Introduction

- Background Information on:
  - Pre-2011 Construction Practice in Christchurch
  - Repair Issues and Role of Insurance in Recovery
  - Reconstruction of Christchurch
  - Quantitative Findings
  - Qualitative Findings – who decides structural system?
- Conclusions

Reinforced Concrete in Christchurch

- RC construction dominated Christchurch before EQ
- Plenty of cement, water, and aggregate readily available (from the river gravels) in NZ (e.g., Waimakariri near Christchurch)
- RC construction, incl. structural walls, since the 1930s
- RC MRF with masonry infill common until about 1970
- Non-ductile RC MRF used until about 1980
- Ductile RC MRF: started in 1970s; prevalent after 1980s
- Multistory tilt panel buildings in 1980s
- Influences of Park, Paulay, Priestley at University of Canterbury helped "cement" concrete as the major construction material in Christchurch

Cost of Steel

- Mid-2008, steel peaked at record high of $1265/ton per metric ton
- Quickly decreased by mid-2009 and fluctuated since
- Record low: 10% of peak price ($90/ton per metric ton)
- Low price of steel makes it more attractive as a building material

- Significant difference in price between US and Chinese steel
- Production 1990-2017 in China increased 14-fold (to 77,000+ tons)
- Accusations of steel dumping
- Issues with quality of steel imported from parts of Asia
  - Some only allow steel from local or pre-approved overseas mills
  - Others rely on extensive testing or their own staff at point of origin
- Parts of steel structures often fabricated in Asia before shipping to New Zealand for final site assembly
- Last 2 multistory buildings in Christchurch before EQ were steel
EQ Insurance Coverage in NZ

- Approximately 80% of the losses in the Christchurch earthquake sequence were covered by insurance (Marquis et al., 2015)
- Lending banks require that buildings be insured
- NZ Earthquake Commission insurance program (covers first $100,000 of residential claim) does not apply to commercial structures, but has insurers comfortable with earthquake insurance market, resulting in a number of distribution channels for relatively cheap insurance
- Loss of rent and business interruption costs were add-ons included in many insurance policies
- Generally: upper limit on insured losses

Insurance Payment for EQ Losses

- Terms of insurance have generally been for “reinstatement” to an effective “as new” condition
- Interpretation: Assessing whether remaining low-cycle fatigue life (and/or ability to resist earthquakes) is likely to be similar (or not) to that required/provided by new structure
- Difference in answers = major differences in repair costs or lead to demolition and reconstruction
- In many cases, cash payments were taken, providing owners with flexibility to sell “as is”, repair, or replace
- Long negotiations for payments delayed demolition and reconstruction
- Lack of available insurance (for a while) delayed reconstruction
- Ongoing aftershock sequence compounded the problem (“why should we insure a building that is still burning?”)

Impact of Insurance on Building Codes

- None - Translation:
  - Per NZ Insurance Council: NZ insurance sector unable to encourage use of specific types of construction with seismic performance beyond code requirements, or of better design/construction of non-structural elements
    - e.g.: URM still being insured in Wellington
  - NZ is < 0.1% of global reinsurance market, and other international drivers control conditions in NZ
  - While insurance costs went up (~300%) initially after Canterbury events, lack of worldwide disasters over the past few years led to a surplus of reinsurance funds, and insurance cost decrease to pre-EQ levels

Legislative Context

- Structures incorporating base isolation, buckling restrained braced frames, rocking walls, and other “low-damage” systems not covered by NZ design standards and are considered Alternative Solutions
- Alternative Solutions approach is quite flexible
  - Onus on engineers/peer reviewers to ensure system satisfactory.
- In NZ, a single peer reviewer is required
  - Outcome depends on his/her specialized knowledge and impartiality
  - Engineers reported challenges/delays when advocates of competing systems (e.g., lead-rubber bearing isolators and sliding-friction bearings) are at odds in their recommendations

Design Requirements

- After EQ, NZ standards did not change to encourage more resilient construction, but
  - Christchurch seismic zone factor increased from 0.22 to 0.30
  - Serviceability level event increased from 25% to 33% of 500-year EQ for ordinary structures, but in late 2016 returned to 25% again
  - i.e., during 2012-16, design force considered for serviceability analyses increased by 80% (i.e., 0.30/0.22 x 0.33/0.25 = 1.8)

