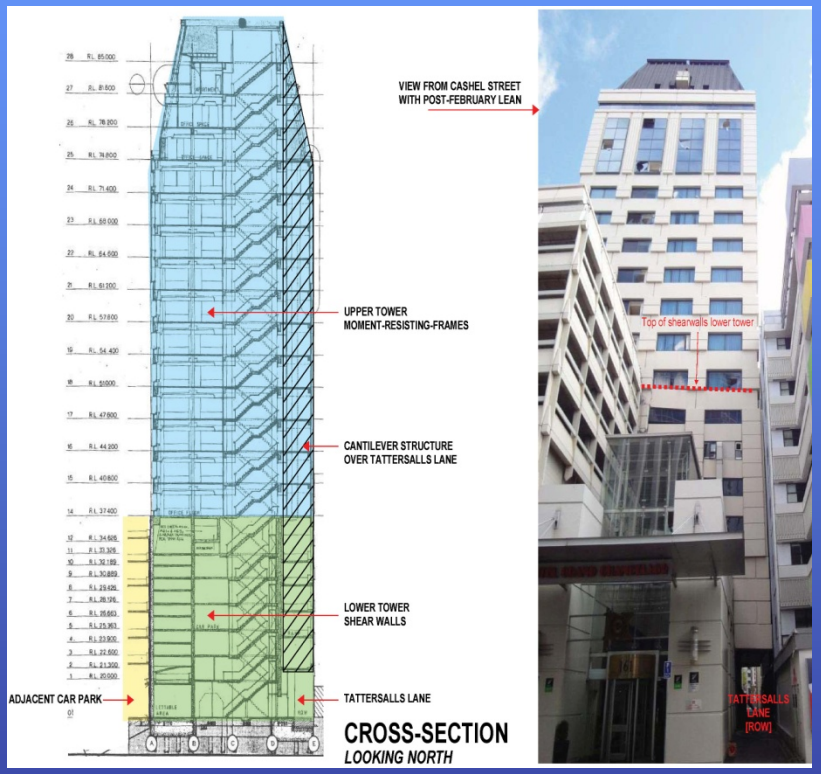
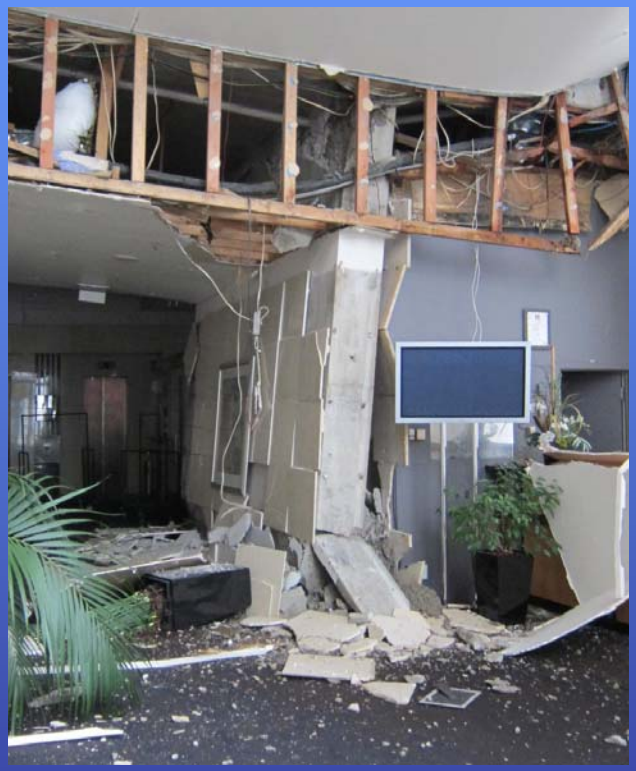
Canterbury Earthquake Royal Commission Hearings - 17 Jan 2012

Seismic Performance of the Hotel Grand Chancellor : Findings and Recommendations





Stefano Pampanin

Department of Civil and Natural Resources Engineering

University of Canterbury

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Terms of Reference for the Expert Panel

Technical Investigation into the Performance of Buildings in the Christchurch CBD in the 22 February Christchurch Aftershock

General

Overall Terms of Reference for the investigation are given in Attachment 1.

Investigations will look at the expected performance of the buildings, when they were built, the impact of any alterations, compliance with the code at the time, and the reasons for the collapse. The investigations will focus only on the technical findings and are not to address liability.

The Department of Building and Housing has overall responsibility for the outcome of the investigation and has appointed:

- *Engineering consultants to investigate the subject buildings*
- *A panel of experts to assist in achieving the overall objectives of the investigation*

These Terms of Reference for Expert Panel describe the roles and responsibilities of the expert panel in the context of the overall Terms of Reference for the investigation.

Outline Approach and Outputs

The main outputs of the investigation will be:

- *Consultant technical investigation reports on each building*
- *A report prepared by the Expert Panel to the Department*
- *A Department report to the Minister on the outcome of the investigation.*

The investigating consultants will be responsible for their own work and for determining the inputs they use to reach their conclusions. The consultant reports will be attachments to the Expert Panel Report.

The Department Report will be based on material in the consultant reports and the Expert Panel Report.

Roles and Responsibilities

The panel members have been chosen to provide a background of experience in the range of matters related to the planning, design, approval and construction of buildings.

In general, it is expected that, individually and collectively, panel members will help the Department to provide comprehensive, accurate and authoritative accounts of why the buildings collapsed and what the implications are for the Building Act and Code.

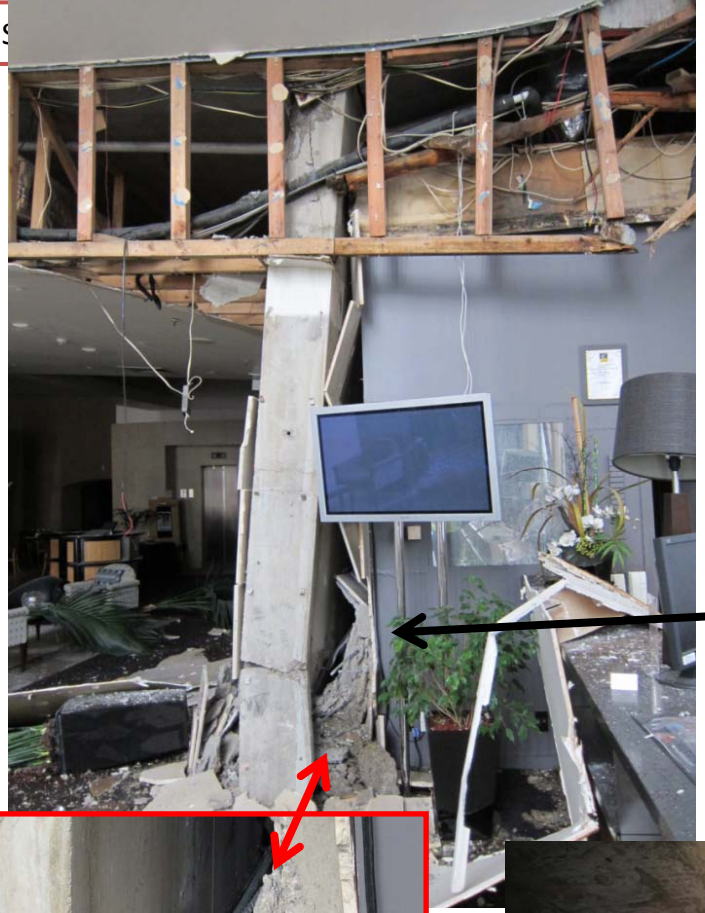
Particular roles and responsibilities include:

- *Providing guidance and direction to the investigation*
- *Advising on the scope and extent of investigation necessary to achieve overall objectives*
- *Monitoring and reviewing the approaches, investigations, data and outputs of the engineering consultants*
- *Recommending to the Department any changes in the scope and nature of work necessary to address the matters for investigation fully, accurately and authoritatively.*
- *Reviewing and approving the engineering consultant reports on each building.*
- *Producing an overview report addressing the matters for investigation and indicating any issues for further consideration by the Department in their role as regulator responsible for the Building Act and Code.*

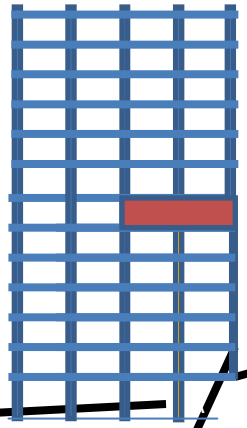
BUI.CAS161.0048.4

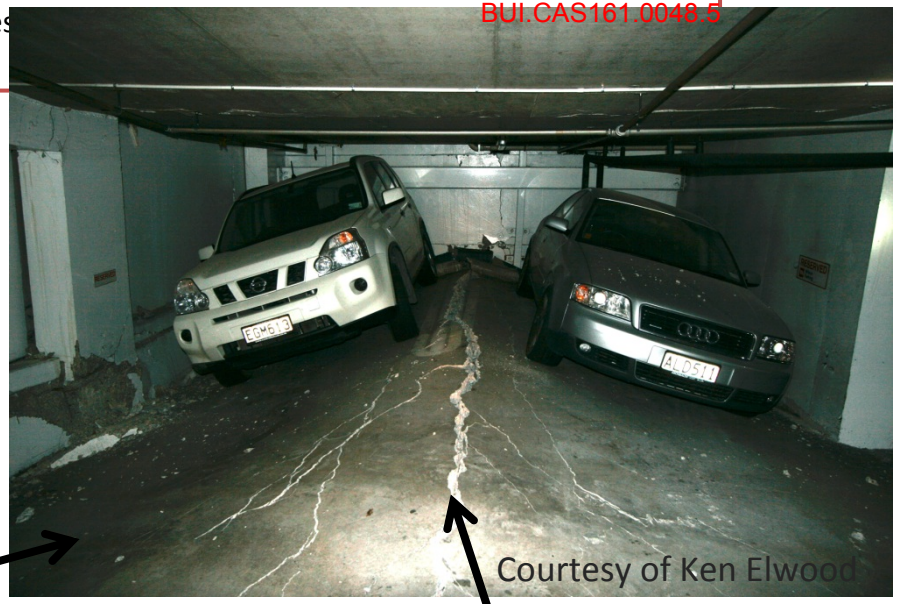
National Hazard Res
Infrastructure

BUI.CAS161.0048.5



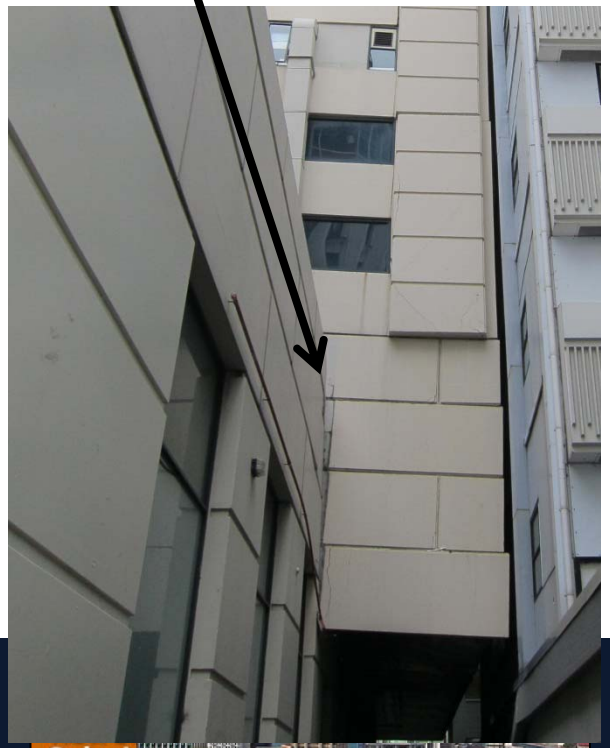
W-E Frame





Courtesy of Ken Elwood

Courtesy of Ken Elwood



Society for Earthquake
gineering Incorporated

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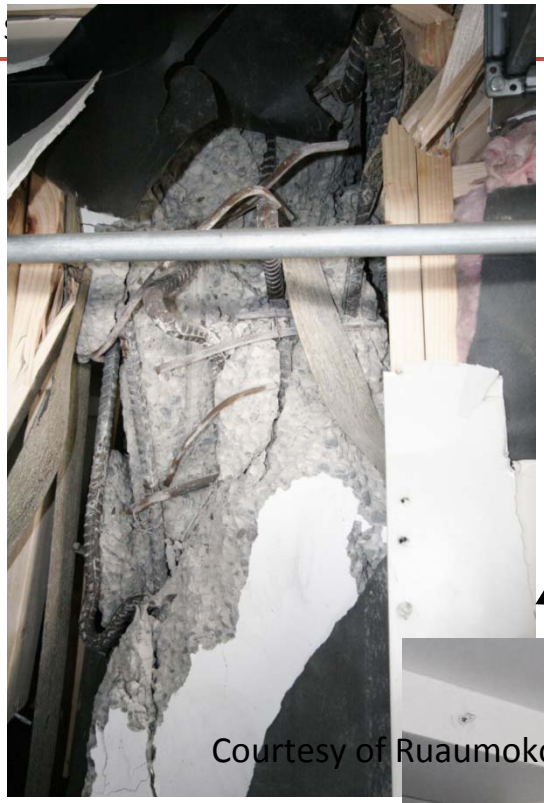
NEW ZEALAND
TIMBER DESIGN
SOCIETY INCORPORATED
A TECHNICAL GROUP OF IPENZ ENGINEERS NEW ZEALAND

Solutions



Courtesy of Ruaumoko Solutions

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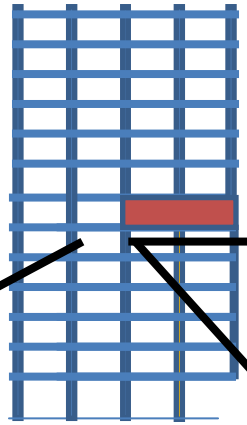
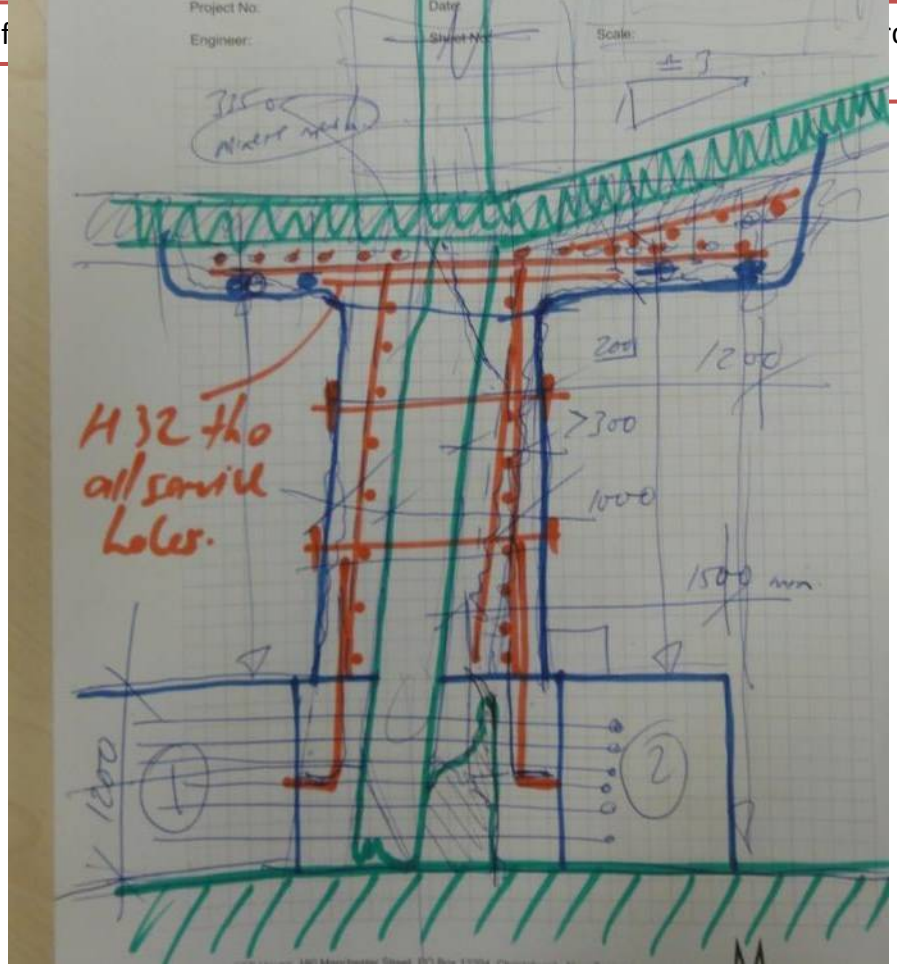


