Lanciano 11 April 2014

Le nuove sfide dell'ingegneria sismica: come rispondere alle crescenti esigenze della società moderna

“

Stefano Pampanin

Department of Civil and Natural Resources Engineering

University of Canterbury

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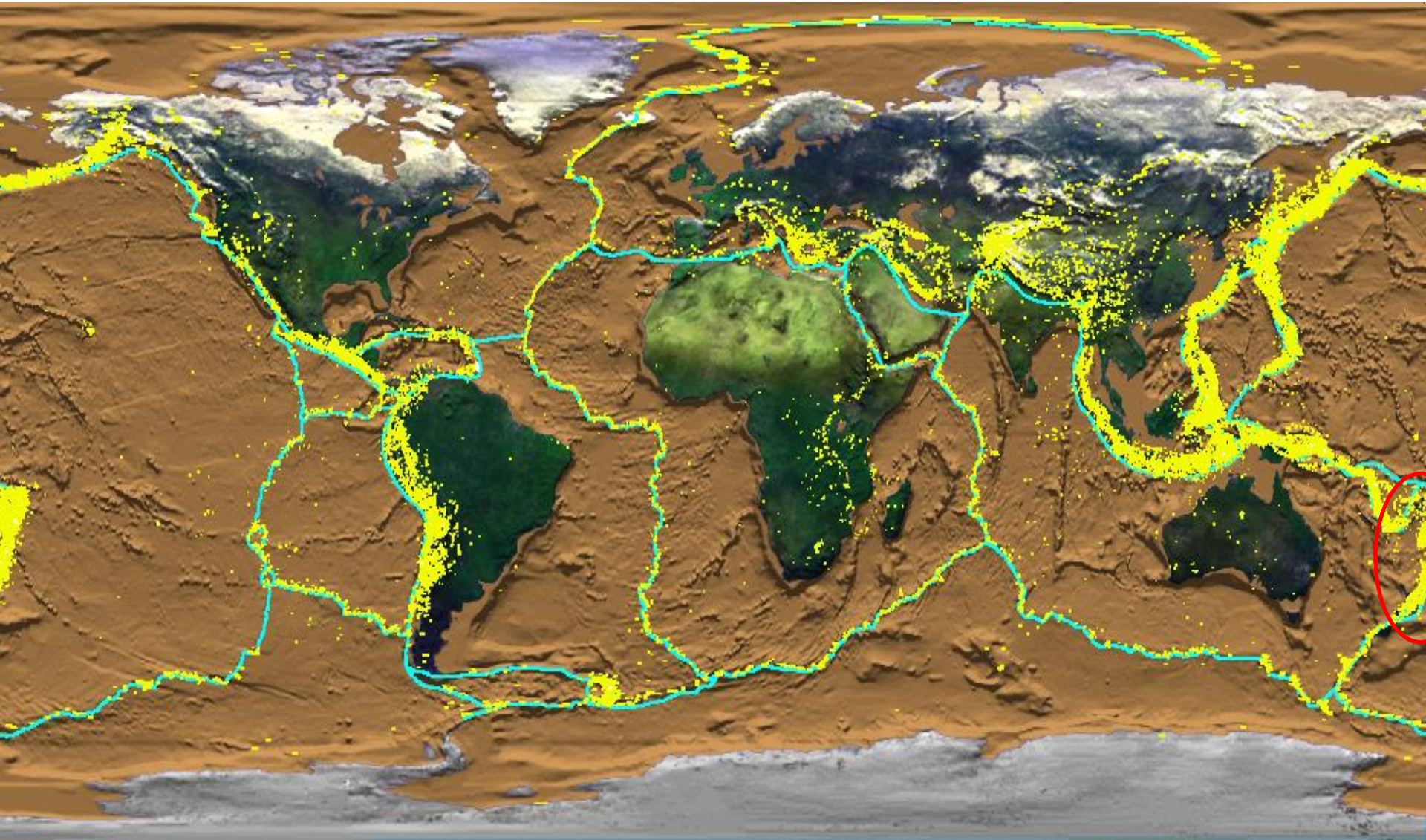
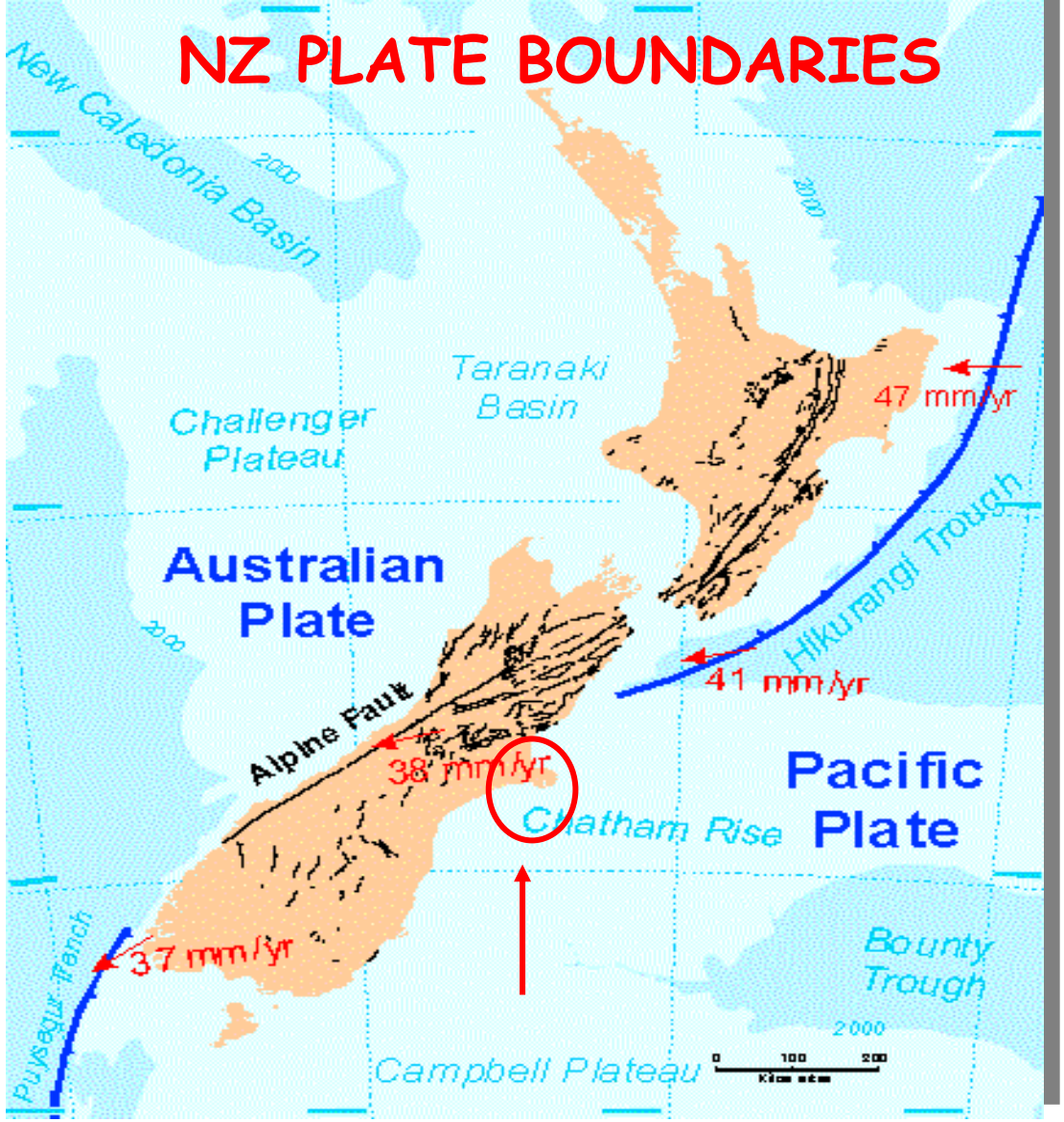
CHRISTCHURCH NEW ZEALAND

The World Seismic Map





"Shaky Islands"

Christchurch

(PGA=0.22g)

23 January 1855
Wairarapa
Magnitude 8.1
24 June 1942
Wairarapa
Magnitude 7.2
2 August 1942
Wairarapa
Magnitude 7

5 March 1934
Pahiatua
Magnitude 7.6

6 February 1995
East Cape
Magnitude 7

19 October 1868
Cape Farewell
Magnitude 7.5

23 February 1863
Hawkes Bay
Magnitude 7.5 3
February 1931
Hawke's Bay
Magnitude 7.8
13 February 1931
Hawke's Bay
Magnitude 7.3