<table>
<thead>
<tr>
<th>Return Period</th>
<th>Annual Probability of Exceedance</th>
<th>Building Importance Levels</th>
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<tbody>
<tr>
<td>1/2500</td>
<td>1.8 ULS</td>
<td>IL1 Low hazard structures</td>
</tr>
<tr>
<td>1/1000</td>
<td>1.3 ULS</td>
<td>IL2 Normal buildings</td>
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<tr>
<td>1/500</td>
<td>1.0 ULS SLS2</td>
<td>IL3 Important buildings</td>
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<tr>
<td>1/100</td>
<td>0.50 ULS SLS1 SLS1 SLS1</td>
<td>IL4 Critical post-disaster buildings including schools, existing buildings, infrastructure, essential facilities, and buildings at risk of secondary effects from disaster in earthquake-prone areas</td>
</tr>
</tbody>
</table>
Design Requirements

- For the 500-year EQ, spectra design values use (R=1.0)
- Spectra values multiplied by 1.8 for 2500-year EQ
- Lateral-force-reduction factor, $k_\mu$, is the minimum of:
  - Value specified for a particular structural material
  - Ratio of ULS and SLS (1/0.25 = 4 for IL2 structure) (>3 from 2012-16)
- No MCE explicitly specified in NZ
- Rebuild: Some Engineers used 7500-year EQ used for some IL4 buildings

Quantitative results

- Information presented as a function of year of consent (year of building permit in a North American context)
- Note: Results for 2017 are only for the first three months of the year (data collected up to March 2017).
- Data on 74 buildings, adding to 482,317 m² floor space.
- For buildings with different types of structural systems in orthogonal directions, each direction was counted as one half of a building when tallying the numbers.
- One building had masonry walls in one direction (counted as 0.5 building), but this small number was lumped together with the concrete walls.

Number of Buildings (Steel / RC / Timber)

- Cumulative number of new buildings having lateral-load resisting systems of each material type

Gravity System in RC Buildings

- Gravity-resisting frame systems (i.e., steel beams+columns) used in:
  - Approximately ¼ of buildings having lateral-force-resisting system consisting of RC walls (still counted as a RC building in presented quantitative results)
- For this reason, the number of buildings containing structural steel is significantly greater than that indicated by the quantitative results presented here

Floor Area of New Buildings (m²)

- Floor area of new buildings having lateral-load resisting systems of each material type:
  - Yearly Percentages
  - 2015-16: 10:1 Ratio
Floor Area of New Buildings (m²)

- Floor area of new buildings having lateral-load resisting systems of each material type:
  - Cumulative numbers
  - Steel: 78.4%,
  - RC: 20.4%,
  - Timber: 1.2%

Type of Structural System

- Data obtained on same 74 buildings, but, for clarity:
  - Not considered:
    - A building with masonry walls in one direction (0.5 masonry building)
    - A building with braced plywood walls (1.0 building)
  - New \( \Sigma = 72.5 \) buildings
  - Some systems counted twice:
    - For example: A system on top of base isolators is counted twice (once as the structural system type, and once as a base isolated structure)
    - Same for buildings with dampers and hybrid buildings.
  - Total of 92.5 buildings = 72.5 systems + 11 base isolated buildings + 2 dampers + 7 hybrids

- Results show that the following lateral load resistance systems have been used for buildings totaling the following floor areas:
  - BRB: 111,000 square meters (23%)
  - CBF: 38,500 square meters (8%)
  - EBF+EBR: 27,500 square meters (6%)
  - MRF+MDF: 202,000 square meters (43%)
  - RCW: 80,400 square meters (17%)
  - RFS+RFC: 15,000 square meters (3%)
Type of Structural System

- The 11 base isolated buildings (15% of number of buildings) alone provide 190,000 m² = 40% of total floor area of buildings considered
- The base isolated buildings have generally been large buildings
  - The two largest base isolated buildings alone, built specifically for public sector tenants = 102,000 m² (21% of the total floor area)
  - The three largest = 129,000 m² (27% of the total floor area)
- Strong correlation between m² of base isolated buildings and steel MRFs

Type of Structural System (Non Base isolated buildings)

- Worthwhile to consider (for steel structures – no change for RC), because:
  - More base isolation in years following earthquake, so data on non-isolated buildings could be indicative of future trends
  - Firms comfortable designing systems outside of standards (such as base isolation) might be over-represented in interviews
  - For its own sake, interesting to identify which systems more dominantly used when buildings not base isolated

For all steel frame systems, most commonly used are:

- BRBs (11 buildings)
- MRFs (9.5 buildings)
- EBF (6 buildings)
- RC Wall buildings number remain the same (31.5 buildings – not shown)

Results shows that most base isolated buildings had steel moment resisting frames or steel concentrically braced frames.