BUI.CAS161.0048.6

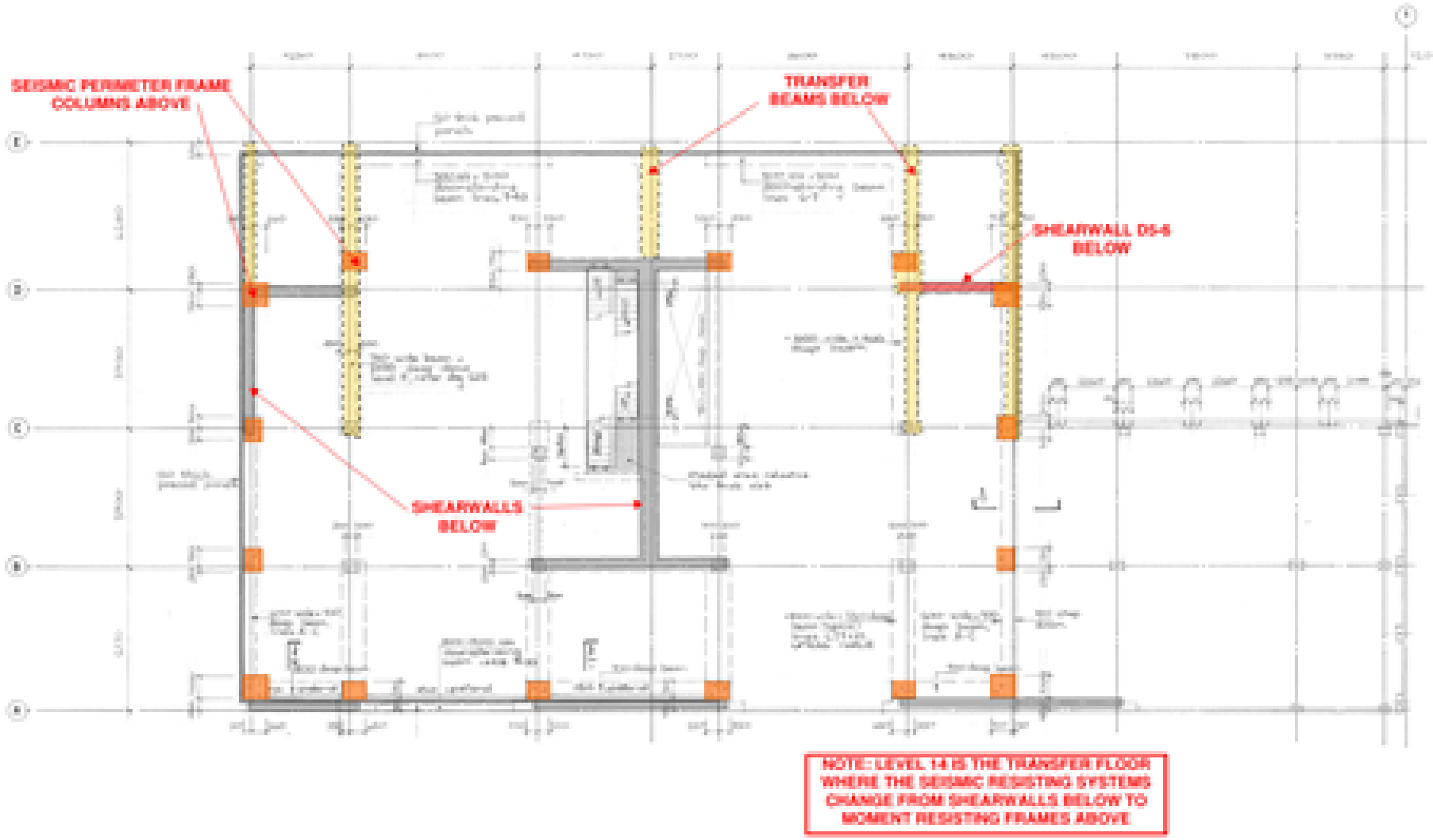
Courtesy of Ruaumoko Solutions



Rapid engineering assessment decisions for repair and temp. stabilisation – led by Dr David Hopkins

Structural wall jacketing/shoring

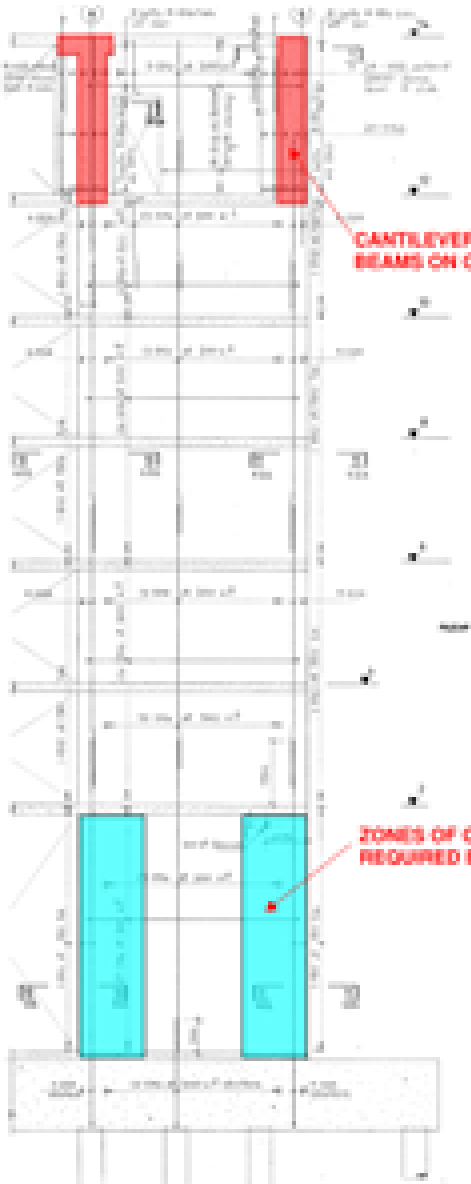
Global Behaviour

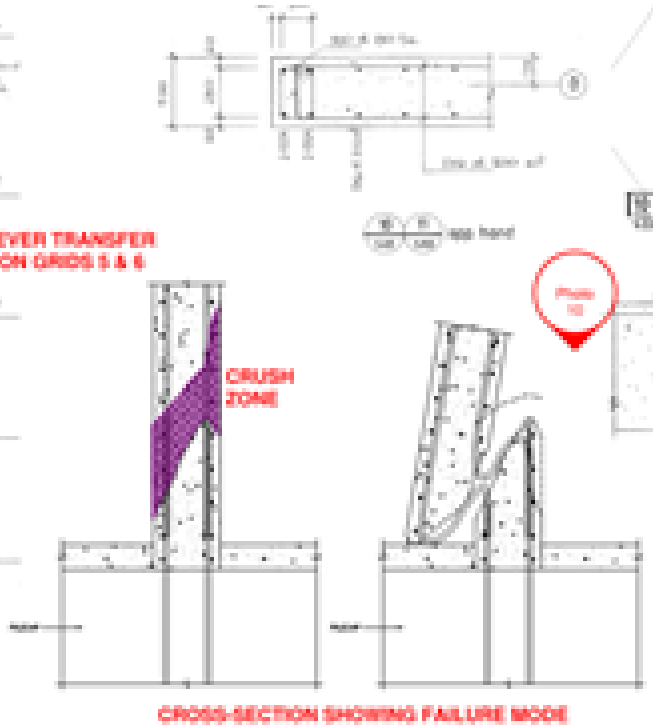


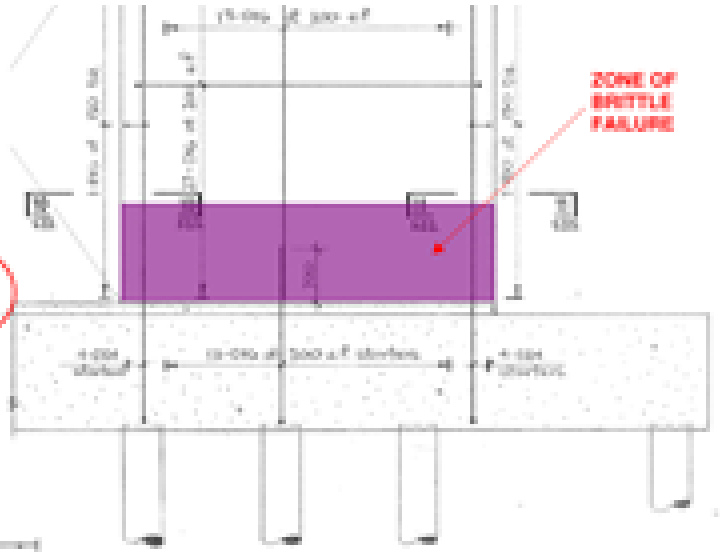
EXTRACT FROM ORIGINAL STRUCTURAL DRAWINGS

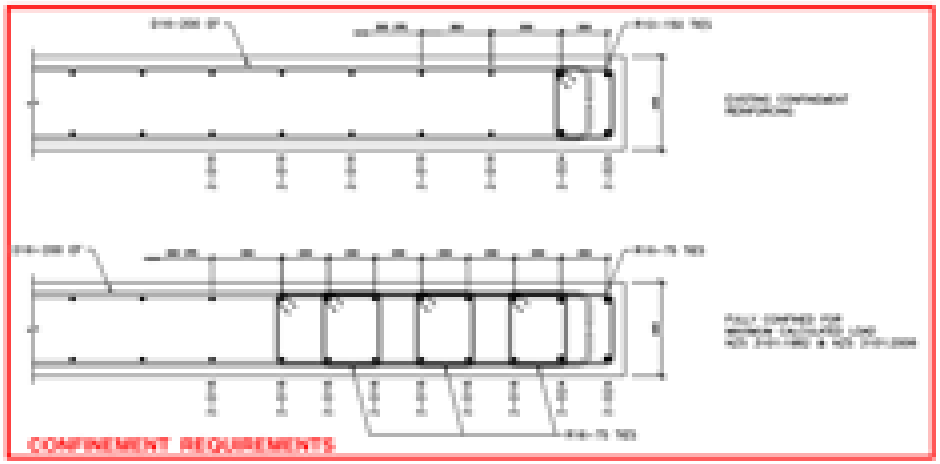
LEVEL 14

Local Behaviour









WALL D5-6

EXTRACT FROM ORIGINAL STRUCTURAL DRAWINGS

Stefano Pampanin and Weng Yuen Kam

National Hazard Research Platform: Resilient Buildings and Infrastructure

BUILCAS161.0048.11

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A Contextualized analysis

Technical Investigation into the Performance of Buildings in the Christchurch CBD in the 22 February Christchurch Aftershock

Report on General Building Performance in the Christchurch CBD

Terms of Reference

1 Background

The Department is responsible for an investigation into the collapses and structura performance of four buildings, CTV, PCG, Grand Chancellor and Forsyth Barr, in the earthquake of 22 February.

The Department has appointed:

- Engineering consultants to investigate the subject buildings
- A panel of experts to assist in achieving the the overall objectives of the investigation

The main outputs of the investigation will be:

- Consultant technical investigation reports on each building
- A report prepared by the Expert Panel to the Department
- A Department report to the Minister on the outcome of the investigation.

The investigating consultants will be responsible for their own work and for determining the inputs they use to reach their conclusions.

The consultant reports will be attachments to the Expert Panel Report.

The Department Report will be based on material in the consultant reports and the Expert Panel Report.

2 Objectives

The focus of the investigation is the structural performance of the four buildings. The purpose of this Report on General Building Performance in the CBD is to give a general description of the ground shaking, the range of buildings affected, and the structural performance of buildings of different types.

This will give a frame of reference to the consultants responsible for the investigations, the Expert Panel and the Department in assessing the performance of the four buildings.

3 Scope

The Report is to provide a general description of the following in rela earthquake of 22 February 2011.

- The nature and intensity of ground motions experienced in the how these compare to those used in design of new buildings February.
- The impact of the ground motions on the soils, particularly soils, and how these compare with those expected in a de prior to 22 February
- The response of a range of buildings (types and ages) to th ground movement and how it compares, in a general s expected response of new buildings.
- The structural performance of a range of buildings (types including secondary structural elements such as stairs, ce cladding.

It is envisaged that the report would need to contain examples to illustrate performance to support the general statements made.

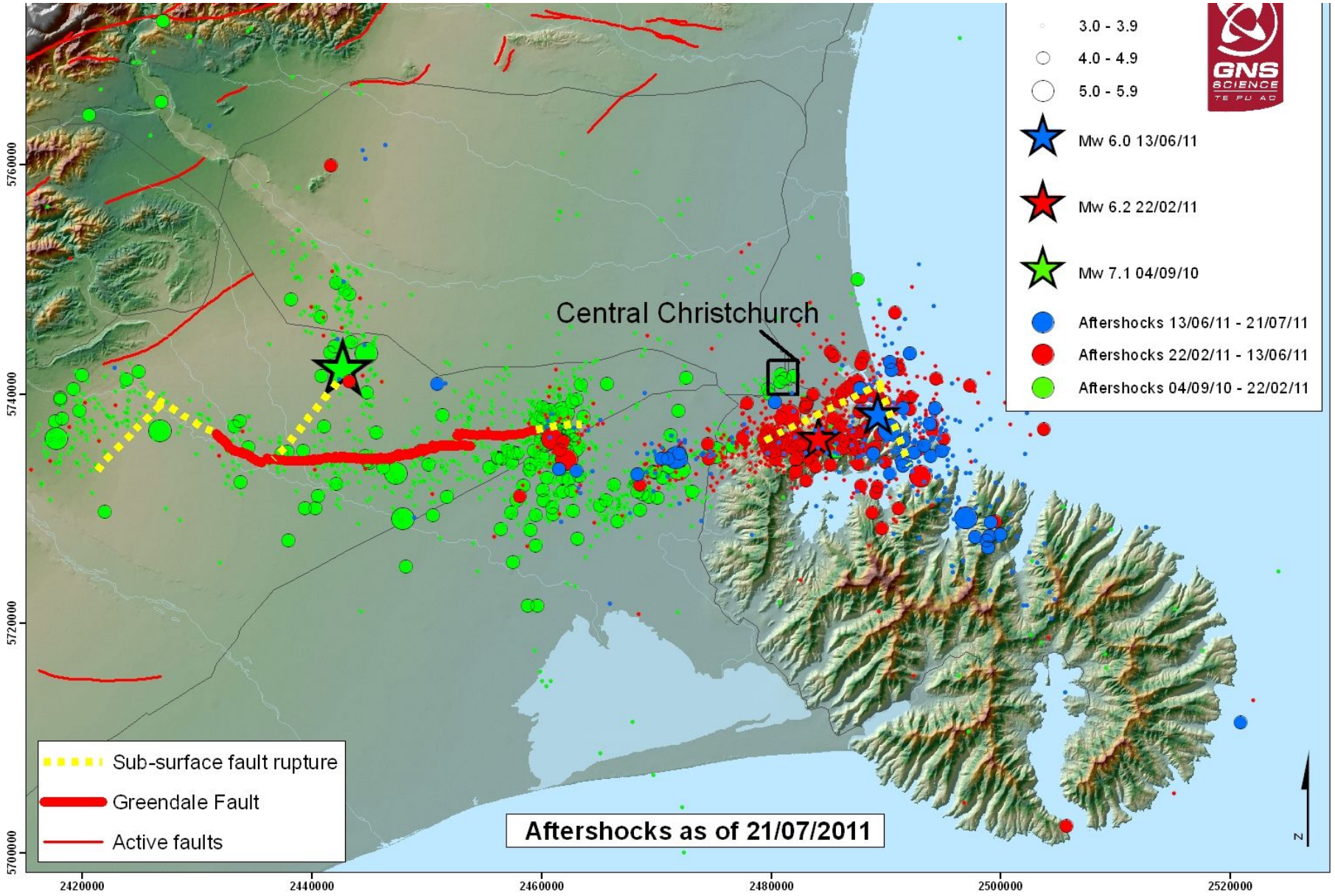
The content and presentation of the report must be in a form that allows Panel members, consultants and Department representatives to obta general understanding of how the earthquake shaking, the impact on soils, the response of buildings and the structural performance of building with expectations.