17 June 1929
Murchison
Magnitude 7.8

24 may 1968
Inangahua
Magnitude 7.1

1 September 1888
North Canterbury
Magnitude 7.3

16 October 1848
Marlborough
Magnitude 7.5

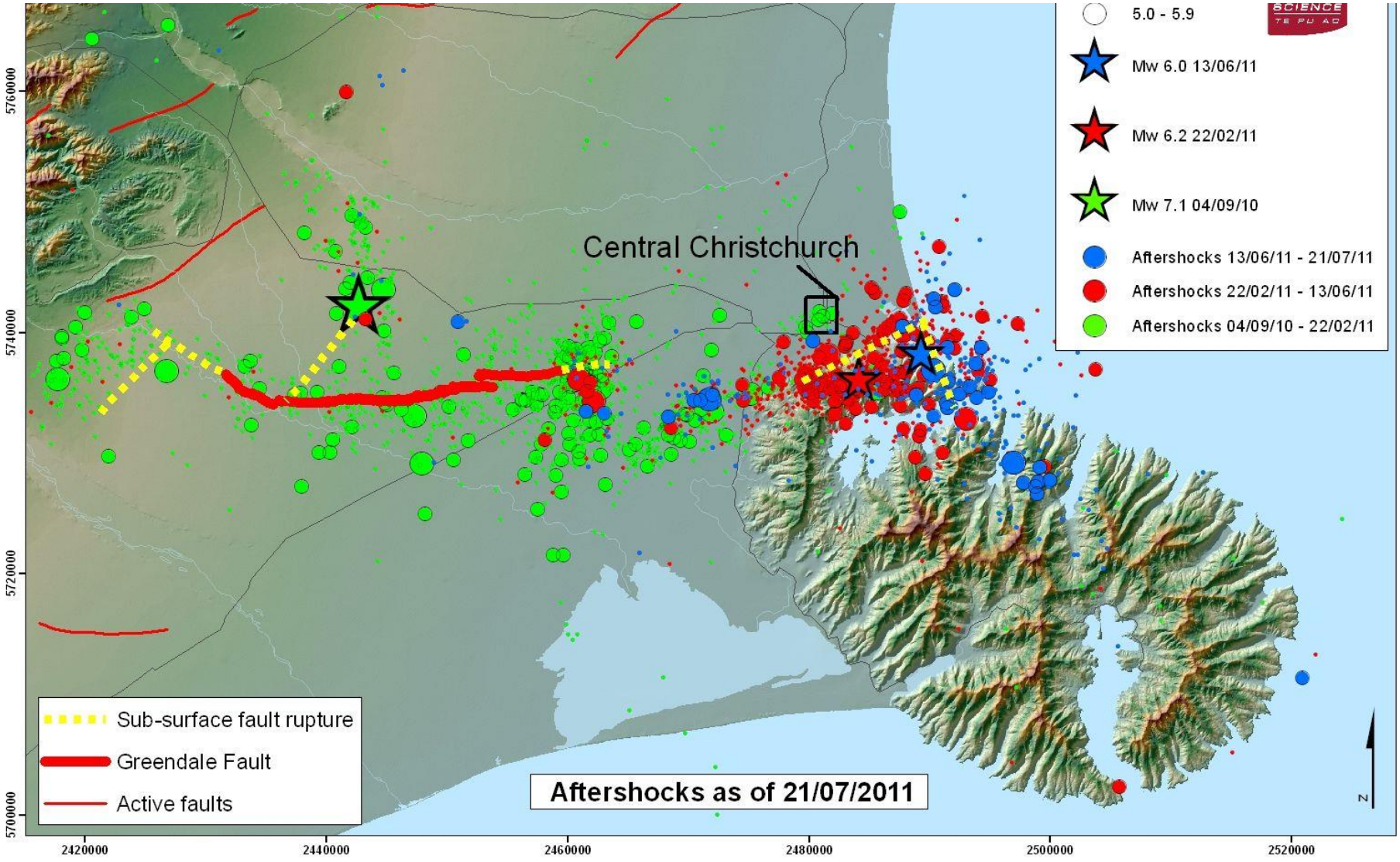
9 March 1929
Arthur's Pass
Magnitude 7.1

12 February 1893
Nelson
Magnitude 6.9

The dramatic "experimental tests"

from the Christchurch Earthquake sequence

(4 Sept 210, 26 Dec 2010, 22 Feb 2011, 13 June 2011...)



The Christchurch Earthquake

4 September 2010 (4:35 am NZST)

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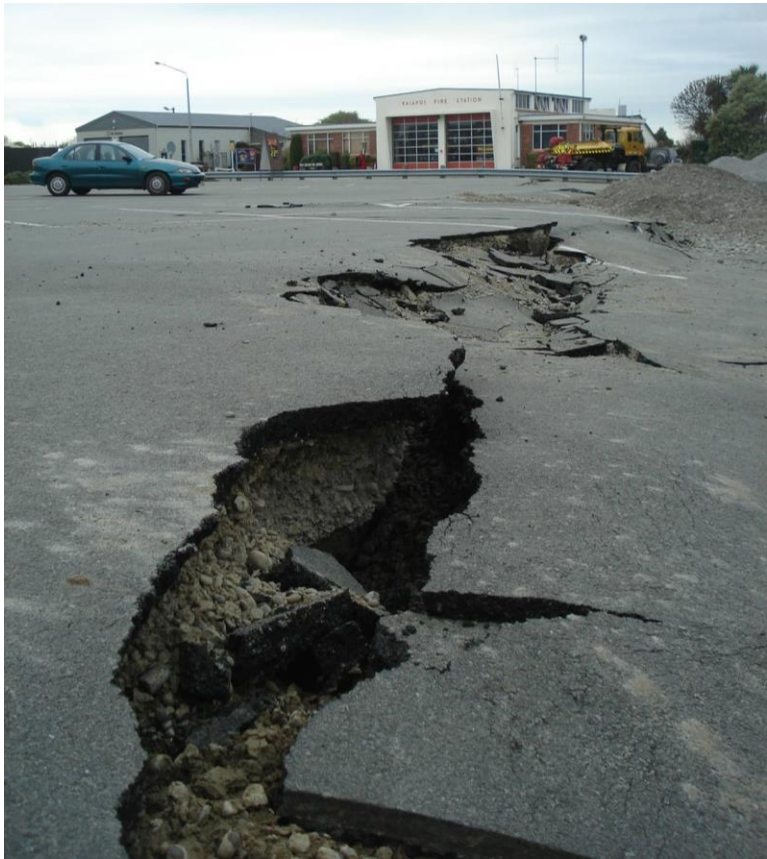
A success story or a wake-up call?



(Source: YouTube, GNS Science)

(Source: The PRESS)

Flight early view

(Source: The PRESS)

Railway

(Source: The PRESS)

Flooding in New Brighton

(Source: The PRESS)

Christchurch CBD

Centre Building District

(Source: The PRESS)

(Source: The PRESS)

Was that the big one?

NEW ZEALAND SOCIETY FOR EARTHQUAKE ENGINEERING
2011 PACIFIC CONFERENCE ON EARTHQUAKE ENGINEERING
BUILDING AN EARTHQUAKE-RESILIENT SOCIETY
AUCKLAND, NEW ZEALAND 14-16 APRIL

UC UNIVERSITY OF CANTERBURY

Considerations on the seismic performance of pre-1970s RC buildings in the Christchurch CBD during the 4th Sept 2010 Canterbury earthquake: **was that really a big one?**

Stefano Pampanin, Weng Yuen Kam, A. Sahin Tasligedik, Patricio Quintana-Gallo, Umut Akguzel

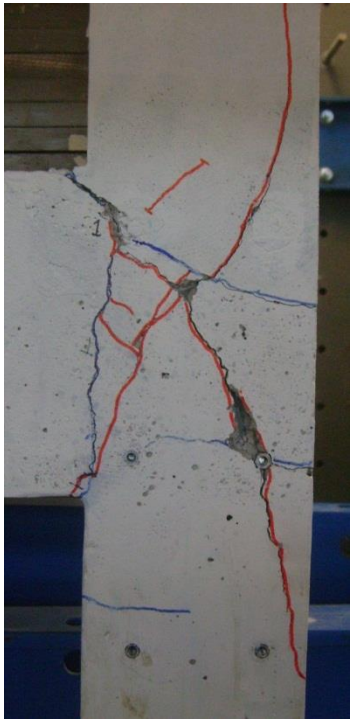
PCEE 2011 NZSEE

Proceedings of the Ninth Pacific Conference on Earthquake Engineering
Building an Earthquake-Resilient Society
14-16 April, 2011, Auckland, New Zealand