Total non-base-isolated reconstruction floor area is:

- BRB: 111,000 square meters (38%)
- CBF: 0 square meters (0%)
- EBF+EBR: 27,500 square meters (9.5%)
- MRF+MFF+MDF: 57,000 square meters (20%)
- RCW: 78,000 square meters (27%)

Relationship to Number of Stories

- Number of new buildings having lateral-load resisting systems of each material type as a function of building height expressed in number of stories:

Who determines the Structural System?
Hierarchy of Priorities (Pre-Earthquake)

- **Tenants**
  - Purpose
  - Functionality
  - Lease Cost
  - Image

  - **Government Health Office/Business Commercial Trade (construction)**
    - Type of tenant defines much of the building characteristics (space needs, functionality, etc.)
    - For examples, choice of structural system can be dictated by:
      - Organizations whose purpose is to promote a certain construction material
      - Residential construction sound isolation requirements
    - Examples:
      - High-profile law-firm has expectation of lease cost for the type of office space they need for their functionality and image they seek to project to their clients
      - A restaurant has expectation of lease cost to remain competitive while seeking attractive grounds to attract customers

- **Developer**
  - Return on Investment*
  - Cost
  - Speed of Construction
  - Lease Rates
  - Tenant expectations
  - Reputation

- **Architect**
  - Client expectations
  - Design Space
  - Architectural Expression
  - Engineering Constraints
  - Tenant expectations
  - Reputation

- **Engineer**
  - Client expectations
  - Design Space
  - Code Compliance
  - Design Constraints

* 'Developer' here taken as either:
  - Working on behalf of an "owner"
  - Planning to sell to an "owner"
  - A "developer/investor" with a long term perspective

- **Not on list of priorities prior to the Christchurch earthquakes**
- Insurance coverage to take care of these issues

- "Business Continuity" and "Reparability"
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**Hierarchy of Priorities (Pre-Earthquake)**

**Client expectations**
- Code Compliance
- Design Space
- Design Constraints
- Architectural Expression
- Engineering Constraints
- Purpose
- Functionality
- Lease Cost
- Image

**Tenant expectations**
- Reputation
- Business Continuity
- Reparability

**MOMENTUM**
“Natural tendency do things as they were done before”
Industry is set up to deliver a familiar “product”,
with well-understood practices, costs, risk, relationships, procurements, etc.
leading to predictable return on investment

**Hierarchy of Priorities (Post-Earthquake)**

**Purpose**
- Functionality
- Lease Cost
- Image
- Business Continuity
- Reparability

**Tenant expectations**
- Reputation
- Business Continuity
- Reparability

- For some types of tenants, this became a prime consideration
- Not so for types of tenants/businesses where employees can temporarily work from home

- Early “anchor” projects intended to herald Christchurch’s recovery “re-open for business”

- Many felt RC buildings did not perform well
- Heavy media coverage of buildings collapses, severe damage, leaning buildings, trapped occupants (e.g. stair collapse), etc.
- Many buildings with low damage (beam plastic hinging and rebar elongation) were deemed “imparable” and demolished
- Life safety seismic performance objective: buildings (generally) behaved / were damaged as engineers (but not as public) expected
- Two tallest steel structures in Christchurch reopening relatively fast after earthquake, led many tenants and owners to conclude that steel structures are preferable

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**Hierarchy of Priorities (Post-Earthquake)**

- Some “altruistic” projects to “give back” to Christchurch
- Trying to anticipate tenants post-earthquake expectations of tenants performance and possible impact on lease rates
- Some owners investing elsewhere due to uncertainties in building market
Hierarchy of Priorities (Post-Earthquake)

Tenants
- Purpose
- Functionality
- Lease Cost
- Image
- Business Continuity
- Reparability

Developer
- Return on Investment
- Speed of Construction
- Lease Rates

Architect
- Client expectations
- Design
- Architectural Expression
- Engine Constraints

Engineer
- Client expectations
- Code Compliance
- Design Constraints
- Reparability
- Business Continuity