4 Timeframe

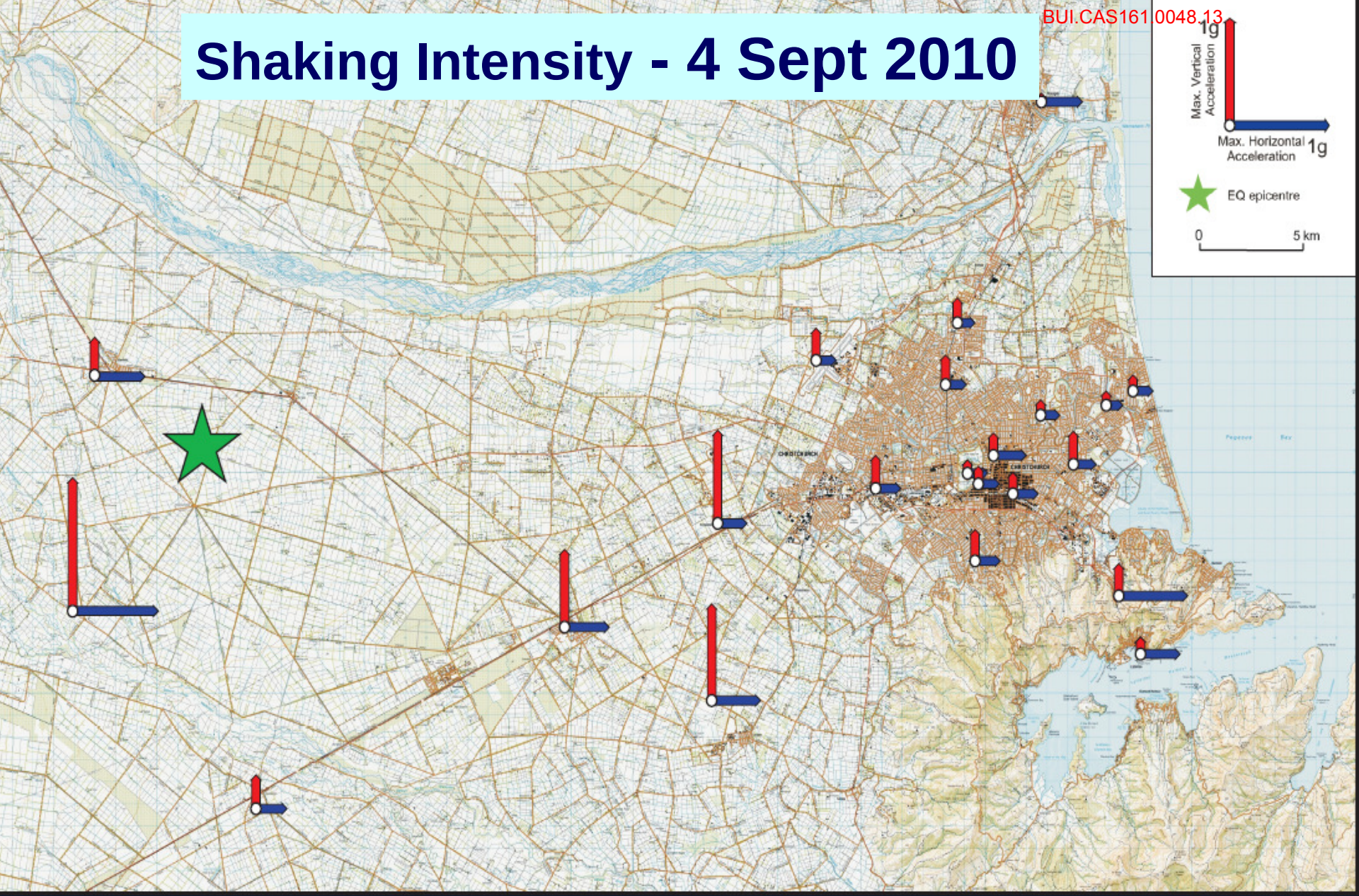
A draft report is required by 27 May 2011 and a final report by 8 June 2011

The Christchurch Earthquakes 2010-2011-..

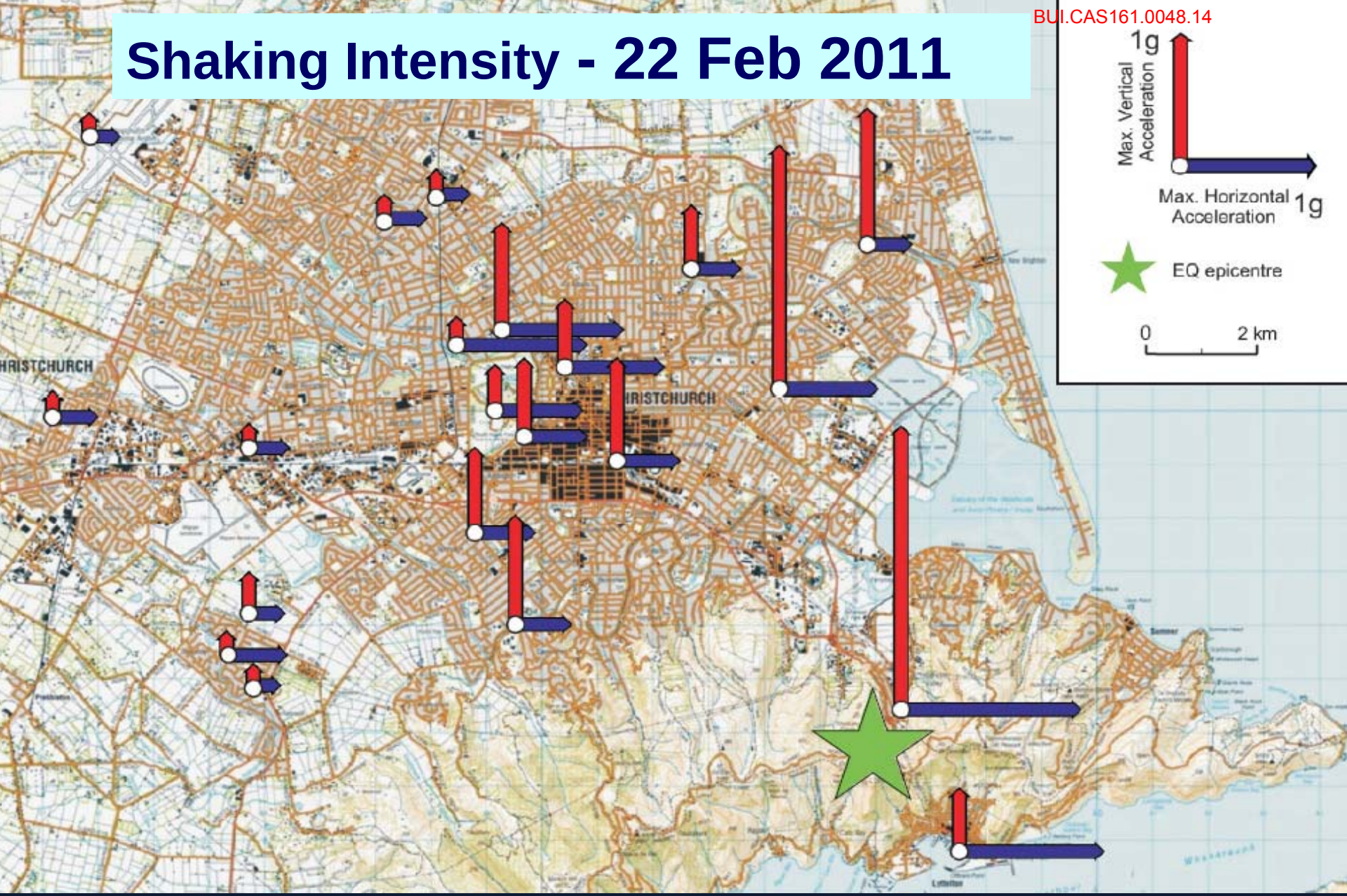
(Sept 4, Feb 22, June 13 and thousands of aftershocks)



Shaking Intensity - 4 Sept 2010

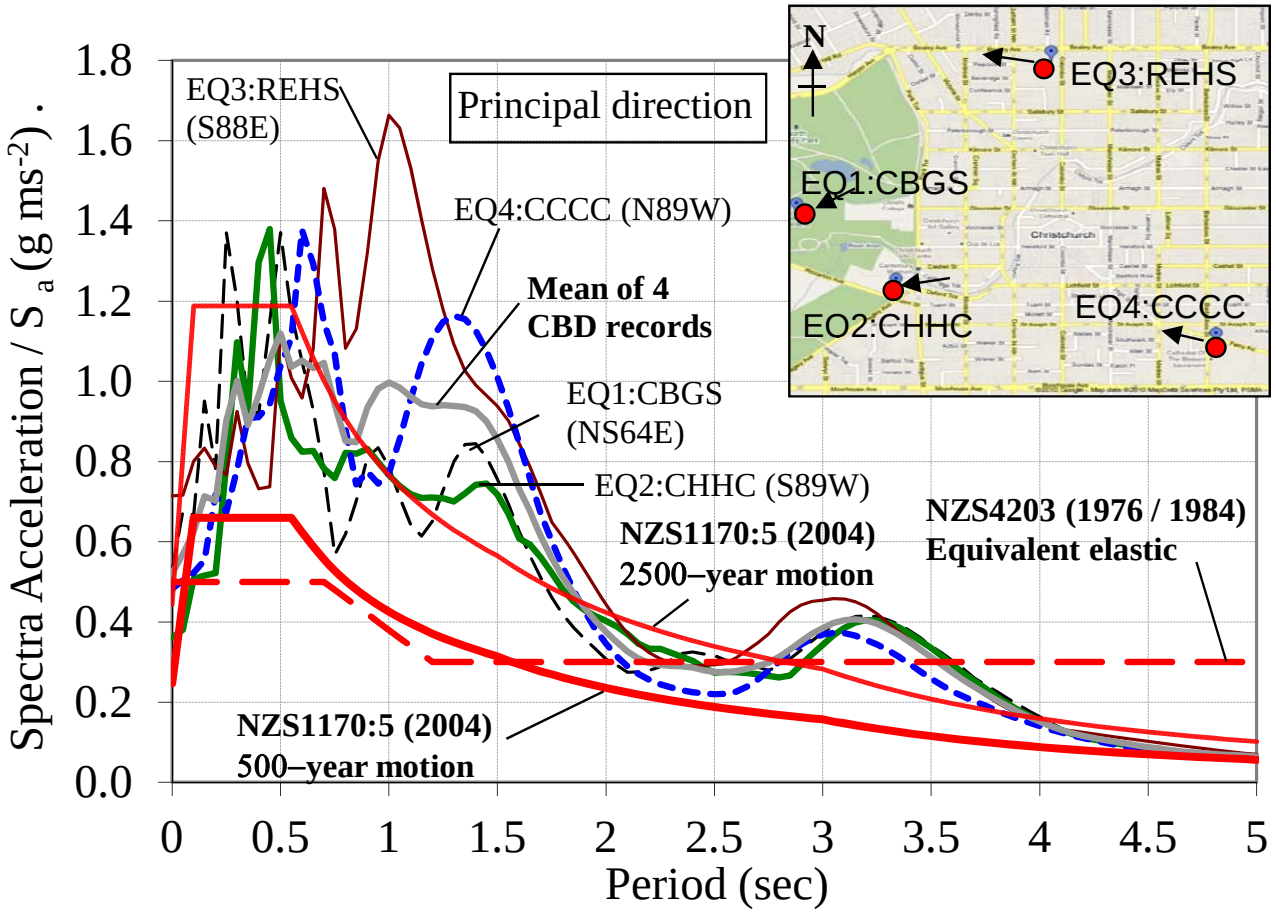


Shaking Intensity - 22 Feb 2011



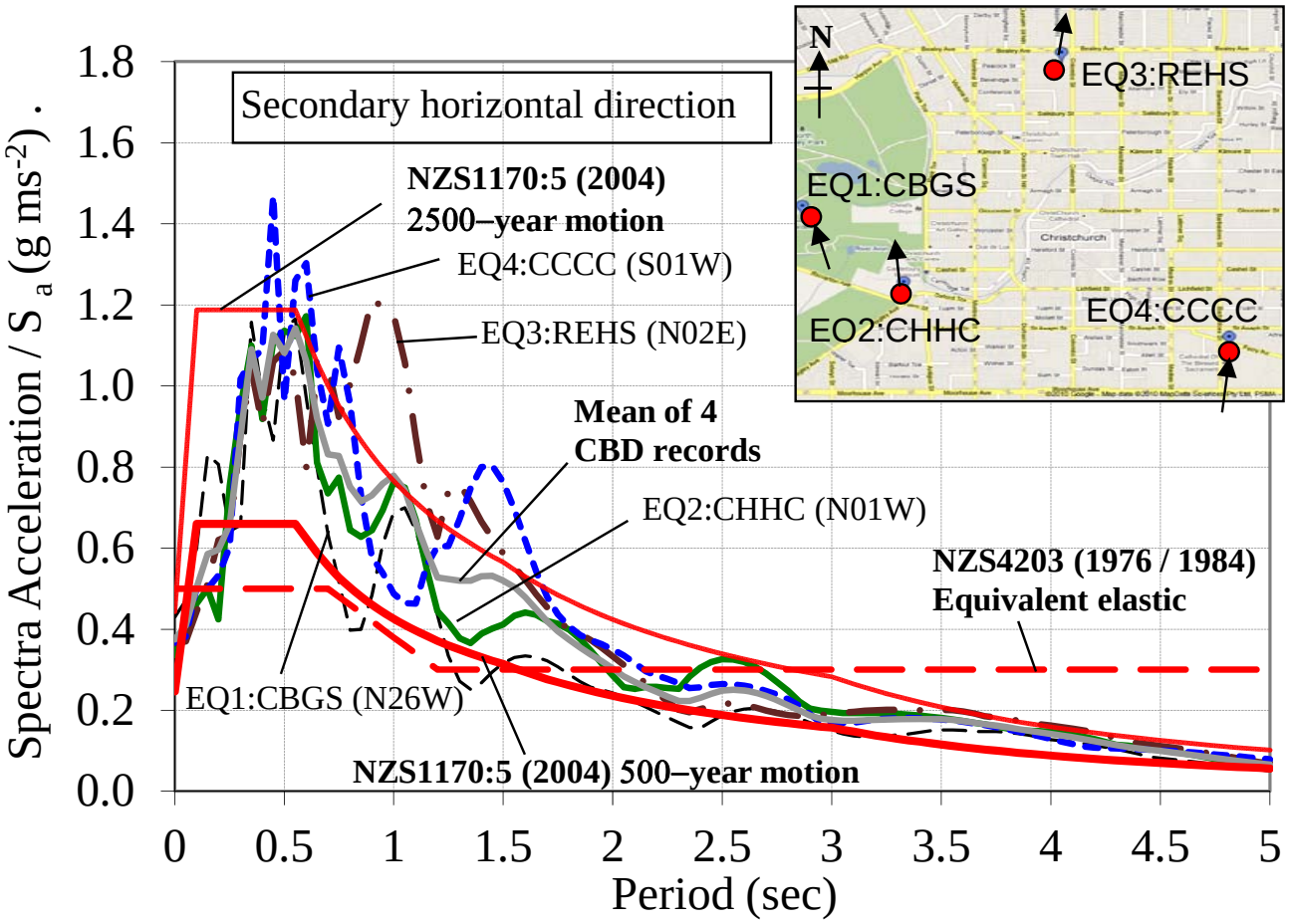
Shaking Intensity 22 Feb 2011

(Stronger Component East-West)



Shaking Intensity 22 Feb 2011

(Weaker Component North- South)