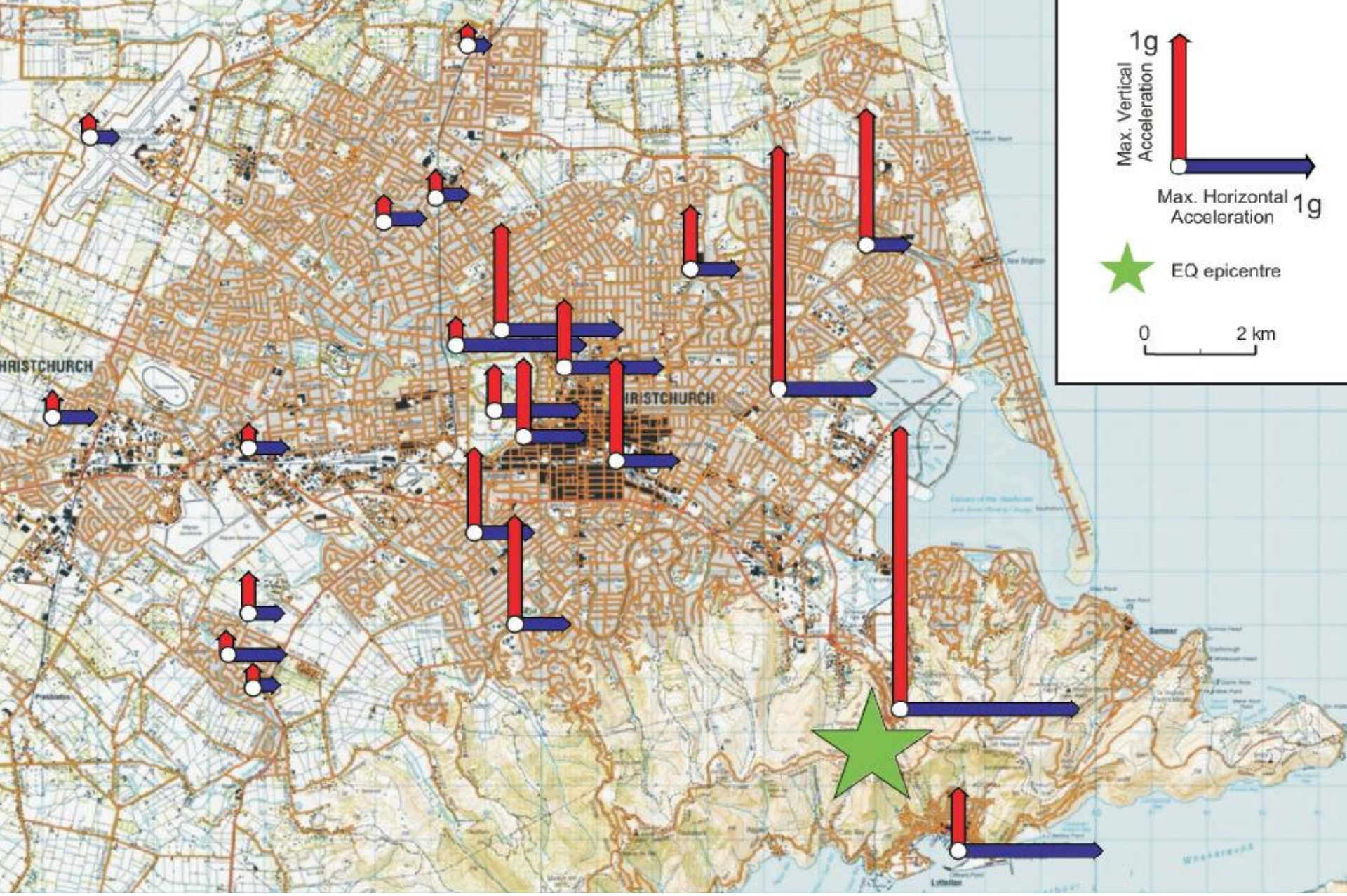
Considerations on the seismic performance of pre-1970s RC buildings in the Christchurch CBD during the 4th Sept 2010 Canterbury earthquake: was that really a big one?

S. Pampanin, W.Y. Kam, A.S. Tasligedik, P. Quintana Gallo, U. Akguzel
University of Canterbury, Christchurch, New Zealand.

ABSTRACT: The 4th of September 2010 M_w 7.1 Darfield (Canterbury) earthquake had generated significant ground shaking within the Christchurch Central Business District (CBD). Despite the apparently significant shaking, the observed structural damage for

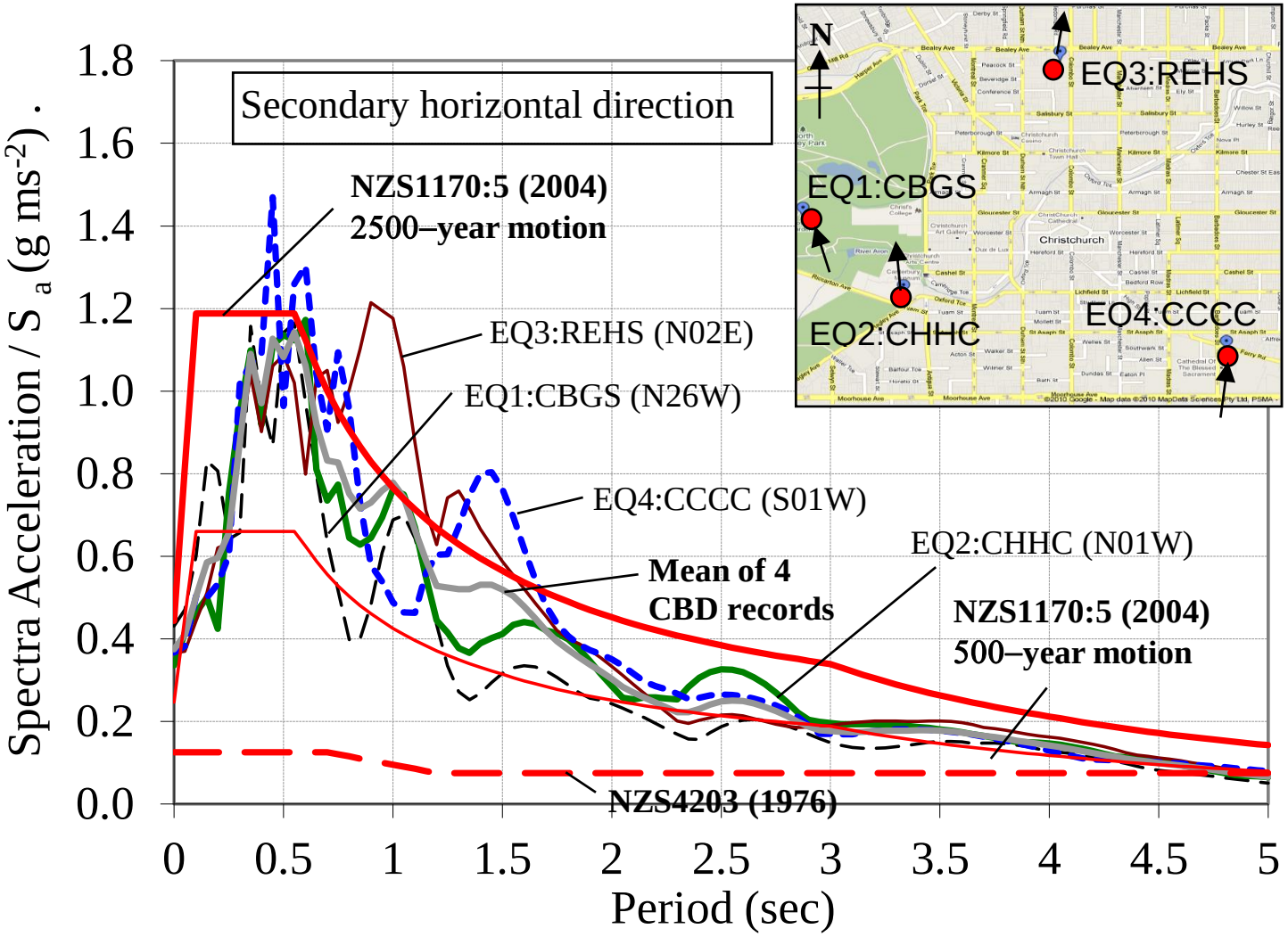


12.51pm 22nd Feb 2011…



Shaking Intensity - 22 Feb 2011 (GNS science)

Bigger than "code-design" level....