Post-earthquake “race for gold tenants” (government, banks, lawyers, accountants, big firms)
- Market shift from office projects to apartment buildings, healthcare and education facilities, and hotels
- Some sectors (w smaller structures) more concerned w project cost than tenant perceptions (e.g., foreign owners w/o memory of earthquakes, seeking shorter-term lease tenants, or for whom insurance settlements are not a factor in decisions)

Tenants
- Purpose
- Functionality
- Lease Cost
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Engineer
- Client expectations
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- Business Continuity

When a consequence of developers and tenants expectations

Engineering elements (e.g. BRBs) integrated into the architectural expression (Christchurch architectural tradition)

Tenants
- Purpose
- Functionality
- Lease Cost
- Image
- Business Continuity
- Reparability

Developer
- Return on Investment
- Speed of Construction
- Lease Rates

Architect
- Client expectations
- Design
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Engineer
- Client expectations
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Professional culture revisited
- Breadth of valid engineering solutions can be regarded as the expression of differences in this culture.
- Structural engineering decisions affected by this, together with different professional opinions regarding:
  - Expected seismic performance of various structural systems
  - Hierarchy of priorities in rebuilding Christchurch
  - How various priorities can be best met for specific buildings
  - No “one-size-fits-all” solution in structural engineering

Tenants
- Purpose
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Professional culture
- Engineering firm’s philosophy aligned with clients they seek (or that seek them)
- Philosophy of practice influenced by:
  - Type of work conducted for clients
  - Experience and professional opinion on the respective benefits of various structural systems
  - Opportunities provided by past project and business relationships
  - Professional development activities
  - Interpretation/synthesis of skills and information from various scientific and non-scientific field
  - Professional ethical and moral obligations

Tenants
- Purpose
- Functionality
- Lease Cost
- Image
- Business Continuity
- Reparability

Developer
- Return on Investment
- Speed of Construction
- Lease Rates

Architect
- Client expectations
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- Architectural Expression
- Engine Constraints

Engineer
- Client expectations
- Code Compliance
- Design Constraints
- Reparability
- Business Continuity

Nearly all engineering firms interviewed designed the building containing their office, including:
- 3 in base-isolated buildings
- 2 in buildings having BRBs
- 1 in a building with viscous dampers.
Hierarchy of Priorities (Post-Earthquake)

Tenants
- Purpose
- Functionality
- Lease Cost
- Business Continuity
- Reparability

Developer
- Return on Investment*
- Speed of Construction
- Lease Rates

Architect
- Client expectations
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- Business Continuity

Professional Culture

Qualitative Factors Affecting Momentum
- 50 pages of the report present opinions expressed by engineers, in their own words (or paraphrasing) on:
  - The various issues and types of structural systems used
    - Base Isolation, Low Damage, IL4, IL3, Reparability, Buckling Restrained Braces, Viscous Dampers, Eccentrically Braced Frames, Steel Structures (General Issues), Reinforced Concrete Walls, etc.
  - These are not necessarily the authors’ opinions
  - A select sample of these opinions are summarized next, for a subset of structural systems

Base Isolation (Client Perception)
- New Zealand public is somewhat familiar with base isolation
  - NZ engineers have pioneered its development
  - Implemented in a number of buildings throughout NZ
  - News reports and showcasing isolators at Wellington’s base-isolated Te Papa Museum and Beehive (Parliament)
  - Whereas clients typically did not express any preference for specific structural systems when approaching engineers, base isolation is the exception to that rule (for some projects)
  - Some of these projects were developed as intended
  - Others were switched to different structural systems as part of the development and cost-assessment process

Base Isolation (Client Perception)
- Some have promoted fact that their buildings are base isolated
  - E.g., Christchurch Justice and Emergency Services Precinct, a 42,200 m² public “anchor project” for 2000 employees, has webpage and Facebook page “showcasing” government’s commitment to investing in Christchurch’s reconstruction
  - Some owners insisted on base-isolation, even if engineer believed it provided no benefits over other structural systems, to provide “peace of mind” to tenants
  - Other owners specifically did not want base isolation, because advised by a professor that it was a bad idea in Christchurch
  - Other client objection was that the resulting design reduced the leasable floor space within a fixed lot boundary

“MOMENTUM IS LOST”

Industry adjusting to deliver various “product”, with new practices, costs, risks, relationships, procurements, leading to less predictable return on investment
Base Isolation (Engineers Perception)