September vs. February

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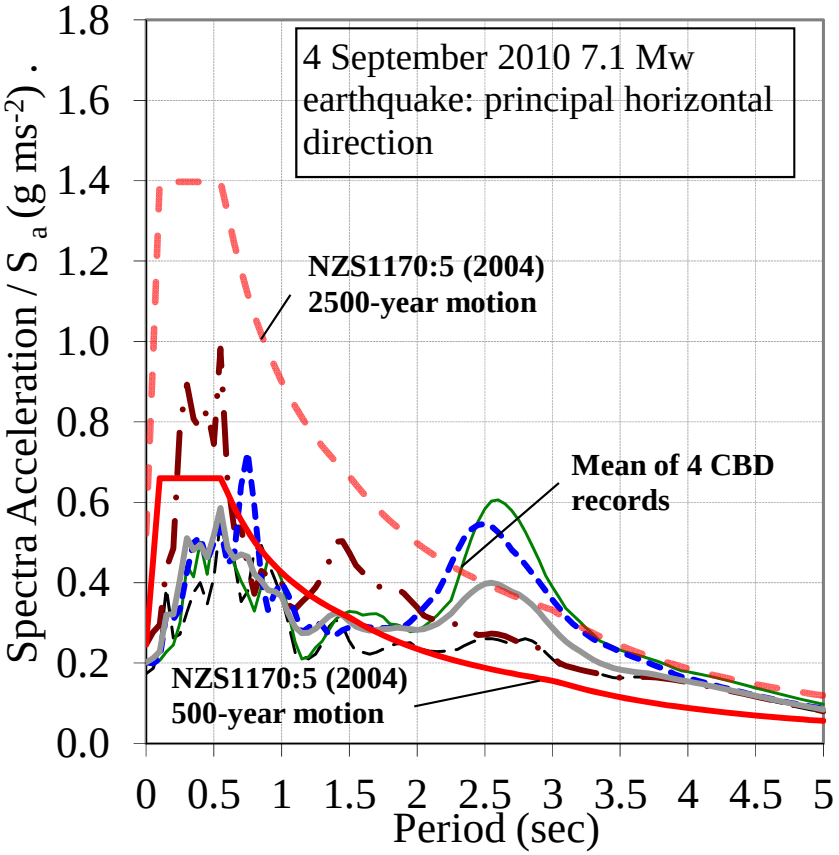
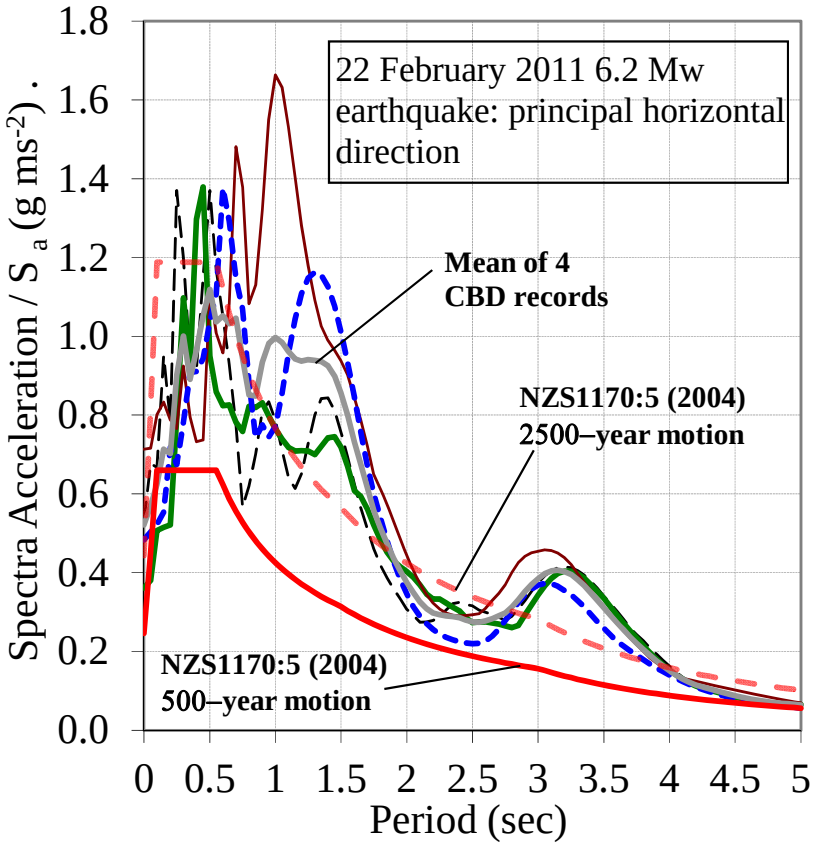
Principal component



North-South

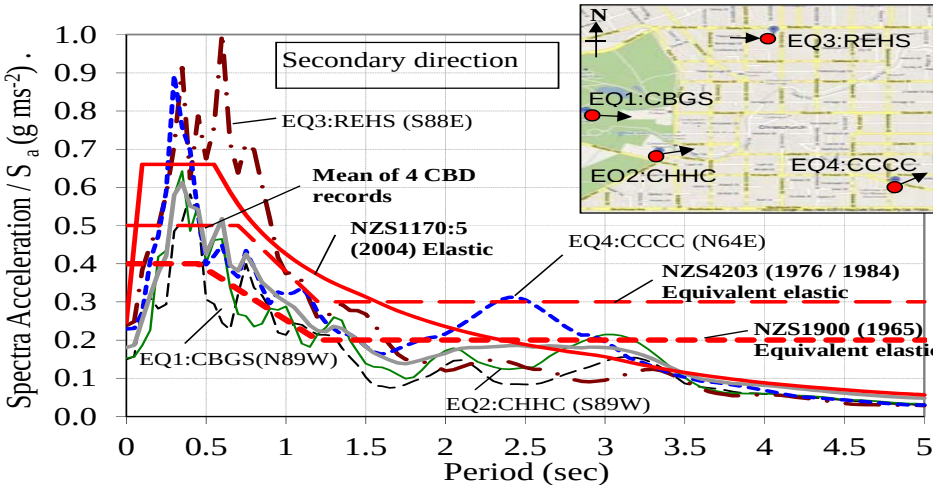


East-West

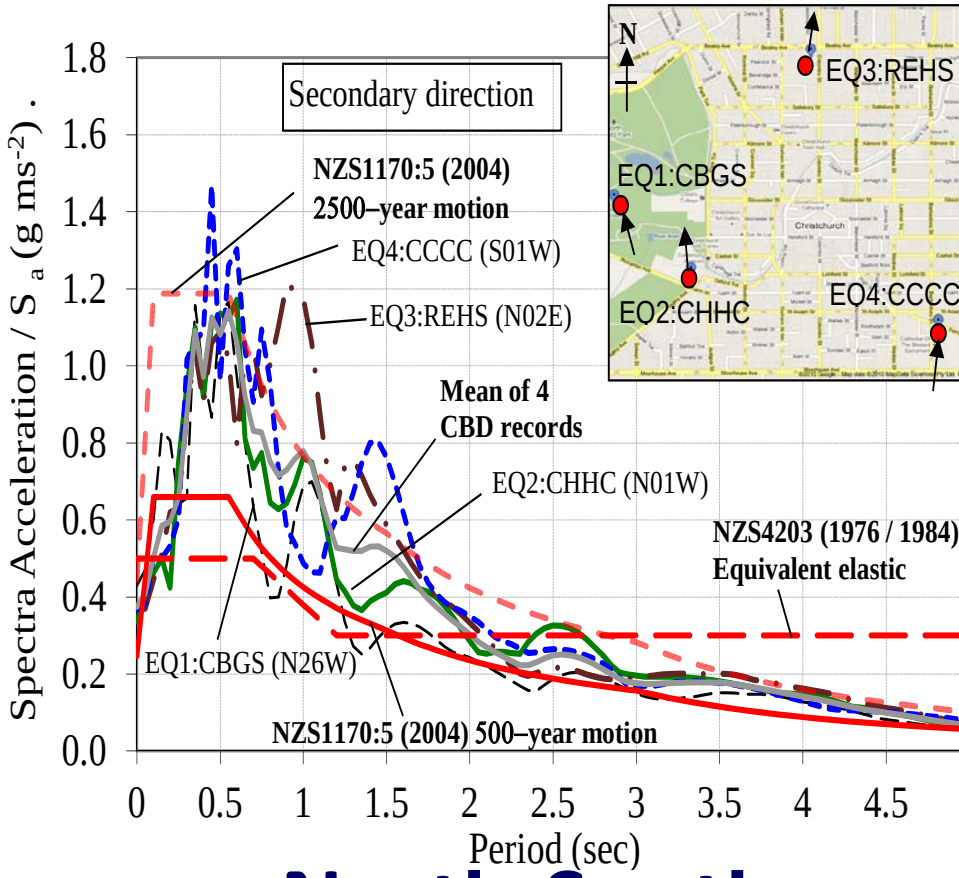
(velocity pulse type)

September vs. February

Secondary component

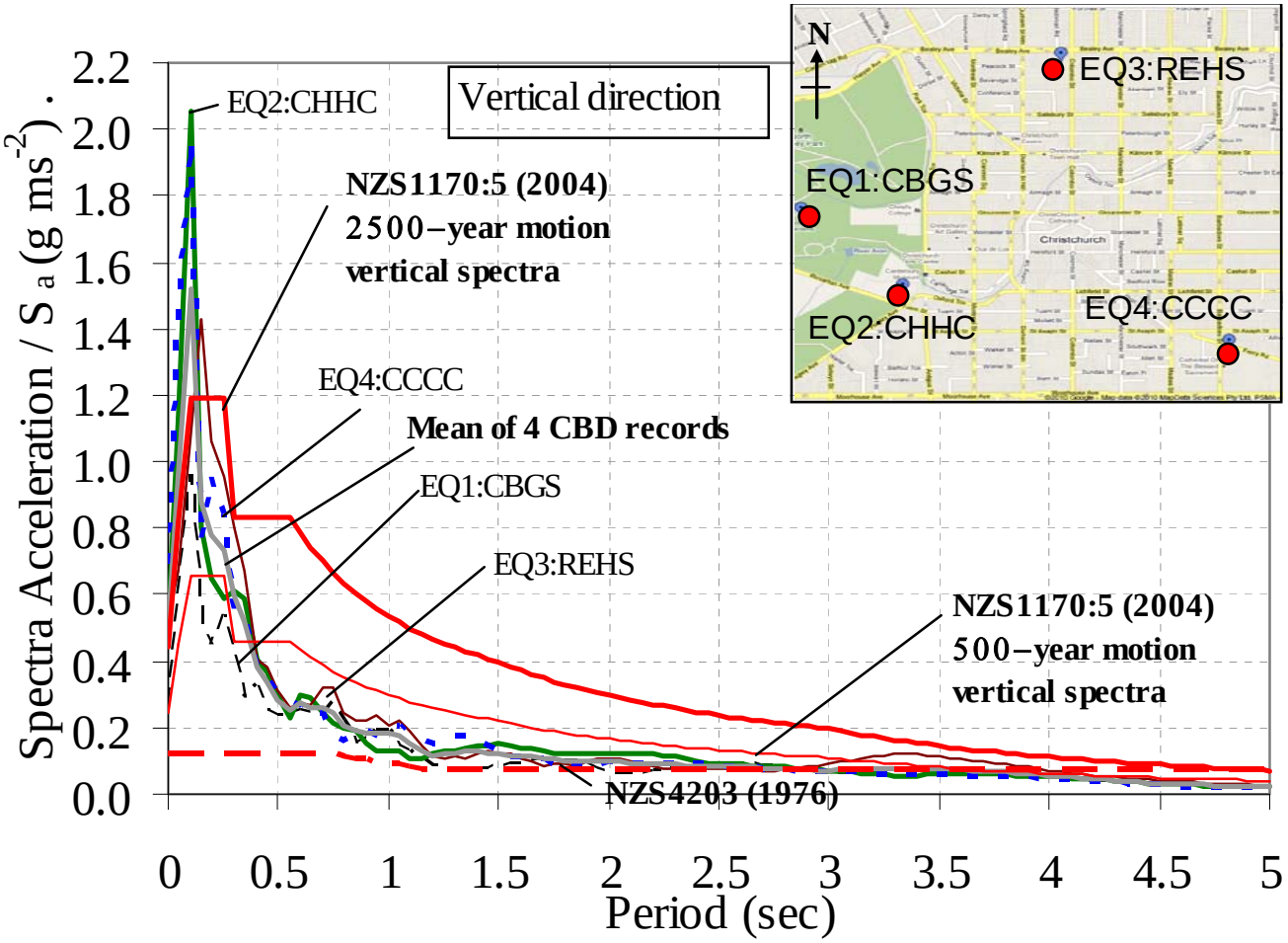


East-West

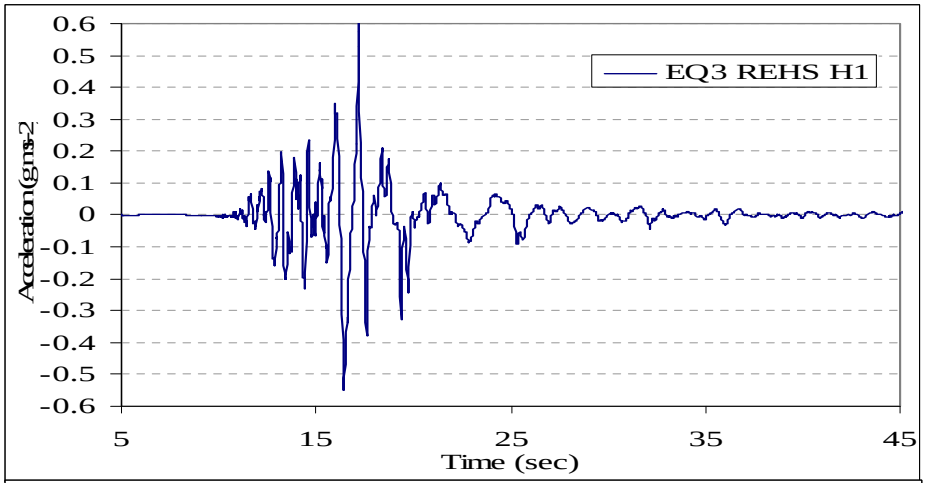


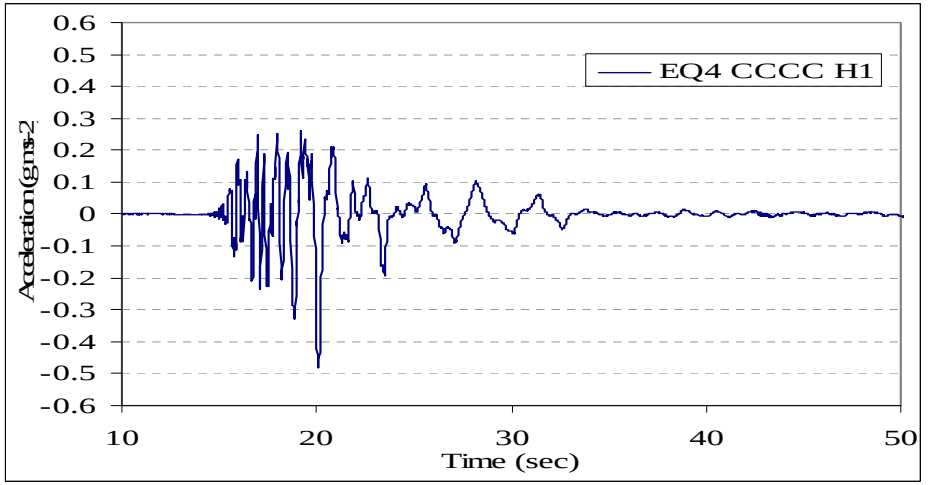
North-South

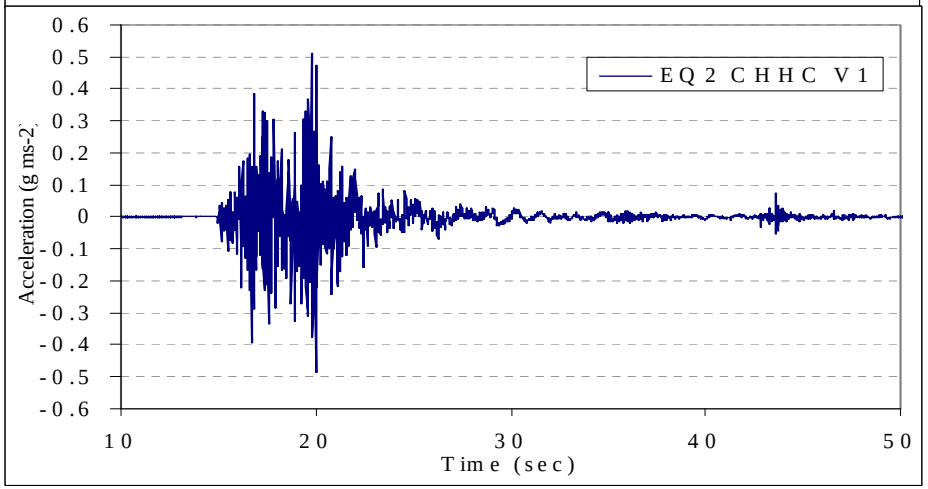
Vertical acceleration Spectrum

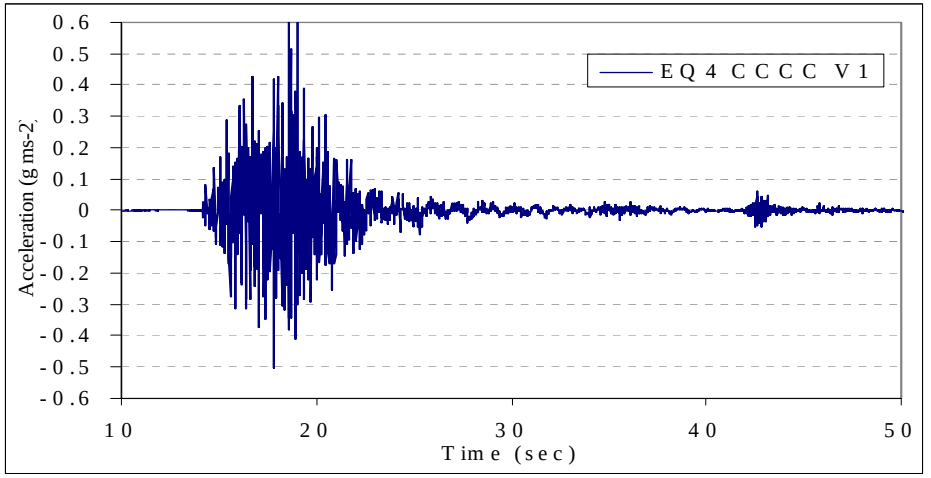


Vertical acceleration records









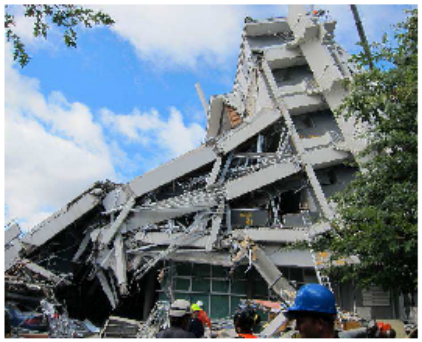
RC Building Damage Report

Report on Reinforced Concrete Buildings in Christchurch CBD
Draft: 22 Dec 2011
-NOT FOR PUBLIC RELEASE-