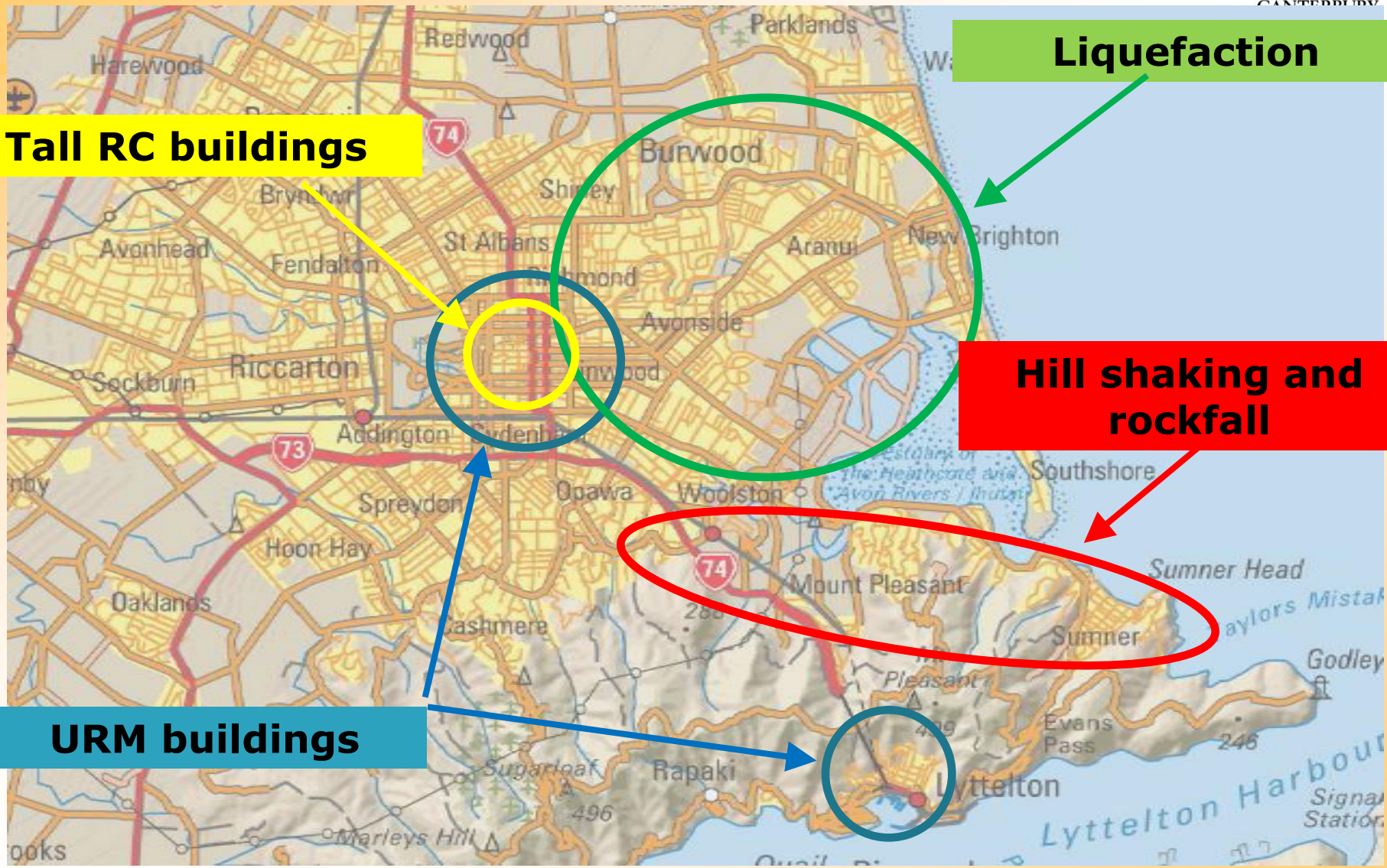
Fallacy

"The earthquake does not read the seismic codes."

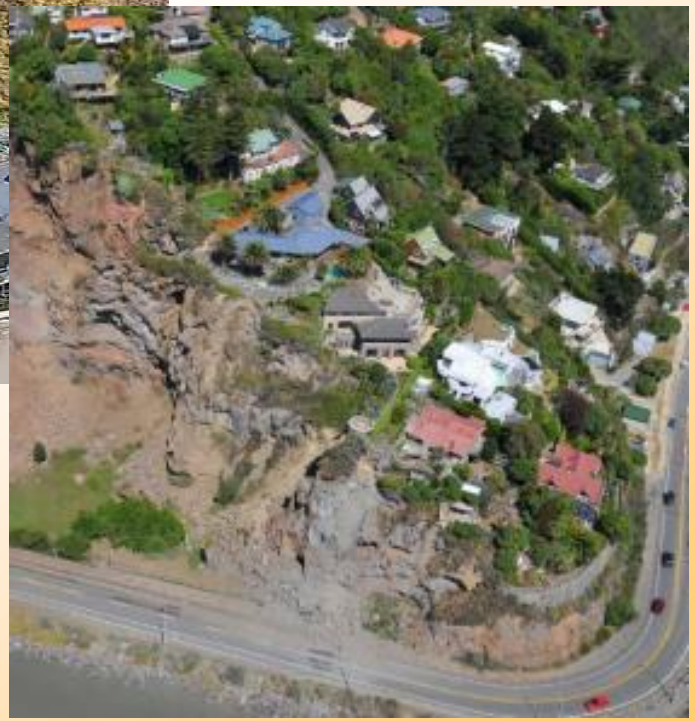
- late Prof Tom Paulay

(University of Canterbury)

