers, contractors, owners and insurers all share a common goal to achieve the performance requirements for our buildings that meet the expectations of all stakeholders. They all actively work together to achieve these performance requirements and embrace and accept the risks they control rather than passing the risk on.

By accepting risk rather than transferring it, they are engaged, take ownership for decision making and are prepared to invest in innovation. Owners and tenants acknowledge, value and can see the benefit in having resilience in their assets.

Stakeholders understand their role in the system

Communities understand the performance requirements of buildings because they have input in setting them.

The government has a coherent regulatory system that is future-focused, simple, clear, allows innovation and is designed to ensure quality outcomes rather than a focus on process.

Owners understand that they have the responsibility to ensure they enable stakeholders to fulfil their roles and accept responsibility.

Designers and contractors work collaboratively together in a best for project manner that involves fully coordinated design and construction.

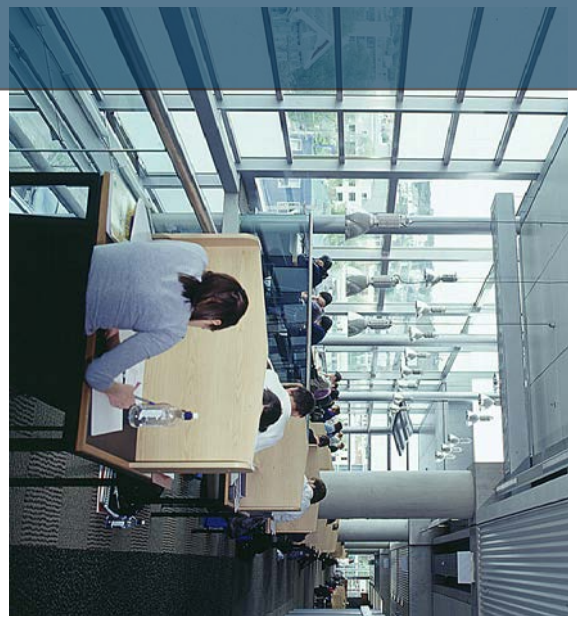
Communication is open and honest

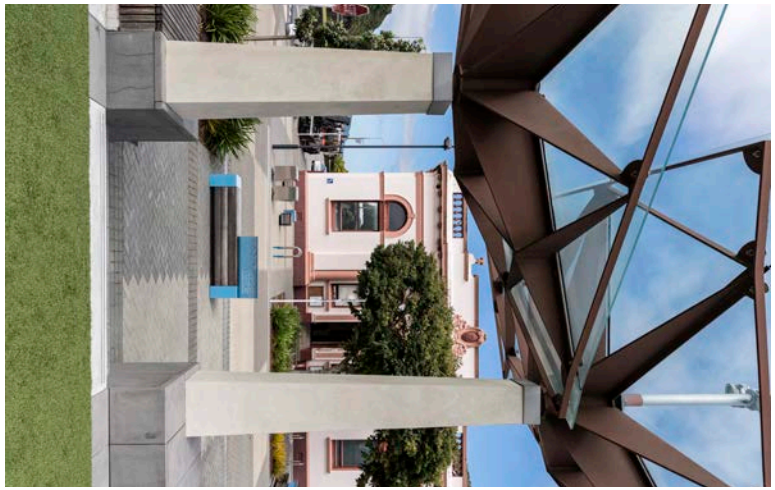
Communities articulate the performance requirements they want buildings to achieve. Owners consider what level of resilience they want for their asset, what they are prepared to pay for and communicate this to both the building occupants and the design and construction teams. The government (regulator) has a framework that mandates minimum agreed performance requirements and oversees a system for verifying that the stated objectives are satisfied and provide guidance on how to achieve enhanced resilience using commonly understood definitions within a consistent framework. The design and construction teams work collaboratively to coordinate, document, construct and inspect the installation of non-structural elements.

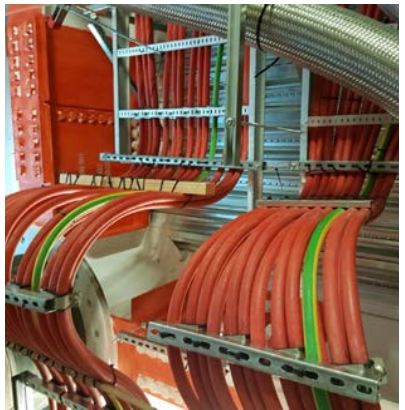
Costs reduce and productivity increases

Having a united, coherent procurement process that enables “doing it once, doing it right”. This may involve shifting the cost to design and coordinate non-structural elements and seismic restraints from the construction phase into the design phase. The benefits of doing this will be realised throughout the industry including improved productivity reduced overall project costs and delivery of completed building projects to programme. Ultimately stakeholders will be happier, produce a better product and be more efficient.