- All understand principles and potential benefits of base isolation, but engineering firms are not unanimous on whether base isolation is an appropriate structural system for Christchurch
- Some engineering firms have actively promoted it
- Others have significant reservations for some designs
- Engineering firms expressed different preferences and relationships (i.e., “not all bearings are similar”) – concerns including:
  - Reliability of performance of specific devices
  - Tuning to a particular earthquake level
  - Behavior of isolated structure under vertical ground accelerations

Cost important consideration

- One engineer underscored that the oft-cited 5-7% of total building cost premium is for large buildings (like a hospital) but is a much higher percentage for an office building

Low damage, IL4, IL3, Reparability

- Some clients, without asking for specific structural system, requested:
  - An IL3 or IL4 building design
  - Low-damage
  - Reparable structural system

- Request done either as part of:
  - Casual discussions
  - Project’s specification brief

Various motivations:
- As asset to attract tenants and for future resale value
- Protection against future code changes

Owners typically asking for IL3 structure generally plan to own their property for a long time, but do not necessarily wish for an IL4 building

Others are owners who originally considered base isolation but backed away when cost estimates exceeded their desired price point

Particularly true for smaller buildings where cost-impact of base isolation makes the solution more uneconomical

Interesting example where opposite occurred:

- Client was contractor not intending to use any innovative systems to keep costs down: A design with CBFs was therefore completed
- When some tenants came with a 10-year lease prospect and asked for an IL3 building, the braces were substituted with BRBs: with a special layout of the BRBs across bays and stories, column sizes remained reasonable and system ductility increased

Buckling Restrained Braces

- Timely promotion by BRB manufacturers following EQ
- Engineers were looking for alternative “low-damage” designs (i.e., limiting drifts) that would allow rapid return to service (i.e., rapid to repair), while being lower cost than base isolation

Some firms stated easier to replace BRB than EBF

  - “A lot of moment frame action and maybe more energy dissipation capacity still exists” when BRB is removed, whereas moment frame action is completely lost when replacing the yielded link of an EBF

Buckling Restrained Braces

- Engineers stated that, although BRBs more expensive than regular braces, their fabrication is quick and they are considered to be a well-tested and robust system – with caution against “blindly accepting test results” from others

- Some BRBs in one project were manufactured incorrectly and experienced problems when tested (problems have apparently been ironed out since)

- A number of engineers have highlighted that BRB frames can “tuned” to demands, eliminating unnecessary overstrength

- Some engineers aware of on-going research questions about limited testing of BRBs in 3D
Buckling Restrained Braces

- Many engineers stated that architects in CHCH desire modern architecture and have showcased BRBs in many projects.
- Architects prefer BRB frames to EBF because BRBs can be “snaked” along the building in different patterns, and connection gussets can be shaped different ways, thus giving more freedom to architectural expression.
- One engineer went as far as saying, “BRB is the vernacular of Christchurch.”

Low damage, IL4, IL3, Reparability

- Buckling Restrained Braced Frames for this purpose
- Strategies implemented to assess the extent of their yielding during future earthquakes:

Viscous Dampers

- Used in only one building by 3/2017 (and one “in the pipeline”)
  - Client wanted low-cost building, but a bit above minimum
  - Engineering firm (as main tenant) was permitted by client to design structural system of their choice provided they met a specified budget comparable to that for a BRB system.
  - One engineer volunteered that: While he preferred viscous dampers to braces, adding a $30k viscous damper to a structure is a “hard-sell” when comparable brace is $4k.
  - Market in NZ might be more in retrofit of older RC MRFs

Steel Structures (General Issues)

- Momentum has shifted:
  - To paraphrase one engineer: While the local industry was geared to do RC buildings out of habit and practice, the industry in Christchurch is now geared to do steel on a large scale.
  - Earthquakes gave engineering community an opportunity to “brush up” and “get up-to-speed” on steel design.
  - Many engineers commented on specific new buildings that were designed with either all steel or part steel but “would have been all-concrete” design prior to the earthquake.
  - One engineer stated that, before the earthquakes, the industry had already started to move away from RC frames because they were too slow to build, and that it was “the right decision” because steel has the advantage that damage is more visible when it happens.