Damage to buildings

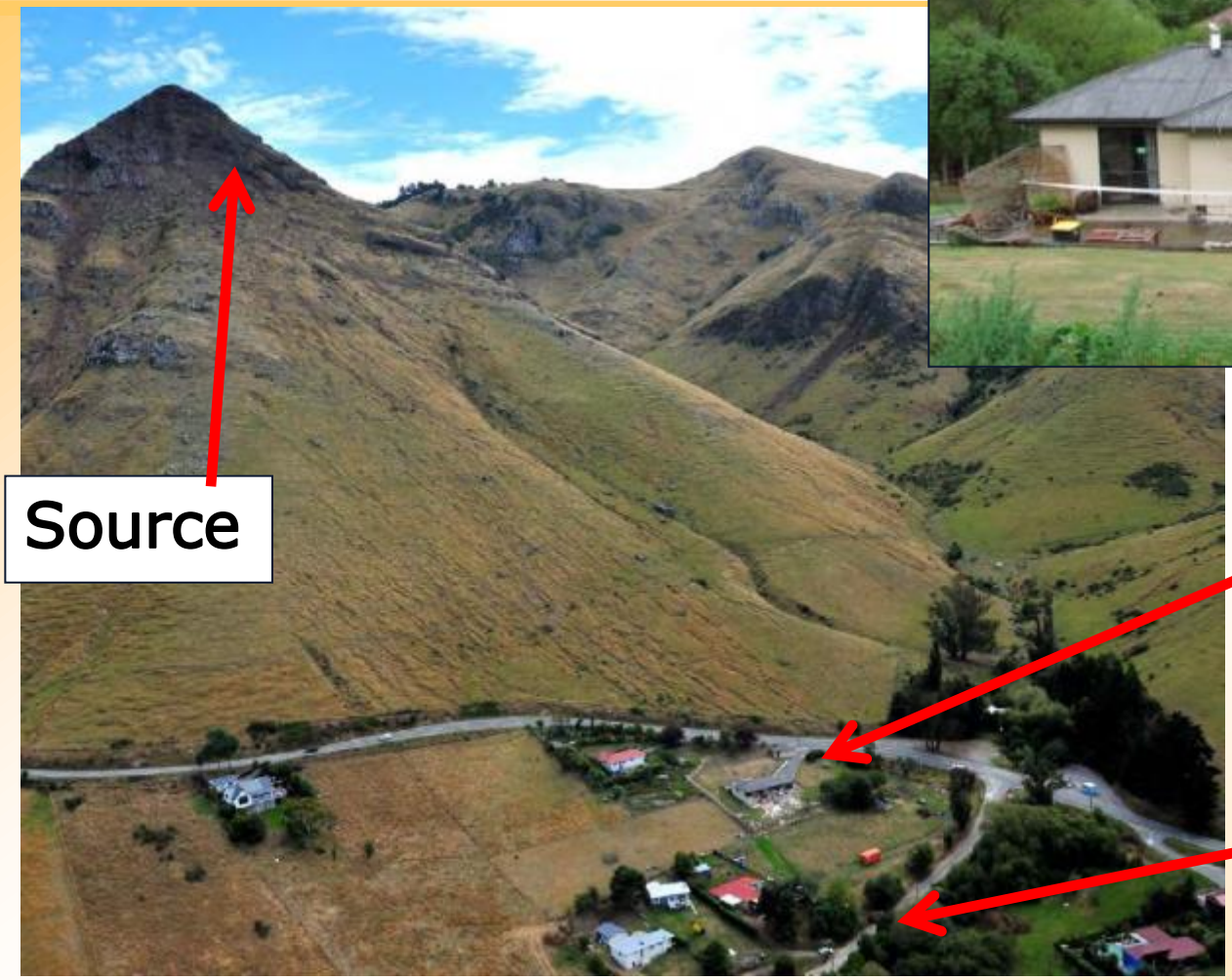


Rockfall, 22 Feb



Rockfall, 13 June

Rockfall



Liquefaction

Pipes and manholes floated up

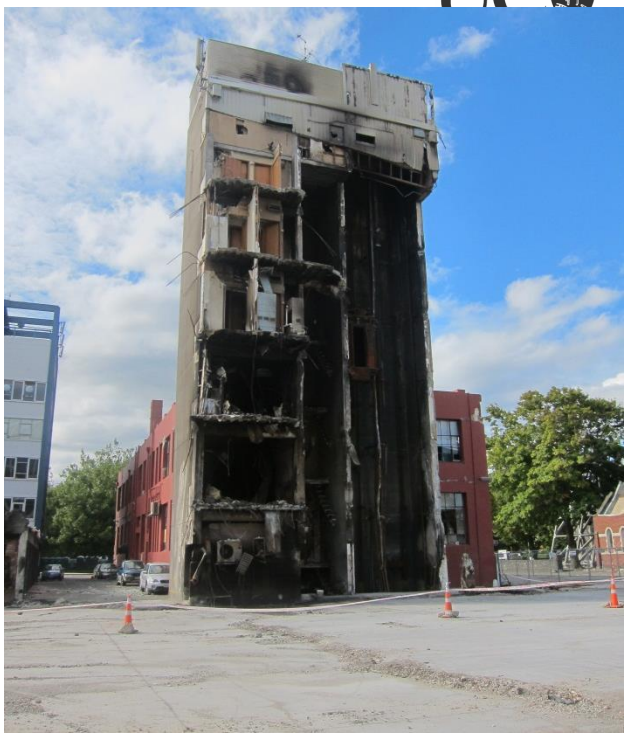
AMI Stadium

PGC Building

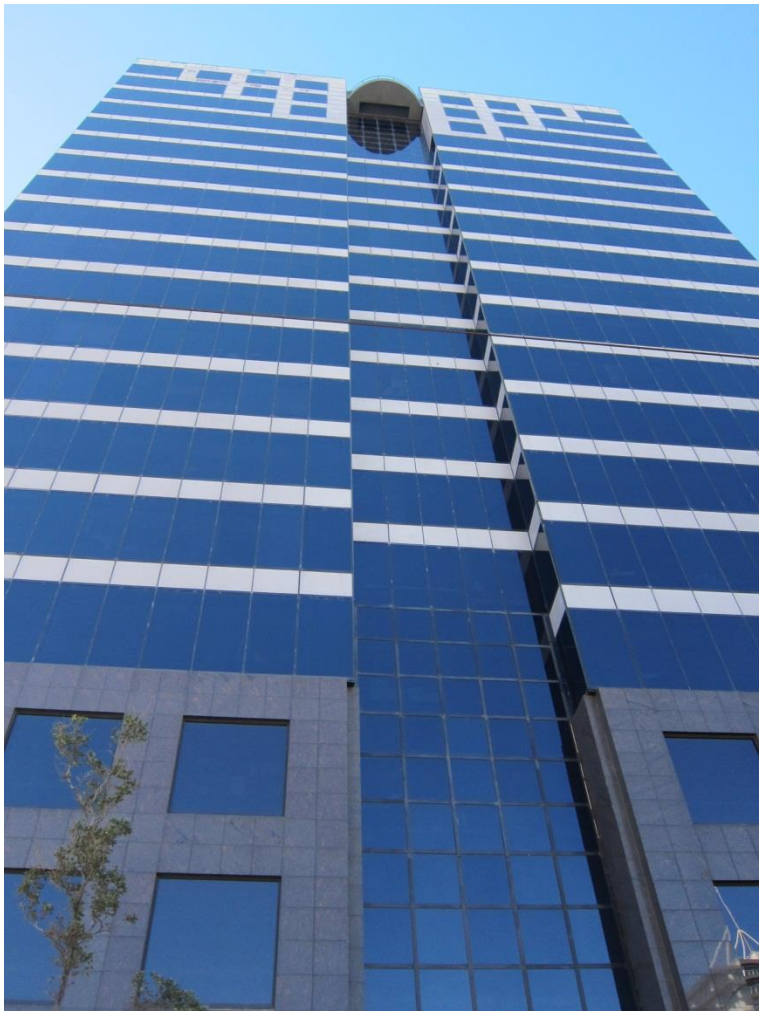
Photo courtesy of Weng Y Kam

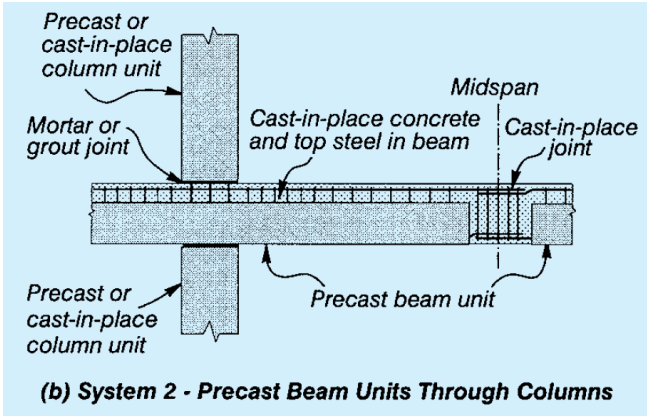
Photo courtesy of Weng Y Kam

CTV Building



Post-1980s Reinforced Concrete Buildings





(b) System 2 - Precast Beam Units Through Columns

Extensive damage (beyond reparability?) to modern Buildings

Typical plastic hinges in beams (intended to act as sacrificial fuses)