REPORT

on

The Observed Earthquake Damage of Reinforced Concrete Buildings in the Christchurch CBD on the 22 February 2011 Earthquake



Final Version: 22 December 2011

Contributing Authors:

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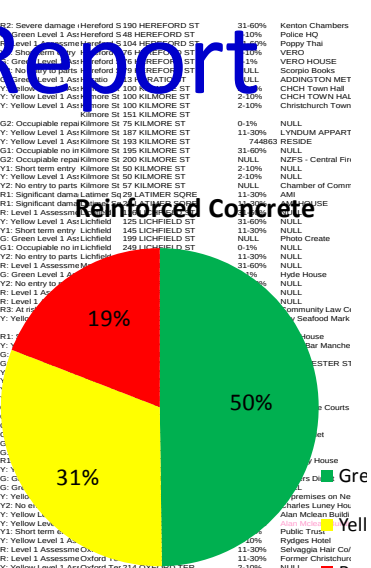
Dr Weng Yuen Kam

Dr Umut Akguzel

Sahin Tasligedik

Patricio Quintana-Gallo



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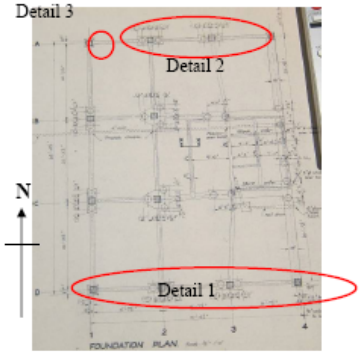
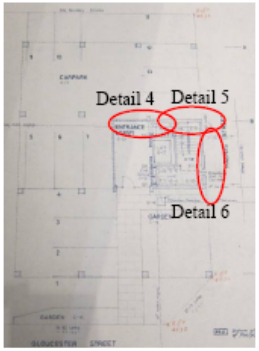
Draft Report on Pre-1970s Reinforced Concrete Buildings in Christchurch CBD
Draft 10th March 2011 -NOT FOR PUBLIC RELEASE-

BUILDING IDENTITY

Building No	70s-73
Building Name	Securities House
Address	221 Gloucester
Zone	XX
Storeys Above Ground Level	8
Approximate Gross Floor Area (m^2)	~330
Year Built	1970-1979
Type of Construction	Concrete Frames with Concrete Core walls
Occupancy Type	Commercial Office

Building Plans





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Draft Report on Pre-1970s Reinforced Concrete Buildings in Christchurch CBD
Draft 10th March 2011 -NOT FOR PUBLIC RELEASE-

Typical exterior damage photos (4 max)

Detail 1: Beam beam-column joints and columns cracks at the South face RC frame. Most of the connections between Level 2 to Level 6 were partly-damaged.

Detail 2: Severe shear failure with concrete spalling of the Level 2 (1st floor) interior columns of the North face RC frame. Many of the interior beam-column joints were cracked.

Detail 3: Corner beam-column joint cracked at level 2 (North-East corner)

Settlement of ground along the foundation transfer beams. Estimated settlement ~ 25-75mm.

Detail 4: Diagonal shear crack of RC block masonry. Minor damage to the RC core walls at the base (circled).

Detail 5: Cracking of RC shear core walls (in the E-W direction).

Detail 6: Cracking of RC flat slab along the column line (in the E-W direction).

Draft Report on Pre-1970s Reinforced Concrete Buildings in Christchurch CBD
Draft 10th March 2011 -NOT FOR PUBLIC RELEASE-

Foundation System

The foundation system is formed by isolated footings for columns and foundation (coarse) beams for walls, attached to the ground using piles (size and depth not specified in available drawings). Footings are attached to each other using slender foundation beams. Wider beams were used on axis 4, whereas thin beams were used to attach the outer ends of the C-shaped wall to the west side columns.

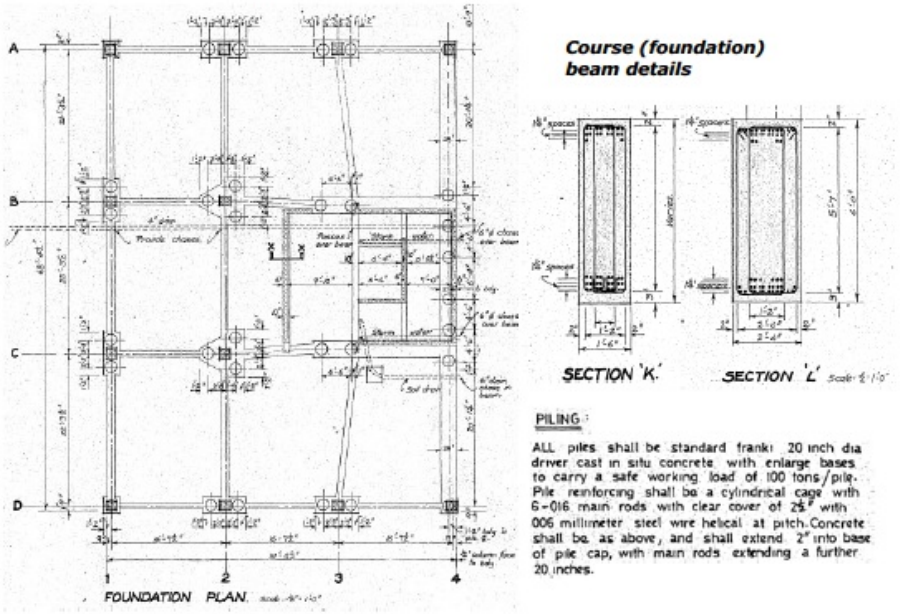


Figure 2: Foundation system. Left: foundation pan view; right: course beam details and piling information

Structural System

The structural earthquake resistant system is conformed by perimeter RC frames and RC structural core C-shaped and L-shaped walls. Gravity loads in the central area are resisted by columns with capitals jointed continuously to the cast in situ floor slab. The C-shaped wall is used as support for stairs together with the L-shaped thin wall, as shown in details. Note the interior RC L-shaped wall has got a single mesh inside, as shown in details. Stairs are jointed at each floor level to the structural walls using cast in situ floor slabs. Floor system consists in cast in situ RC slabs 5 in. thick (130mm).

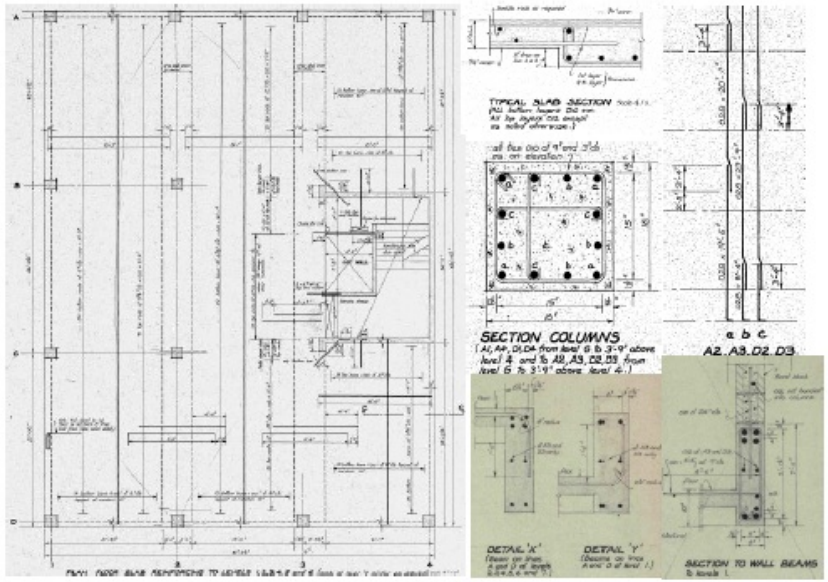


Figure 3: Structural System. Left: typical plan view; right: Column, beam and slab details

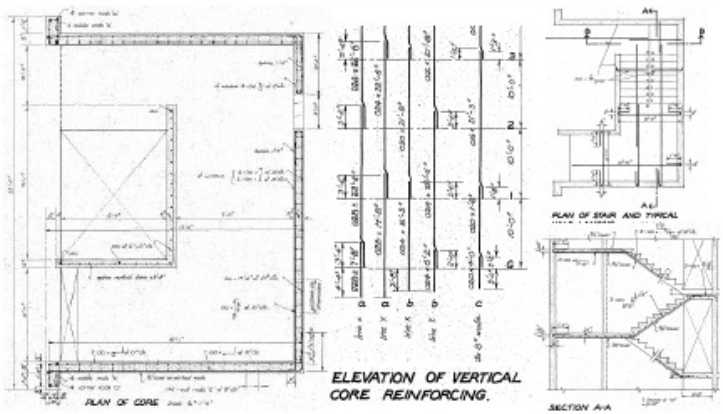
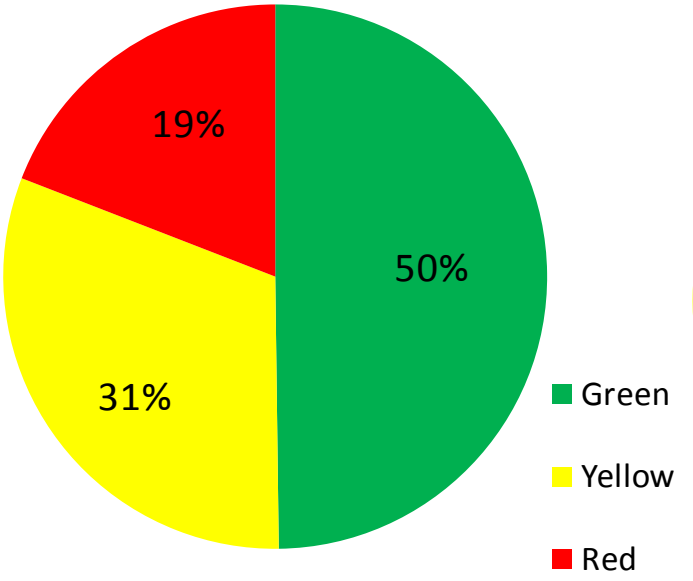


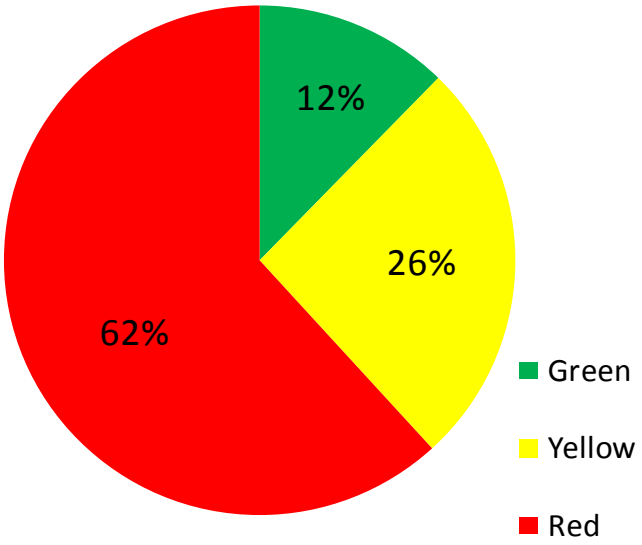
Figure 4: Structural System. Left: C-shaped wall details; right: stairs connection details

Damaged buildings
(after 22 Feb 2011)