How Do We Get There?







We recommend seven key steps to deliver more resilient outcomes. These steps require commitment and action from the regulator, designers, contractors, owners, insurers, our iwi and communities.

Everyone has a role to play with collective ownership of the system.

1. Training, Guidance Documentation and Code of Practice

Industry training would be widely available to all parties including clients, councils, consultants, project managers and contractors. The training would provide the technical how and why for consultants and contractors, along with training for quantity surveyors, insurers, owners on what the new system is and what it delivers.

In the future, all important aspects of seismic performance of non-structural elements would be well understood in the industry, similar to fire and acoustic disciplines. Specialist designers (Independent Qualified Persons, IQP) specifically trained in the seismic performance of non-structural elements, would be widely available to provide advice and share their knowledge to the industry and junior colleagues.

In consultation with stakeholders a suite of industry guidance documentation will be developed. These will include:

- Overarching document that provides the high-level principles and performance requirements to achieve functional recovery of buildings following various seismic events. Guidance will likely include recommendations for earthquake return periods, acceleration and drift limits to achieve various performance states, i) no damage, ii) functional recovery of buildings and iii) collapse prevention. This guidance documentation would benefit designers, contractors, building owners and tenants as it will provide, in plain English, the performance requirements of the building, which will enable better understanding of the risk of loss of function of buildings in moderate earthquakes. The document will include clarity on what work to existing non-structural elements constitutes an Alteration to the building, in accordance with section 112 of the Building Act.

- Guidance document which describes procurement methodologies, risk allocation and the resulting risk to building owner. Recommended procurement methods will be described as well as discussion on procurement methods that are not recommended.

- Technical guidance document. This is expected to provide sufficient detail that in time it could become a future verification method in the New Zealand Building Code. It would include the two-tier compliance pathway recommended in

this report as well as include approved standard details and anchor types for support and seismic restraint of non-structural elements.

- Guidance document for the inspection of non-structural elements and systems. The document will have two sections, the first for inspection and assessment of existing systems and the second which will provide information for independent inspection of new non-structural elements. The sections will include chapters for various non-structural elements.
- Following release of the guidance documentation, feedback will be taken on board and a Code of Practice will be developed. The Code of Practice would likely be the first step towards a new New Zealand Building Code Clause.

2. Define roles and responsibilities

Work with the industry to define the roles and responsibilities of owners, tenants, architects, building services engineers, structural engineers, seismic coordinators, contractors and sub-contractors with regard to the design and coordination of non-structural elements and systems.

Definition of responsibilities will support more effective construction monitoring which is expected to improve non-compliance issues and the incidences of unapproved product substitutions being used.

3. Carry out research and testing

There is a need for the development of at least one high performance testing facility in New Zealand that can undertake experimental testing of non-structural components under dynamic/high speed cyclic loading.

Further to this university research has demonstrated gaps in technical knowledge, both nationally and internationally, especially regarding how various non-structural elements respond and interact with other building components during seismic events. Research will investigate these issues further and provide recommendations for changes to design practice and effective retrofit of deficient non-structural systems in existing buildings.

> ***"We need to work together to achieve the productivity and performance outcomes so that our building stock of the future will meet the expectations of our communities, iwi, owners and tenants.***

> ***The issues facing the construction industry won't go away through tinkering with codes, demanding cheaper costs or scattering enforcement or resilience through random projects. We need to be bold and take the step change that is needed. Taking action will challenge the industry, it won't be easy.***

The research will support the introduction of a range of acceleration and drift limits for different non-structural element types and restraint systems.

The research programme will support the development of a new New Zealand Standard/ Verification Method for the seismic design of non-structural elements.

4. Introduce an independent quality provider and certification body

A new Independent Quality Provider (IQP) and Certification Body will be established, which would be similar to the independent inspection and certification requirements currently used for Sprinkler Systems with a broader responsibility of ensuring QA of all NSEs. All projects would be inspected and signed off as being code compliant by an IQP and submitted to the Building Consent Authority with the Request for Code Compliance Certificate documentation.