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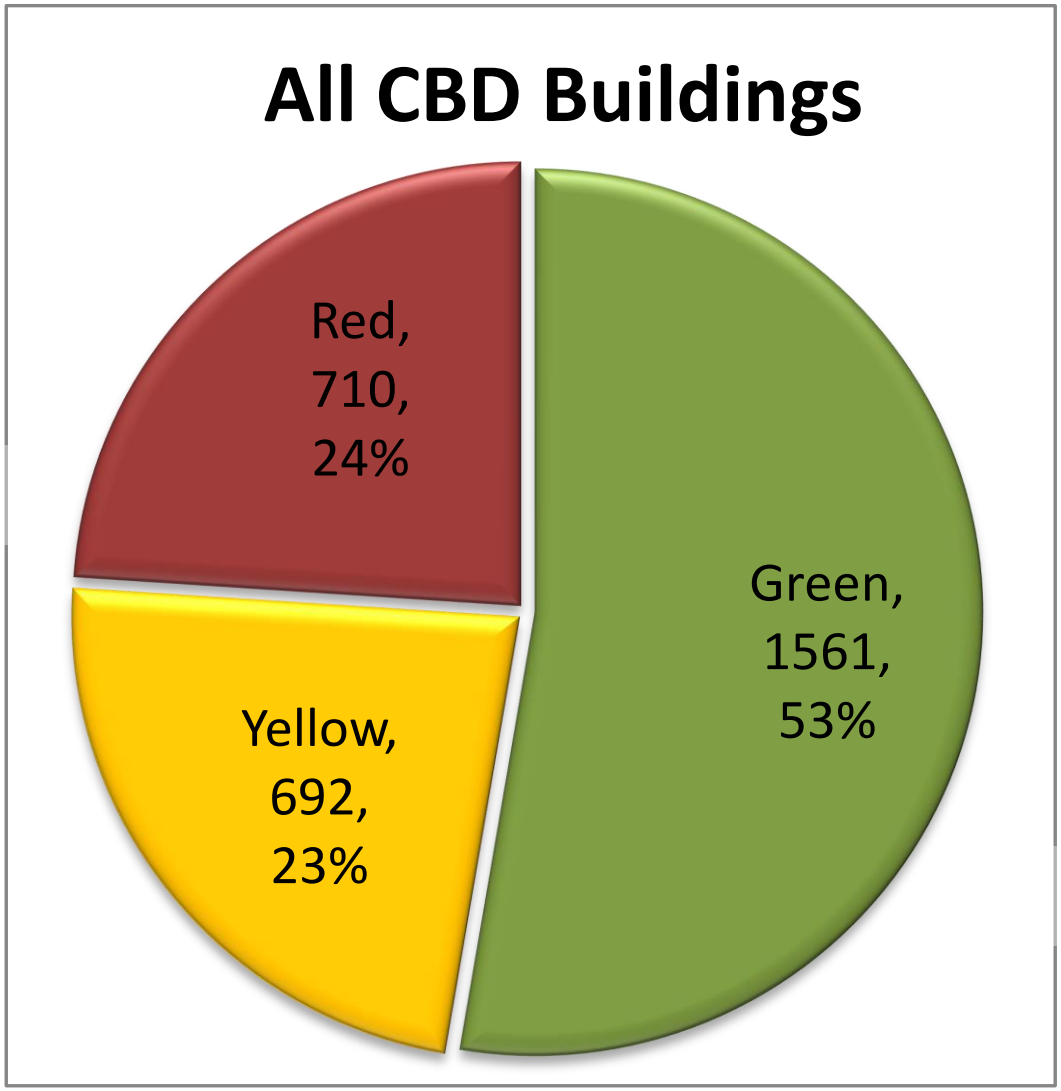
A very common end : Man-made Demolition

Number of Buildings in Demolition List: 1300-1400



As per 12 June 2011
Source: CCC Data (Kam, Pampanin, Elwood, 2012)

"But they [buildings] did what they were meant to do"


CERA
Canterbury Earthquake
Recovery Authority
00:26
HD
vimeo


CERA
Canterbury Earthquake
Recovery Authority
00:29
HD
vimeo

Photo courtesy of Kam Yuen Weng and Umut Akguzel

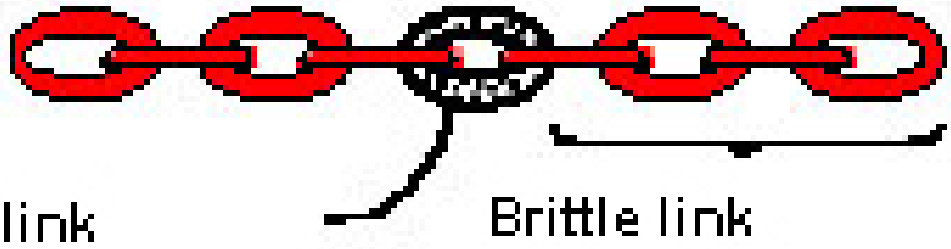
The Breakthrough of

CAPACITY DESIGN or DUCTILE DESIGN

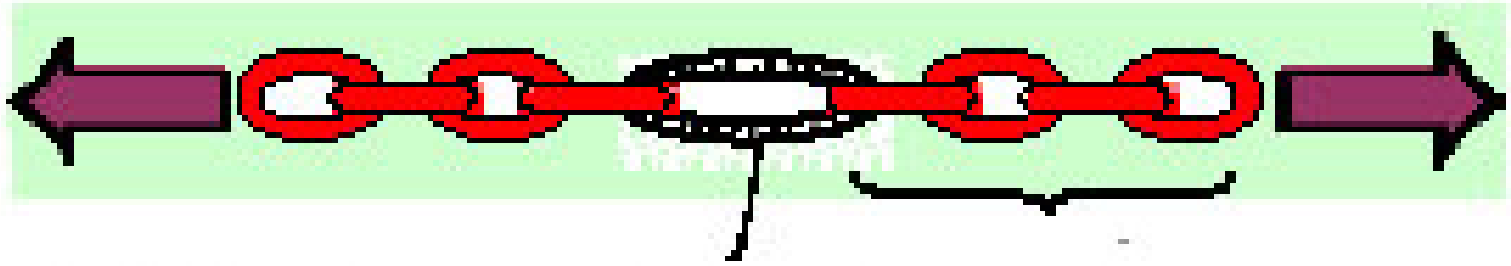
University of Canterbury's Professors Bob Park and Tom Paulay

(from 1960-1970s)