Reinforced Concrete



Unreinforced Masonry

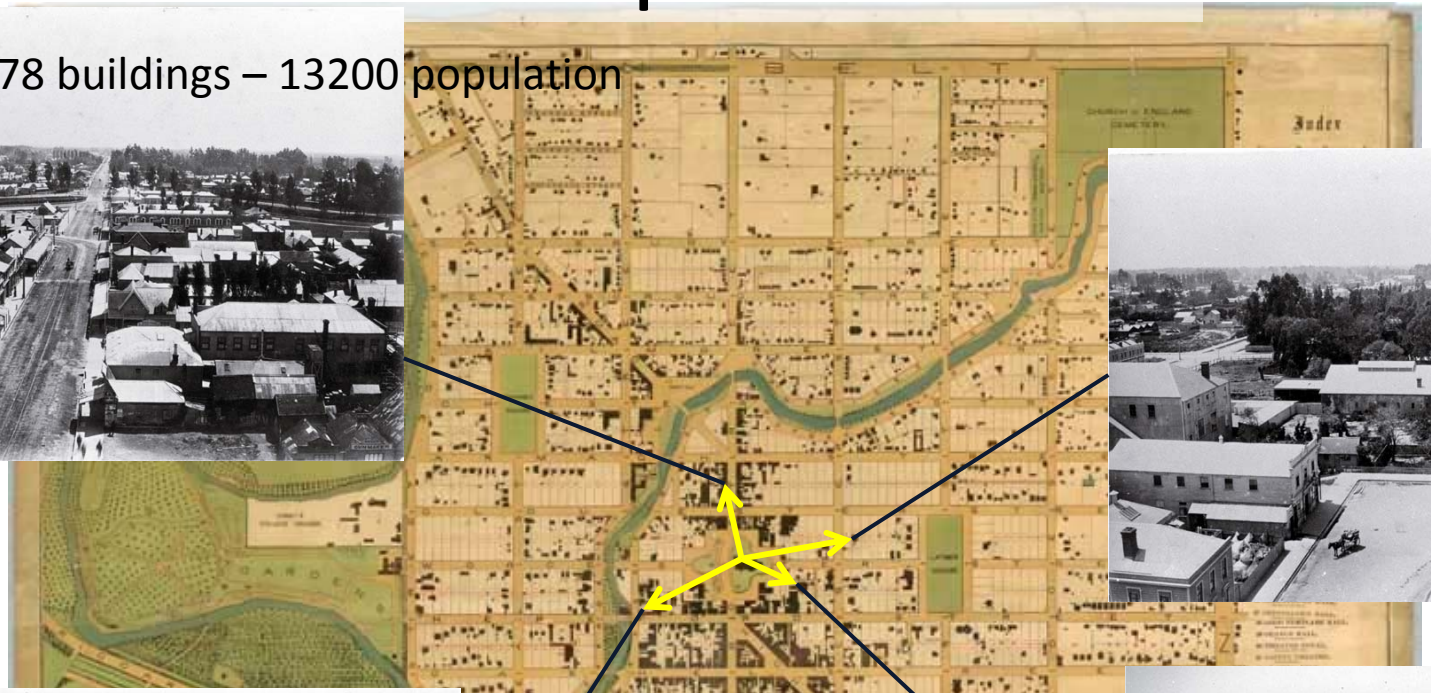


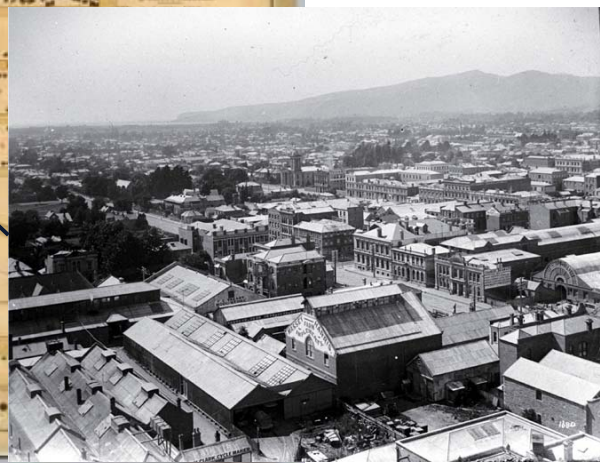
As **per 18 Mar 2011** – CCC Data

Christchurch pre-1900s

1877: 4178 buildings – 13200 population

CCC Images

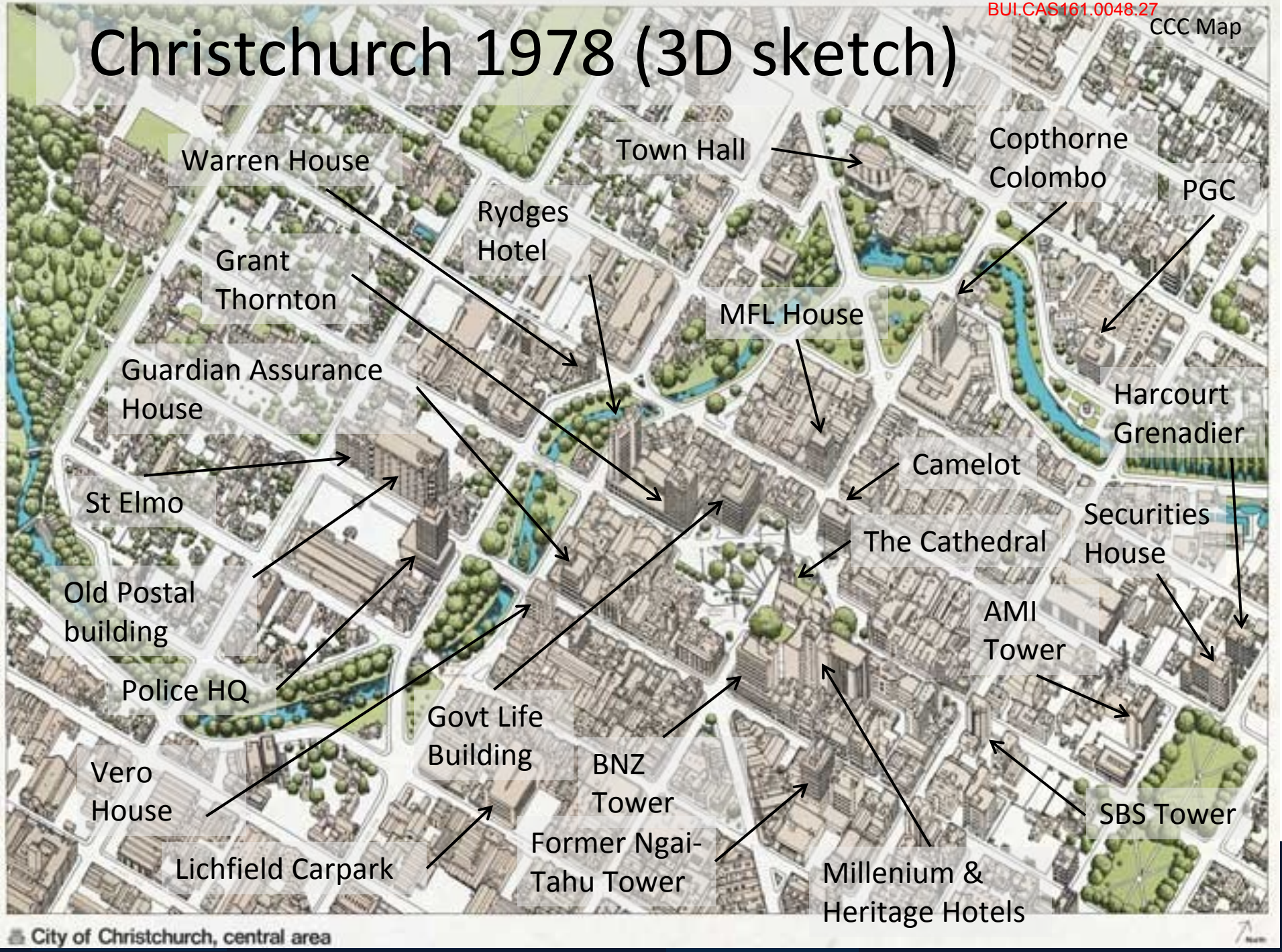




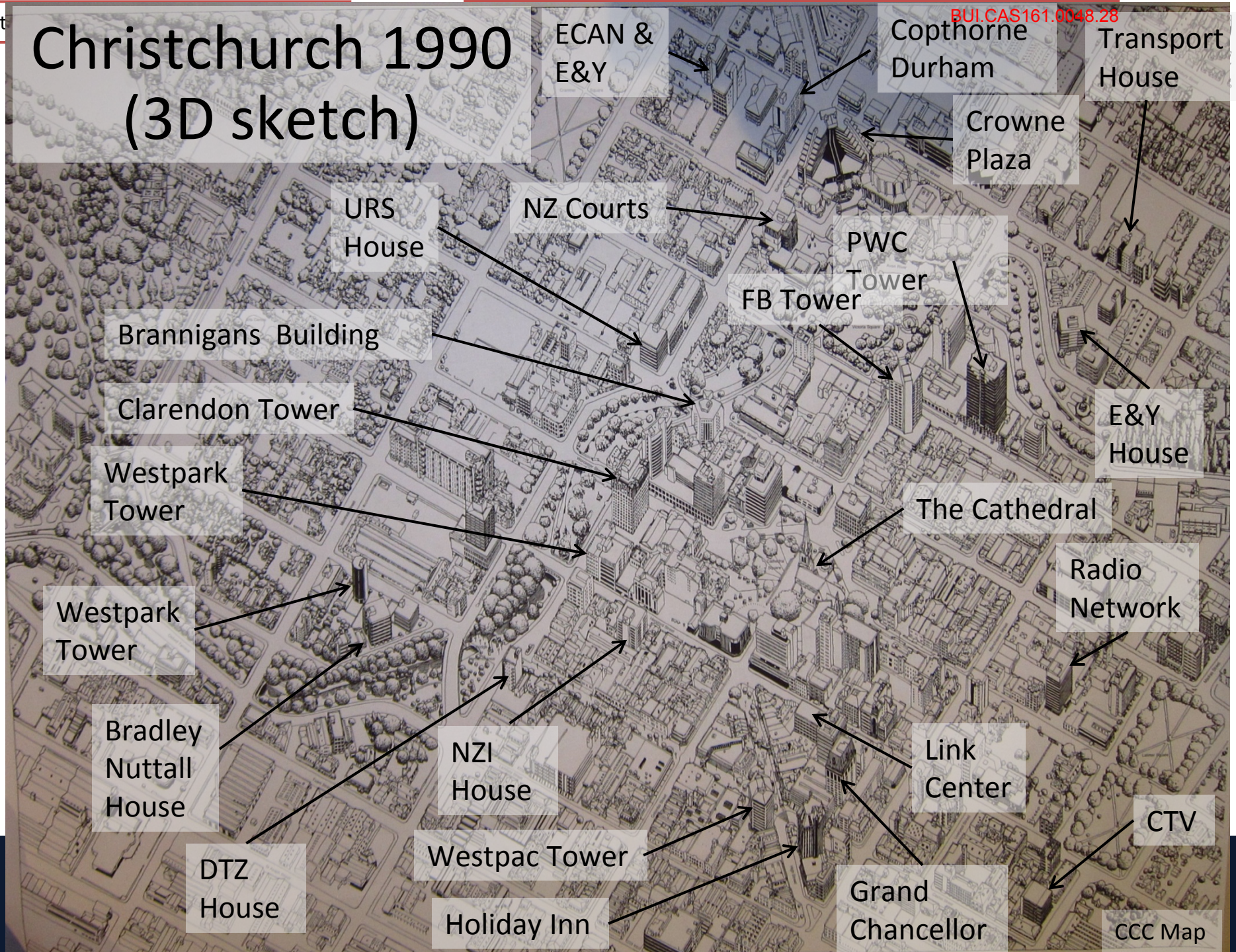
Christchurch 1960s

CCC Map

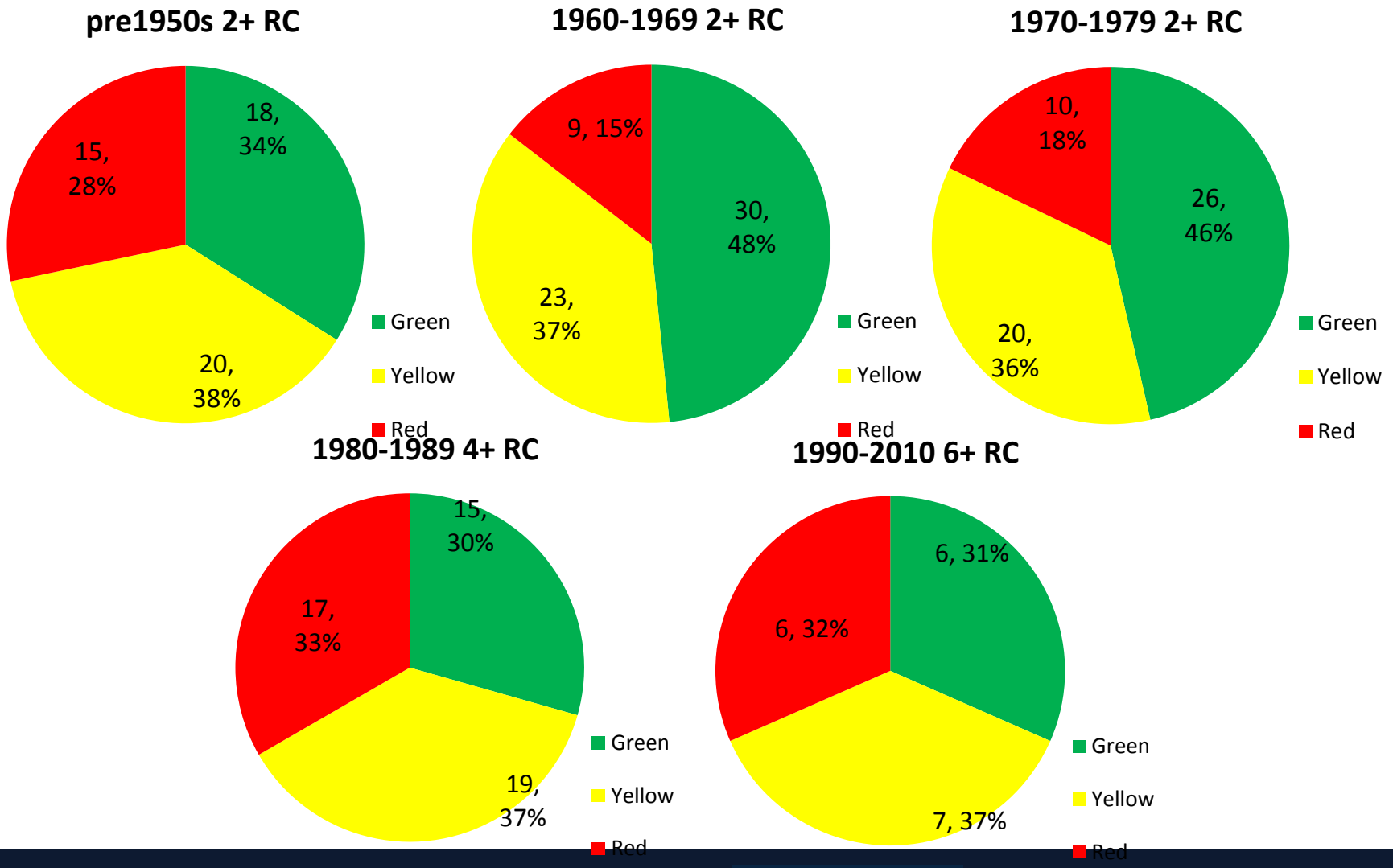
Christchurch 1978 (3D sketch)



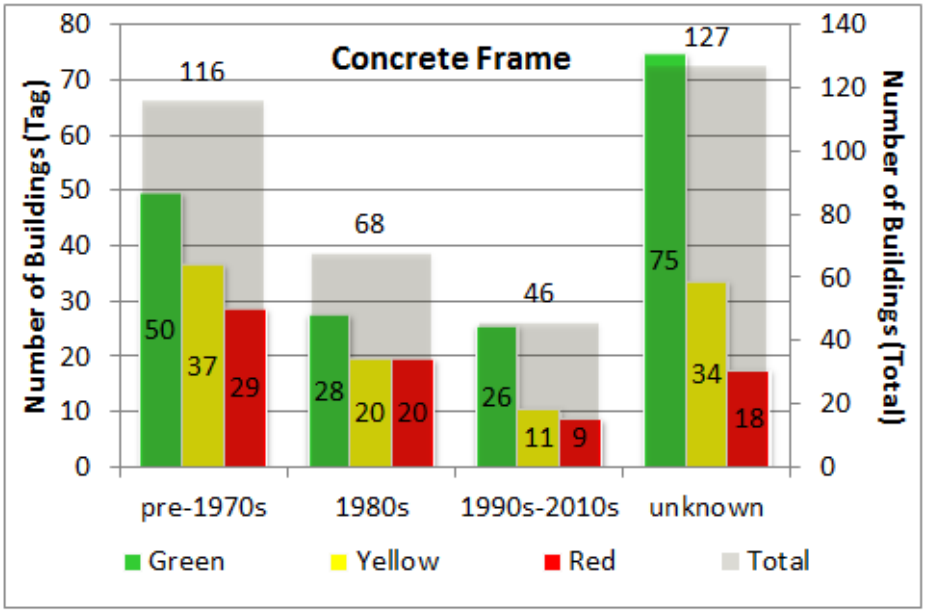
Christchurch 1990 (3D sketch)