The IQP individuals will have considerable experience in the design, coordination and installation of non-structural elements. Given the wide range of components and sub-trades in buildings it may require more than one IQP to provide the necessary knowledge base to complete inspections and certification of complex buildings.

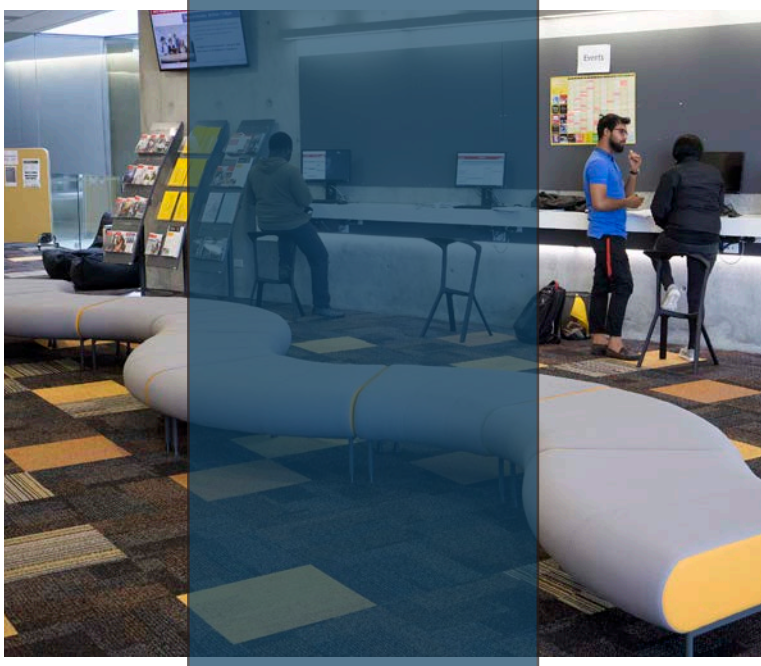
5. Introduce a new clause in the Building Code

Instead of a fragmented regulatory system, introduce a new clause that covers all aspects of seismic performance for all Non-Structural Elements. A working title “B3 Non-structural Elements and Systems” is proposed. It is envisaged that this new clause will cover objective, functional and performance requirements like the other clauses of the Building Code.

The performance requirements section would be based on functional recovery with checks to confirm the elements achieve life safety objectives. We propose a philosophy that uses a significantly enhanced ‘serviceability’ load over current New Zealand Standards. We recommend this as there will be little to no additional cost for many NSE elements and the increase in performance and resilience of non-structural elements will be significant.

By having this new clause all stakeholders will be required to use the same ‘single source of truth’.

The Code of Practice developed as part of Recommendation 1, is expected to be the first step towards a new Building Code Clause for non-structural elements.



6. Withdraw the seismic provisions from current NZ Standards and associated industry guidance for non-structural elements and replace with one NZ Standard or verification method

The performance requirements in the current NZ Standards for seismic design of fire sprinkler systems, suspended ceilings and buildings services do not align and, in some cases, contradict each other. Industry users of the current non-structural Standards, have advised there are gaps and errors in the current Standards with regard to seismic restraint and it has been demonstrated, within the research community, that current code provisions provide poor prediction of the acceleration demands and drift limits for non-structural elements.

The new Standard or verification method would provide a consistent framework for mandatory independent inspection, reporting certification for non-structural elements and systems. This would involve inspection and certification by an IQP which would be required to be submitted with the application for Code Compliance Certificate. Currently NZS 4541 extends the IQP involvement to annual inspection, reporting and certification linked to the issue of the annual BWOF.

The new Standard will include definitions of what constitutes maintenance work and what constitutes an alteration in terms of the Building Act. If work to existing non-structural elements and systems is deemed an alteration, or new components are being installed, the works would need to be assessed by an engineer experienced in the design and coordination of non-structural elements and systems, to ensure that appropriate design is undertaken and at the completion the building will comply with section 112 of the Building Act. An IQP will inspect and certify that the installation complies with section 112 of the Building Act.