Eccentrically Braced Frames

- Split opinions on EBFs with or without replaceable links
  - Some expressed strong preference for bolted replaceable links and decoupling of link and link-beam design.
  - Others held that replacing links might not be performed as easily as foreseen (due to floor slab and residual drifts).
  - Many held that replacing the link in a conventional EBF is not necessarily more difficult: severely yielded links can be cut and replaced by new segments welded-in-place (as done in a number of post-Churchch repairs).
  - Concerns voiced that some of the replaceable links in new buildings appear out of proportion with the rest of their frame.

Reinforced Concrete Moment Frames

- Mentioned multiple times as part of the interviews that prior to CHCH earthquakes, many buildings had RC frame structural systems, both for gravity and for lateral-load resistance.
  - None of the engineers indicated a desire to design such systems in the future.
  - An engineer cited the example of a building that had been designed as an RC MRF before the earthquakes, redesigned and built as a steel MRF after the earthquake (although with precast walls on both side walls).
  - Steel gravity frames also replaced the RC beams and columns in the non-seismic frames of the building.
Drift Control and Design Ductility

- Drift limits in NZ Code have not changed after Christchurch earthquakes
- Many engineers indicated preference for systems that can provide lower drifts under the design earthquake level, to limit non-structural damage
- While not a general rule or standard practice, nearly all firms interviewed indicated a tendency to steer their new designs far from the 2.5% drift limit
- Drift demands of 1% to 1.5% were often cited as a desirable outcome (i.e., "in-house design guidance targets")
- More difficult to obtain with MRF, rather than braced or wall, structures
- Low drift limits seen in performance specifications for some projects
- Likewise, many firms expressed preference for lower values of design ductility demand
- Some firms indicated always using effective design ductilities of 3 or less (as a consequence of SLS considerations governing design)

Factors driving decision of structural system

- Client Requests
- Site Layout
- Soil Conditions*
- Site Conditions
- Costs
- Construction Time
- Construction Cost
- Requested Construction Time
- Requested Lowest Cost
- Choice of Structural System
- Showing Structural System
- Engineer’s Decision Cost or construction time
- Showing structural system

Post-Earthquake Choice of Structural System

- Client required (37):
  - No concrete: 2
  - Base Isolation: 6
  - R: 10
  - E: 4
  - No Damage: 3
  - Low damage: 12
- Constraints (10):
  - Site Layout: 4
  - Soil Conditions*: 6
  - Site Conditions
- Engineer’s Choice: 52
- Showing Structural System: 9
- Cost-related (50):
  - Construction Time: 5
  - Construction Cost: 8
  - Requested Construction Time: 9
  - Requested Lowest Cost: 28

* Soil constraints in Christchurch are implicit in most designs as not necessarily "flagged" as driving decisions out-of-ordinary
Post-Earthquake Choice of Structural System

Client required: 37
Constraints: 10
SE’s Choice: 52
Showcasing Structure: 9
Cost-related: 50

Trends (Consolidated Categories)

Impact on Wellington and Auckland

- Revised Seismic Zones Map
  - Auckland: Largest city in NZ (pop.: 1,500,000)
    - Low seismic zone
  - Wellington: 2nd Largest city in NZ (pop.: 400,000)
    - National Capital
    - Largest seismic zone

Conclusions and Key Points

- There are:
  - “Conclusions”: From the quantitative information
  - “Key points” drawn on the basis of above findings and discussions with those interviewed
  - “Conclusions” would be a summary of presented findings, so, in closing, focusing here instead on 6 “key points” arising from this study

6 Key Points:

1. It is becoming a more widely held belief that preventing loss of life as a seismic performance objective is simply not sufficient for a good modern structure
2. Structural engineers’ opinions impact the adoption of low-damage systems
3. Tenant expectations strongly impact choice of structural systems
4. Additional increase in seismic performance, if desired for all buildings, would need to come from government regulation
5. Context affects final decision outcome
6. Reconstruction experience has paralleled increase in stakeholder knowledge

“Bonus Content” – Case Studies
Parting Thought

- The Christchurch experience may be unique today, but it is likely to repeat itself in other similarly developed urban centers worldwide after future devastating earthquakes.
- As such, the Christchurch rebuilding experience is significant, providing a unique insight into some of the mechanisms that can dictate structural engineering decisions during the post-earthquake reconstruction of a modern city.

Acknowledgments

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For more information:

- 170 pages = more “nuggets” than could be covered today

- [http://resources.quakecentre.co.nz/reconstructing-christchurch/](http://resources.quakecentre.co.nz/reconstructing-christchurch/)