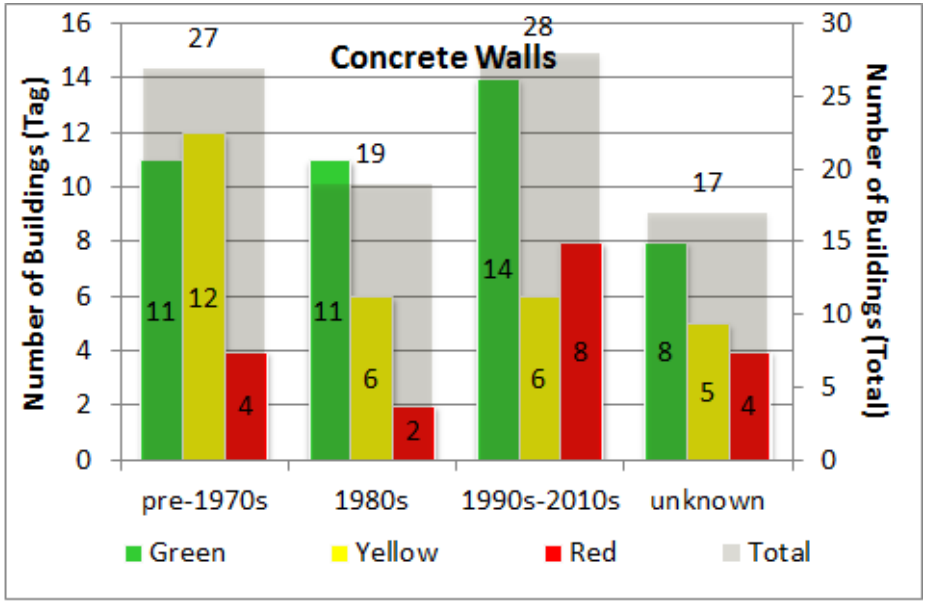


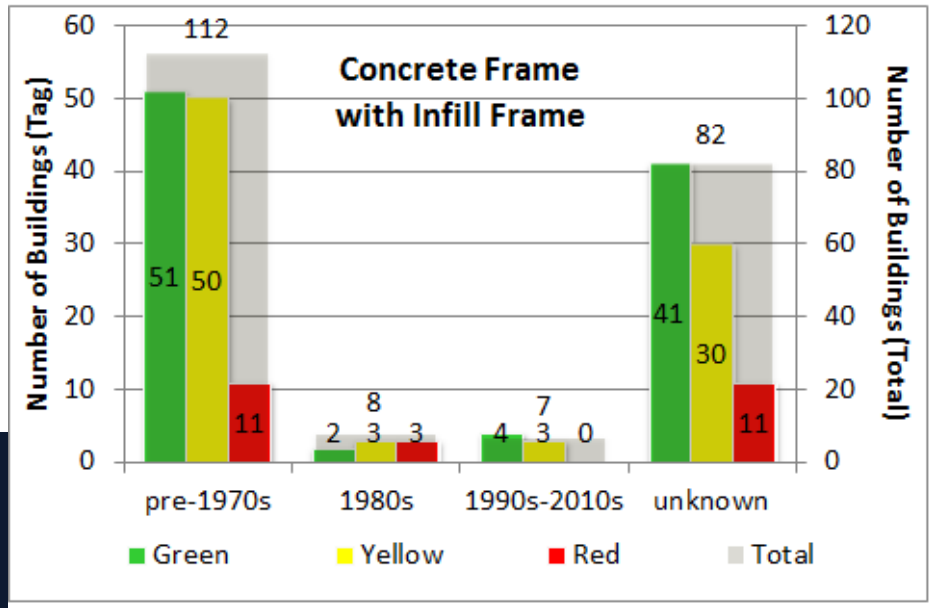
Performance of RC buildings by age

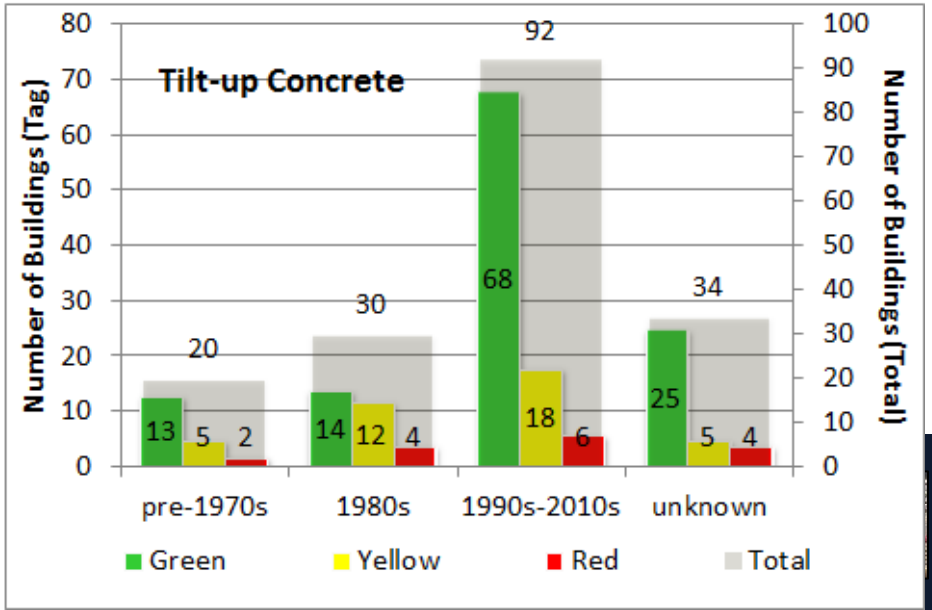


RC Buildings Performance (at 12 June) by type/age/height

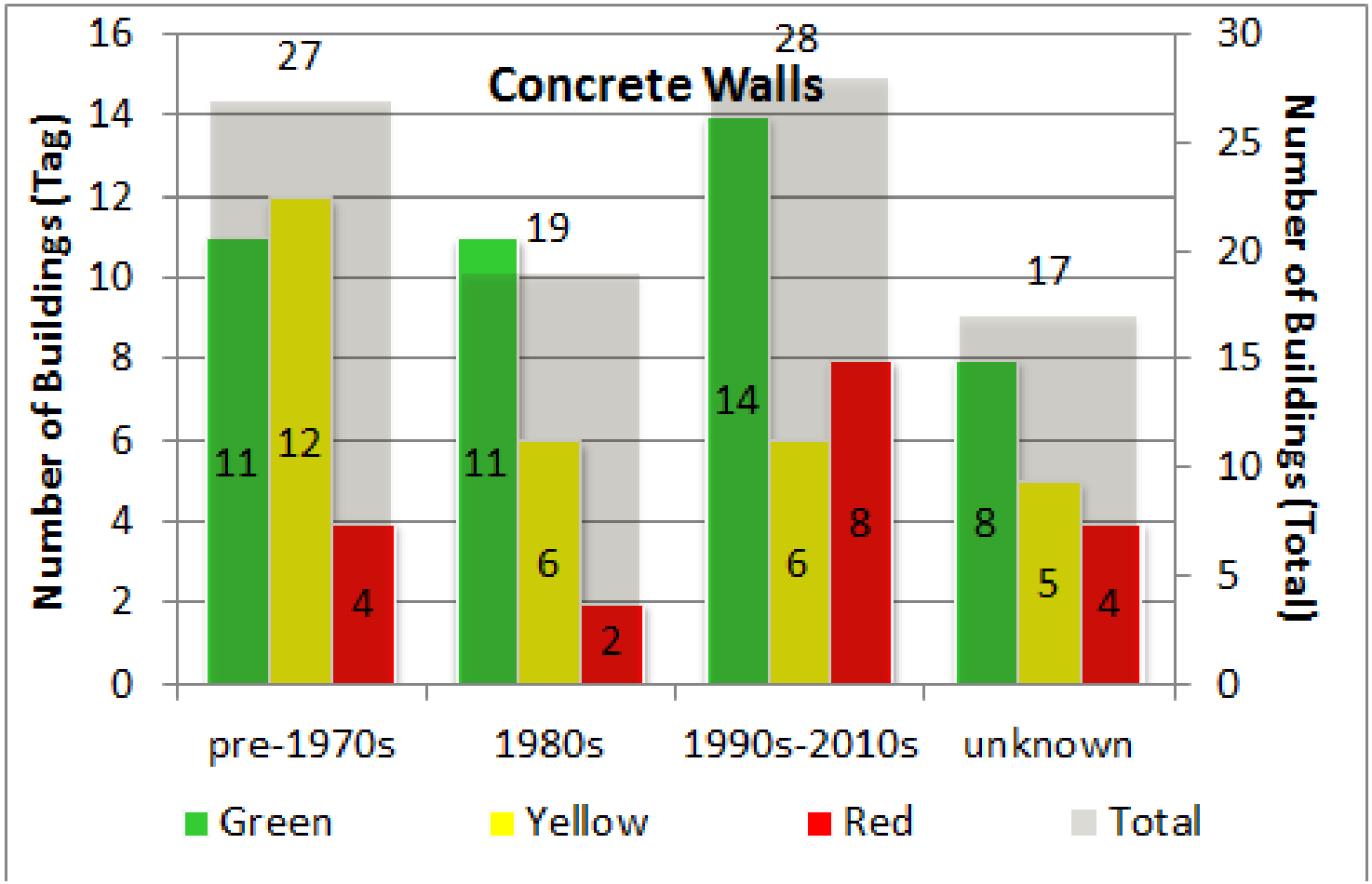




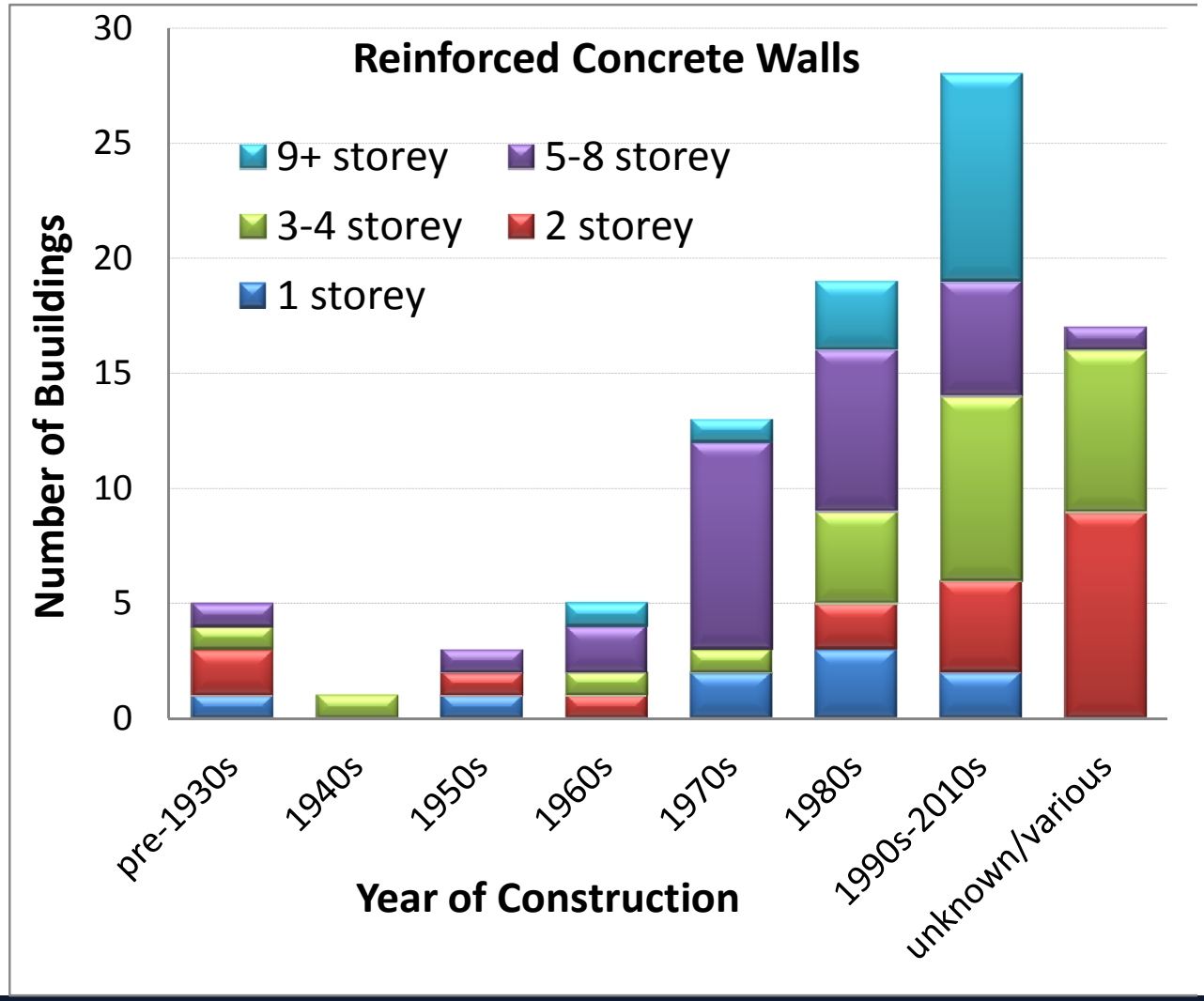




RC WALLS by age



RC WALLS Stock Distribution by age and height



Modern (post-1970s) RC Walls Buildings

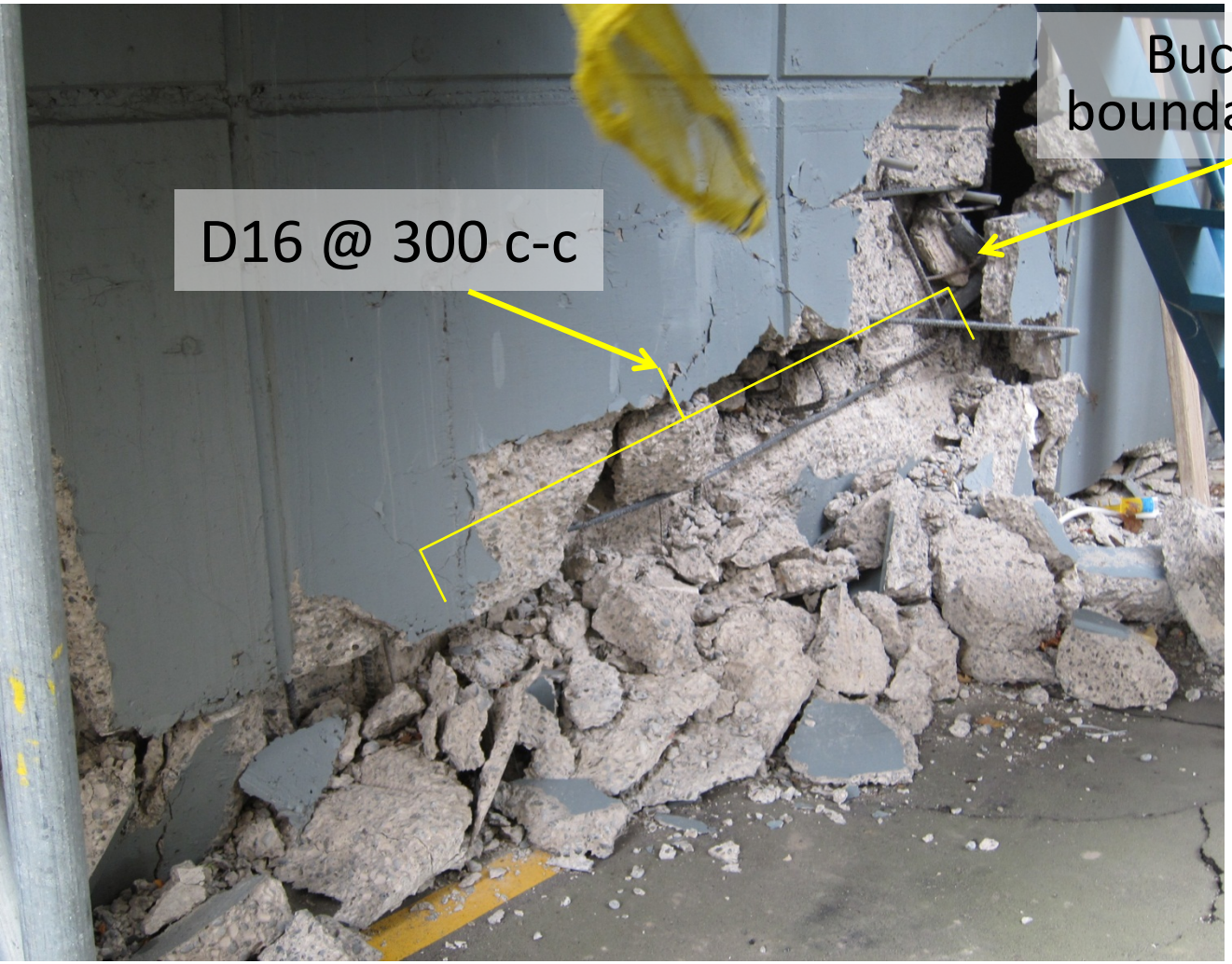
- RC structural walls, or shear wall buildings were a relatively popular structural system for medium to high-rise buildings since the 1970s.

- Perhaps due to the **apparent increase in sophistication in design and structural analysis in recent years**, a large percentage of the recently constructed RC walls was **considerably thinner and more slender** and with a **minimum level of reinforcing and higher levels of axial load ratio**.

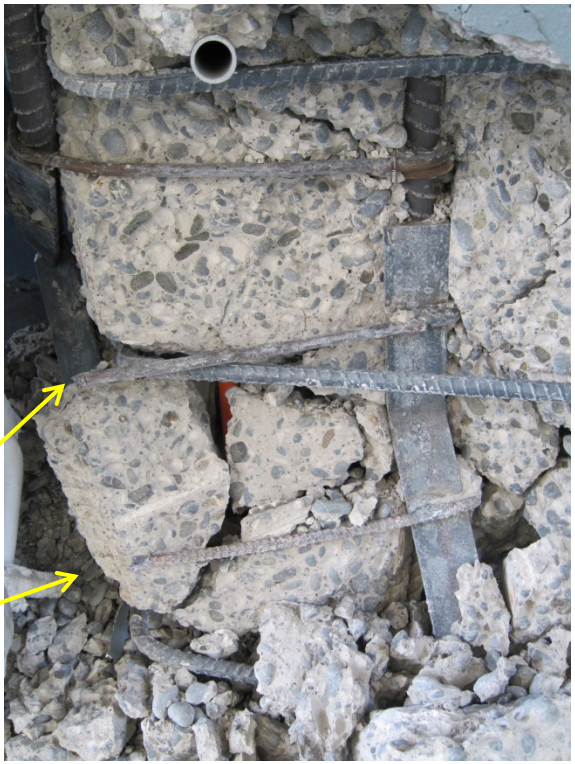
•These walls, while detailed for flexural action, failed in brittle shear-compression (in some cases likely to be exacerbated by vertical acceleration effects) or premature reinforcing tensile/compressive fracture, leading to an irreparable state of the buildings.

•The high number of severely damaged modern RC wall buildings has indicated that the current design for slender RC walls **with inadequate confinement steel outside the confined boundary zone**, **irregular shapes,** or with inter-panel grouted (poorly confined) lap-splice is inadequate.

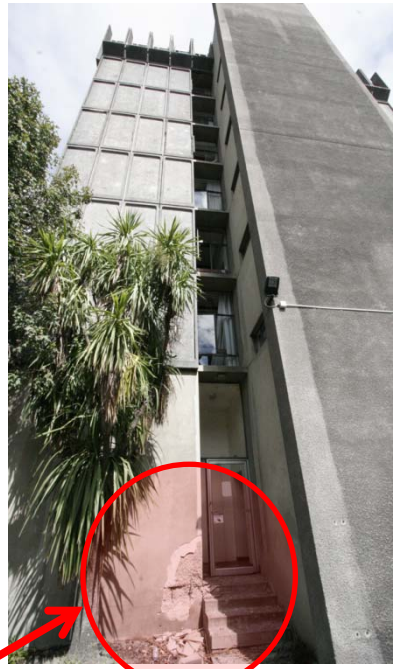
RC walls (9 storey 1980s)



Boundary confining steel



Late 1978-80 Shear wall building



Post-1990 RC Wall buildings

Stefano Pampanin and Weng Yuen Kam

Ductile RC Structural Walls

Minor residual crack (= minor damage?)