Original Chain



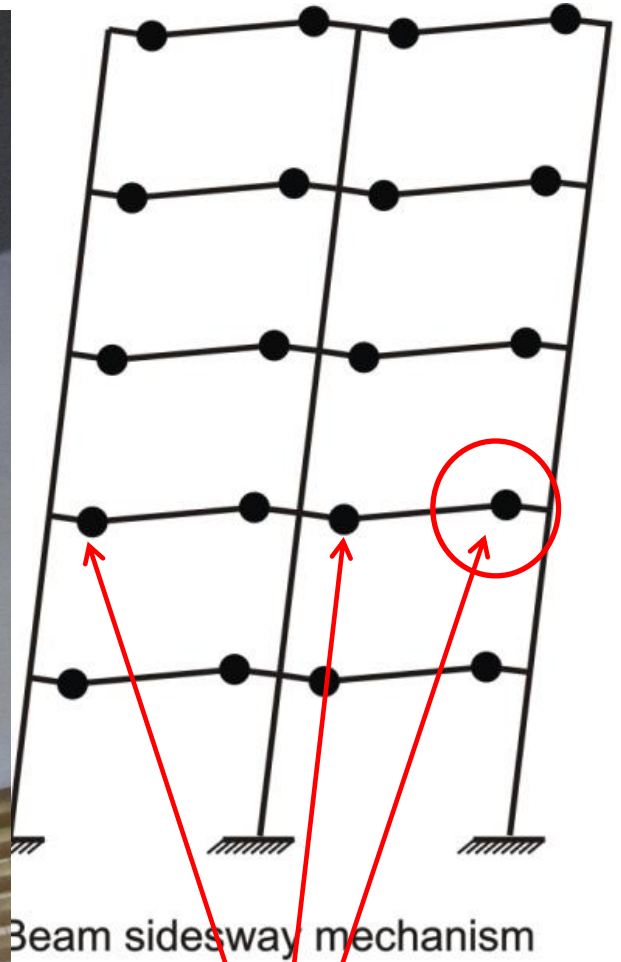
Loaded Chain



Ductile link stretches by yielding before break

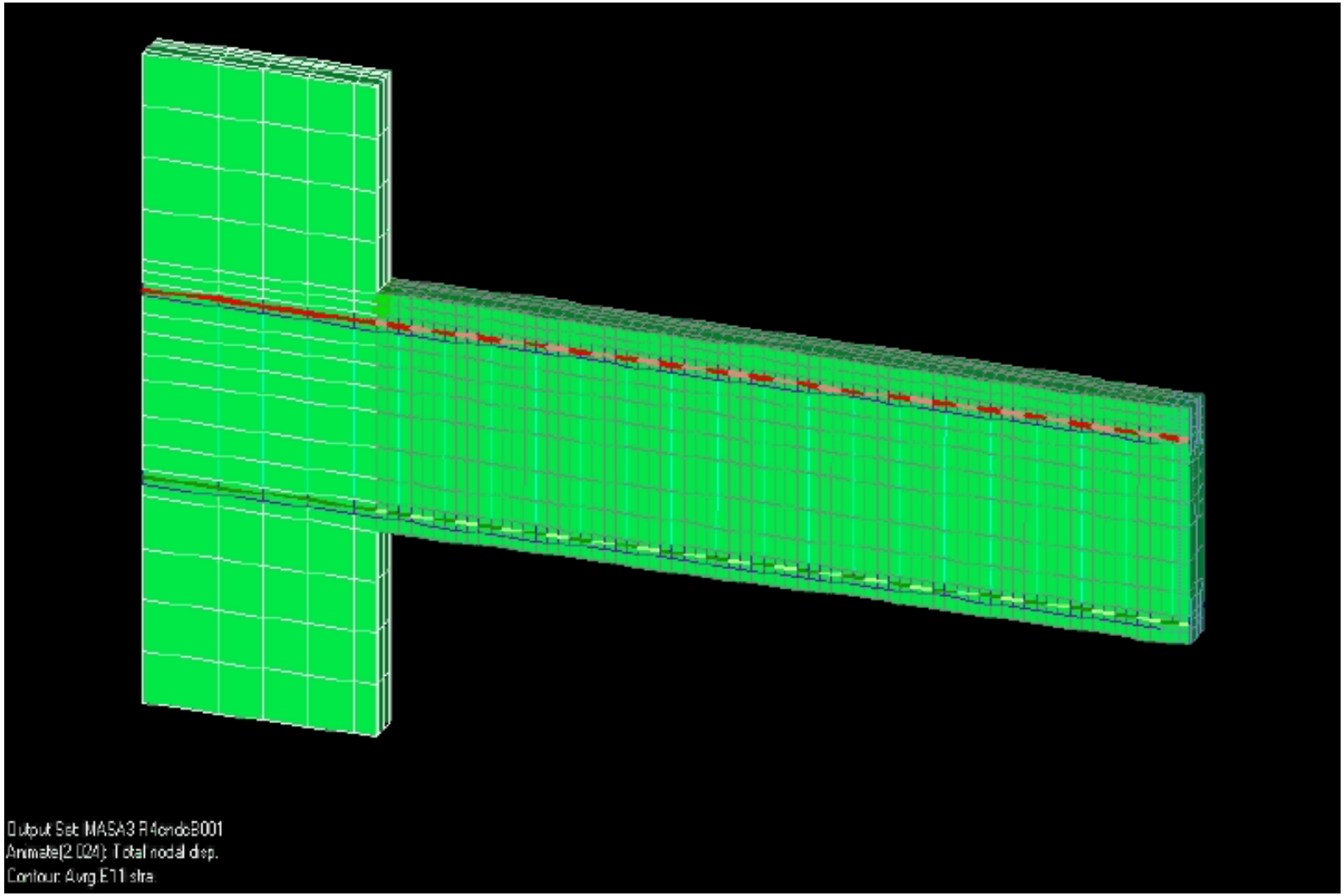
SOFT-STOREY OR PANCAKE Collapse

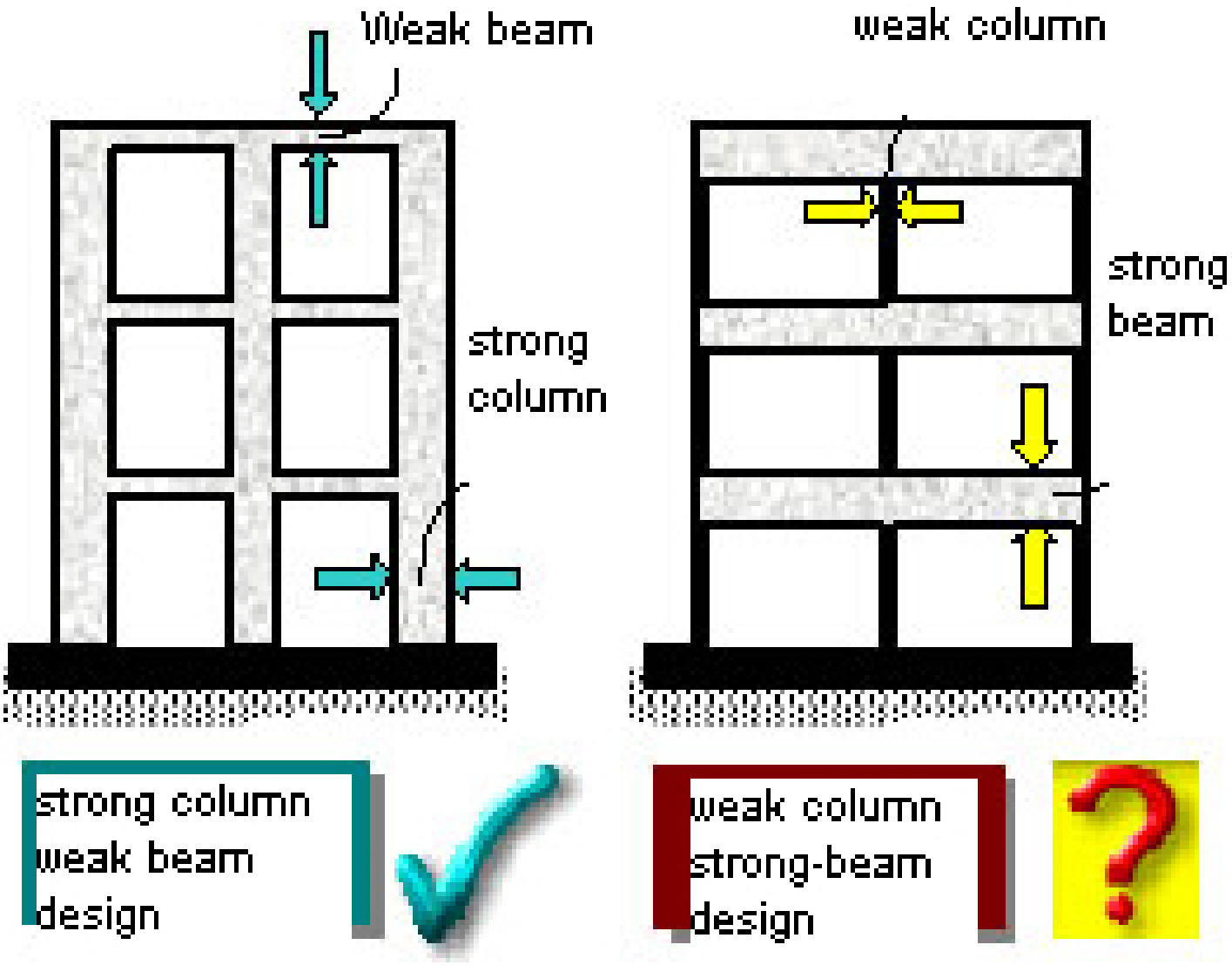
DUCTILE MECHANISM



Computer Modeling of Plastic Hinge

(Research collaboration with University of Stuttgart, Germany)