7. Introduce two tier compliance pathway

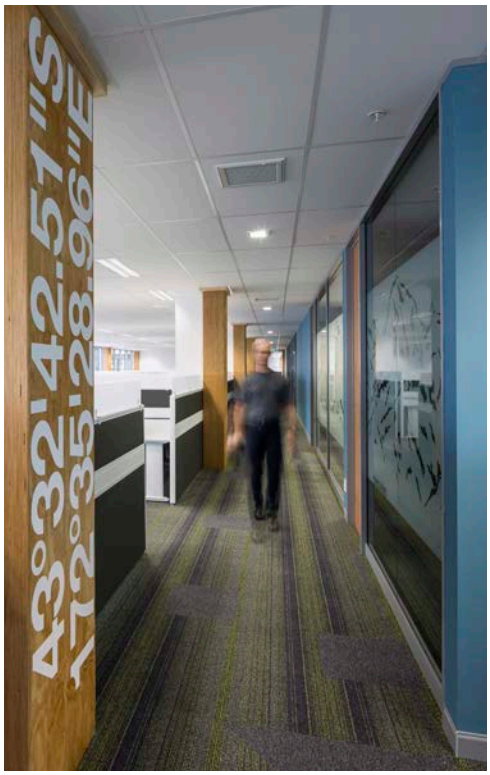
The recommended addition to the NZ Building Code 'B3 Elements', would include a two-tier compliance pathway, AS1 and VM1. The detail of the two-tier compliance pathway is expected to be tested and updated to reflect industry input following use of the Industry Guidance Documentation described in Recommendation 1 of this report, but is expected to include:

AS1 – Use of Approved Standards

Building consents would be approved with a specimen design, approved standard seismic restraint details, along with a performance specification for non-structural elements. This compliance pathway provides for design and coordination by the main contractor, various subtrades and consultants during construction and would require a Building Consent Amendment once the design for all non-structural elements has been completed and fully coordinated. This Acceptable Solution is likely to include increased ceiling voids to a minimum of 1m deep to reduce the complexity of installation of non-structural elements and their seismic restraints in constrained locations. An independent inspector (IQP) would be engaged to inspect and certify the installation has been constructed in accordance with the completed and coordinated design and achieves code compliance prior to the Code Compliance Certificate being issued.

VM1 – Customised design for non-structural elements and systems

Design and coordination of all non-structural elements within ceiling voids, risers etc are fully complete (to LOD350 or equivalent level of detail when BIM is not used on a project) and submitted for Building Consent. There would be no minimum or maximum depth of ceiling void, but the depth chosen must be confirmed through full design and coordination. An independent inspector (IQP) will inspect the installation of the non-structural elements and provide certification that the installation is completed in accordance with the coordinated design and achieves code compliance prior to the Code Compliance Certificate being issued.



Conclusion

If implemented the seven recommended changes will significantly improve the seismic performance of buildings in New Zealand and substantial co-benefits will be realised including:

- Improved community resilience as the changes penetrate further into our new and existing building stock,
- Improved productivity of the construction sector as the processes described in this report are streamlined and expanded to encompass the building as a whole, resulting in projects routinely done once and done right,
- Improved quality control, through clear definition of roles and responsibilities and the introduction of an Independent Qualified Persons (IQP) body,

Building owners, tenants and insurers will better understand the risk of building damage and downtime as a result of more frequent seismic events, and take ownership for decision making and be prepared to invest in resilience.

Research Acknowledgment

This report is an output from Quake Centre's Building Innovation Partnership (BIP) programme, which is jointly funded by industry and the Ministry of Business Innovation & Employment (MBIE). Under the contract the University of Canterbury's Quake Centre has with MBIE, this report forms partial completion of Theme 3 Fit-for-Purpose Building Components, resulting in improved seismic performance through Research Aims 1.9 (new data of engineering relevance on the seismic performance of non-structural elements), 1.11 (new low-damage technologies for non-structural building components) and 1.12 (new technologies and approaches for the effective retrofit of non-structural components).

Limitations

The opinions provided in this report are based on research and industry workshops and the sources are believed to be reliable. The use of this information in this report is provided using a degree of care and skill normally exercised, under similar circumstances, by reputable professional consultants practicing in this field at this time.

This report is prepared for the Building Innovation Partnership (BIP) led by Quake Centre, to assist with understanding the current industry position and outcomes being realised for the design, construction and seismic performance of non-structural elements in New Zealand. This report is expected to be used to inform initiatives and research that will provide improvements to the efficiency and productivity of the construction sector and improve the seismic performance of non-structural elements in new and existing buildings in the future.

This report is not intended for any other purpose.

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Powell
Fenwick


JOHN JONES STEEL


Holcim