Impact on neighbouring building

BUI.CAS161.0048.42

NZCS

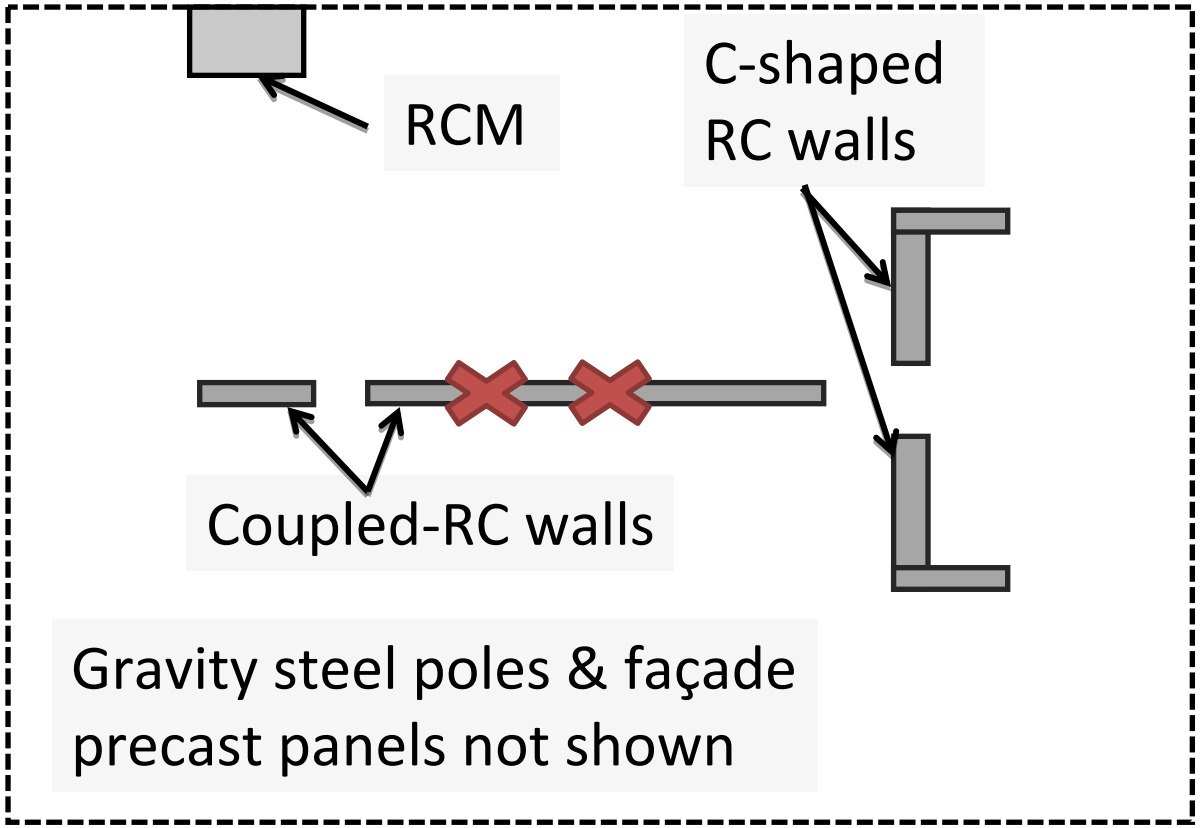
NZ Society for Earthquake Engineering Incorporated

SESOC

NEW ZEALAND TIMBER DESIGN SOCIETY INCORPORATED
A TECHNICAL GROUP OF IPENZ ENGINEERS NEW ZEALAND

Seismic Retrofit Solutions

Slender RC walls

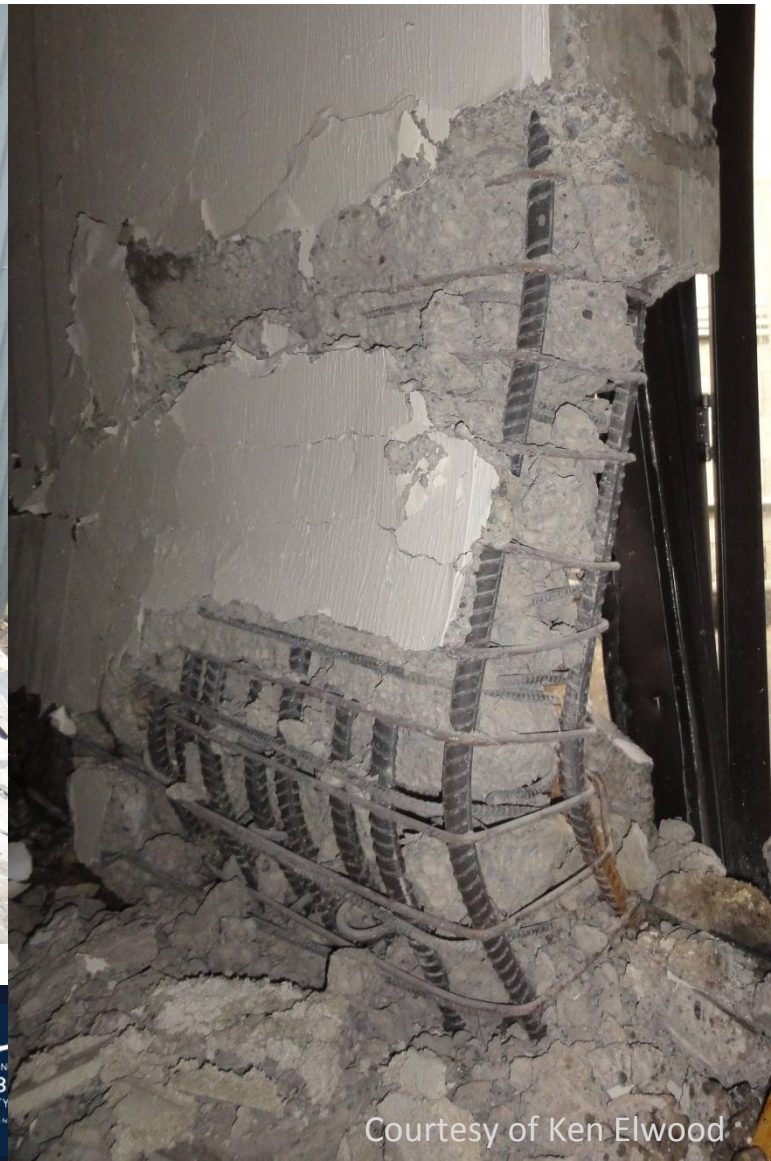



15m long
200mm thick
T-shape wall

Lapped horizontal shear reinforcements?

V-shaped RC shear wall

Large tension flange, compressive buckling of confined RC walls



Buckling of unconfined grouted lap-splices (precast walls)

Similar Evidences & Lessons from recent earthquakes overseas

Bolu, Turkey 1999 Bingol, Turkey 2003

Bolu, Turkey 1999

Bingol, Turkey 2003

Bingol, Turkey 2003

Chile Earthquake 2010

BUI.CAS161.0048.52

Photo courtesy of Patricio Quintana-Gallo

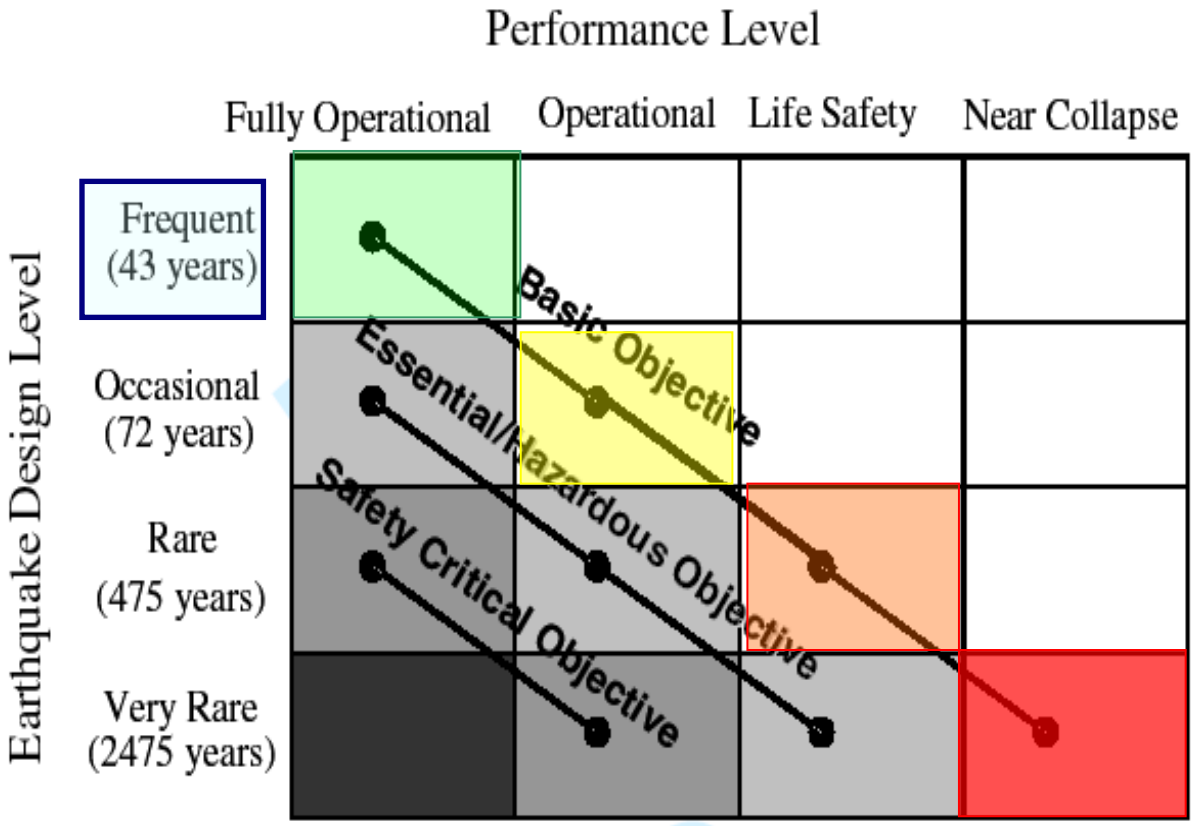
Chile Earthquake 2010

Photo courtesy of Patricio Quintana-Gallo

Current Performance-Based Design Philosophy

Is this GOOD ENOUGH?

Repairable → Irreparable



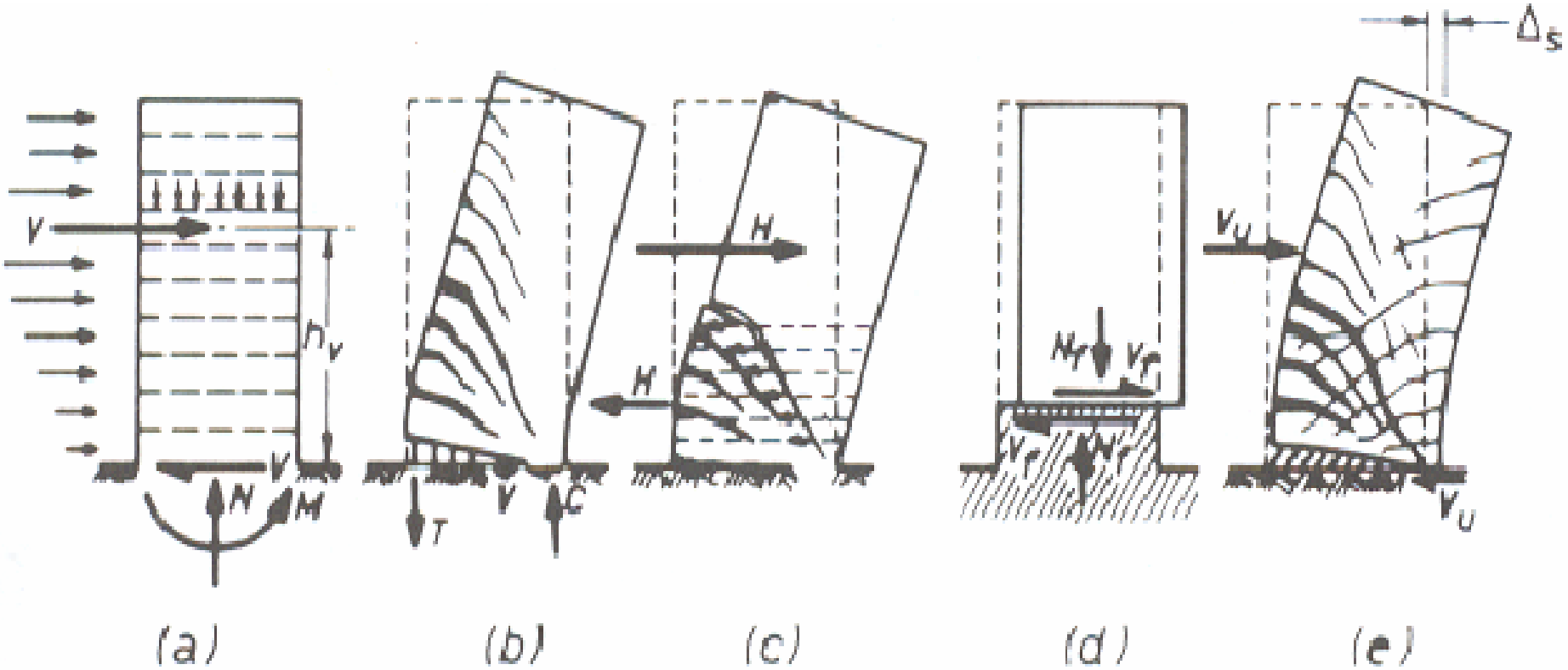
Fallacy

*The Code-Standard is **NOT** meant to be used as a Target or Ultimate Goal but as a minimum by law*

Corollary:

*An Earthquake-Proof Building (following minimum standards and traditional technology) is likely **NOT** to be as "earthquake-proof" as people think/wish*

Typical (2D) Failure mechanisms in walls



Paulay and Priestley, 1992

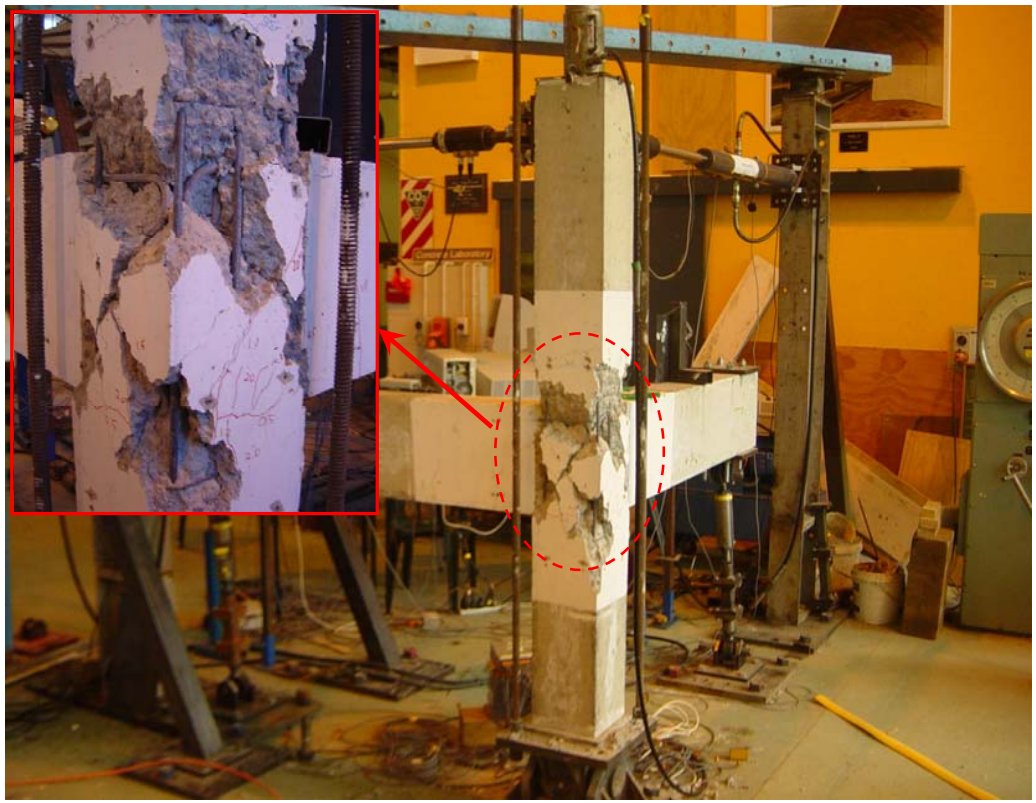
What are the effects of 3D response of bi-directional loading?

Bolu, Turkey 1999

Bingol, Turkey 2003

Beam-Column Joints

Laboratory Testing vs. Real Earthquake Testing



Hertanto and Pampanin (2006)

Boys, Bull, Pampanin, (2008)

Columns

Laboratory Testing vs. Real Earthquake Testing

Boys, Bull, Pampanin, (2008)

Boys, Bull, Pampanin, (2008)

Walls?

Laboratory Testing vs. Real Earthquake Testing

?

What will be the next generation of design codes?

"Modern" Concrete Standards

NZS3101: 1982

NZS3101: 1995

NZS3101: 2006

NZS3101:201X?