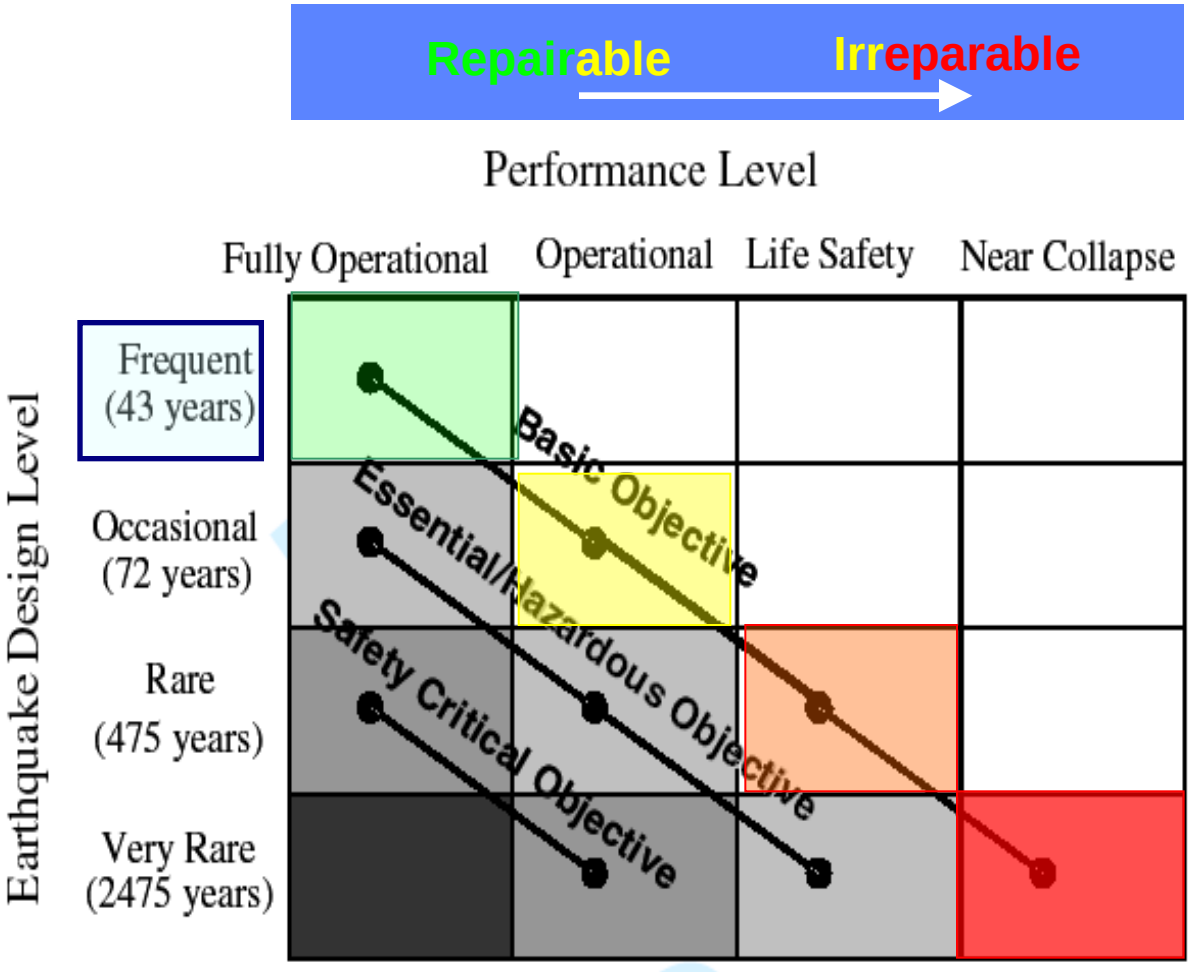




The Higher Expectations from the Society

- **No victims** nor **collapse** (**D**eaths)
- Minimum level of **damage** or direct costs (**D**amage = **D**ollars)
- Minimum **business interruption** and recovering (indirect) costs (**D**owntime)

The renewed Challenge of Eartquake Engineering: The Higher Expectations from the Society



From SEAOC Vision 2000 (1995)

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*

*Is this really **the Best***

we can do in the 3rd Millenium?

Learning From our Ancestors..

Destruction of Sparta in 464 B.C. (frame by Egisto)

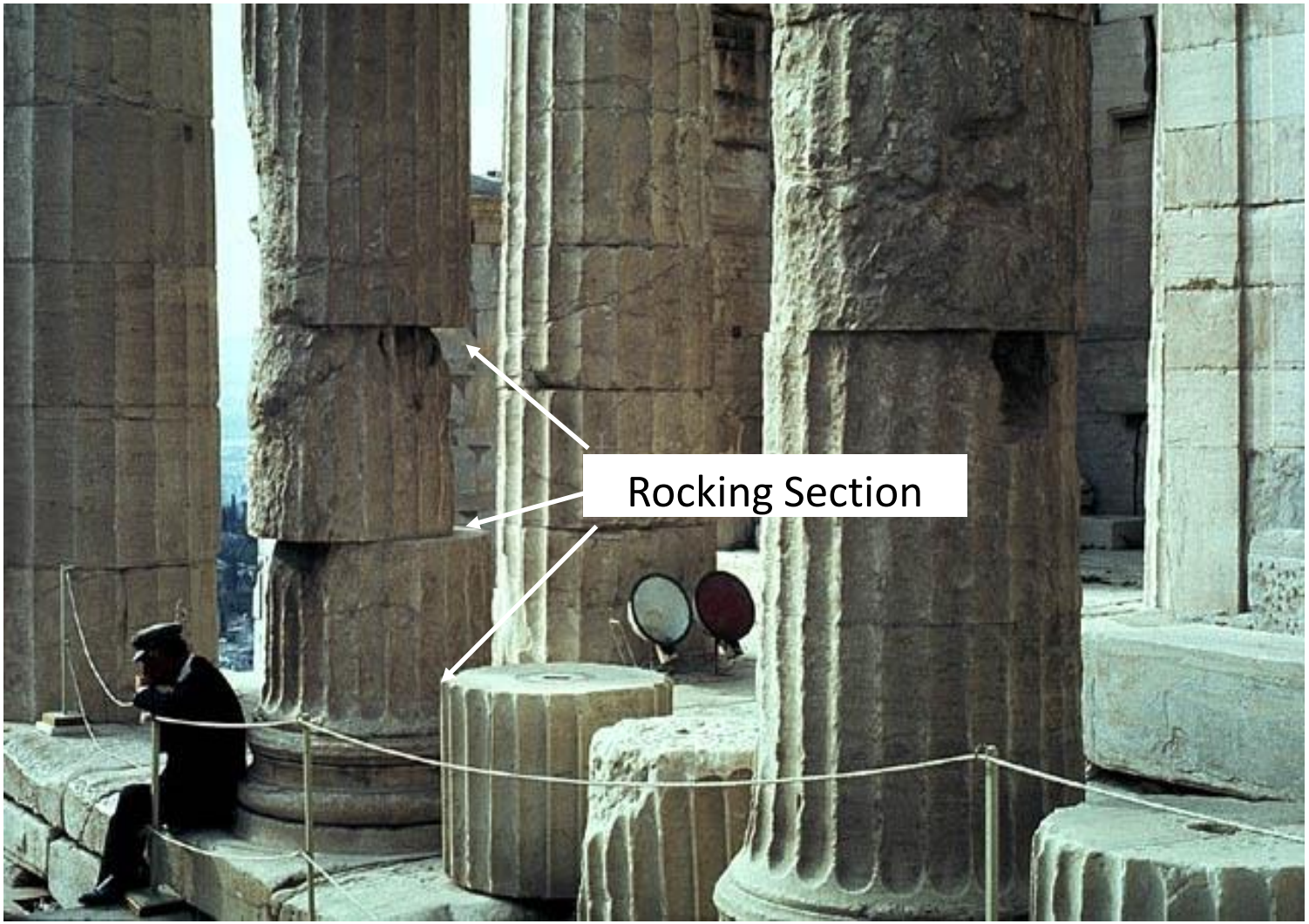
Vulnerability of towers

Napoli, 1806

Tuscany, 1896

Fori Romani

A robust earthquake-resisting system

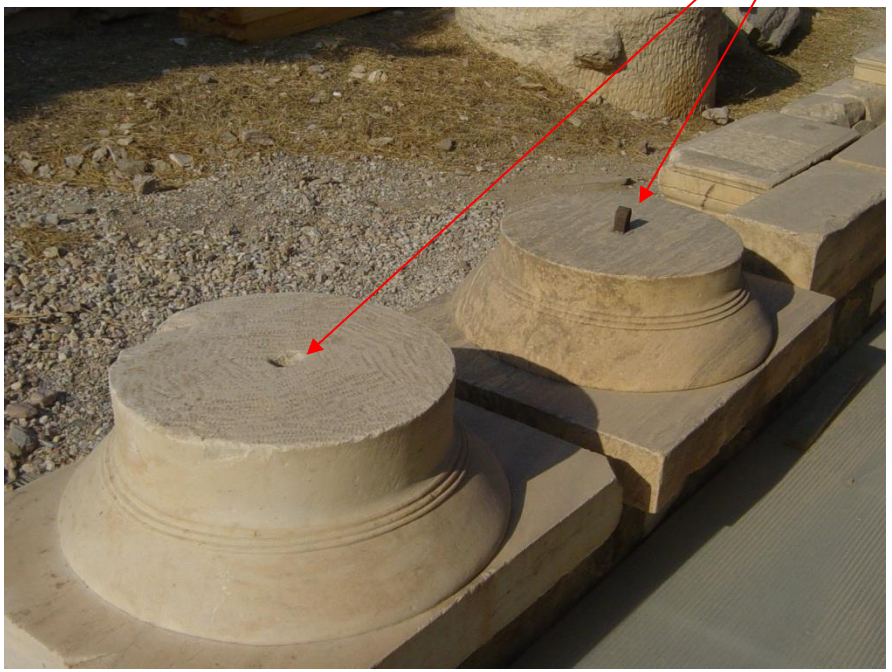


Multi-block Rocking: Athens Acropolis

One of the first applications of Rocking-systems

Temple of Haephestus, Ancient Agora', Athens

Shear keys



The “bridge of knowledge” of our cultural heritage

Modern segmented Bridge in US

Olympia

2500 years later…….

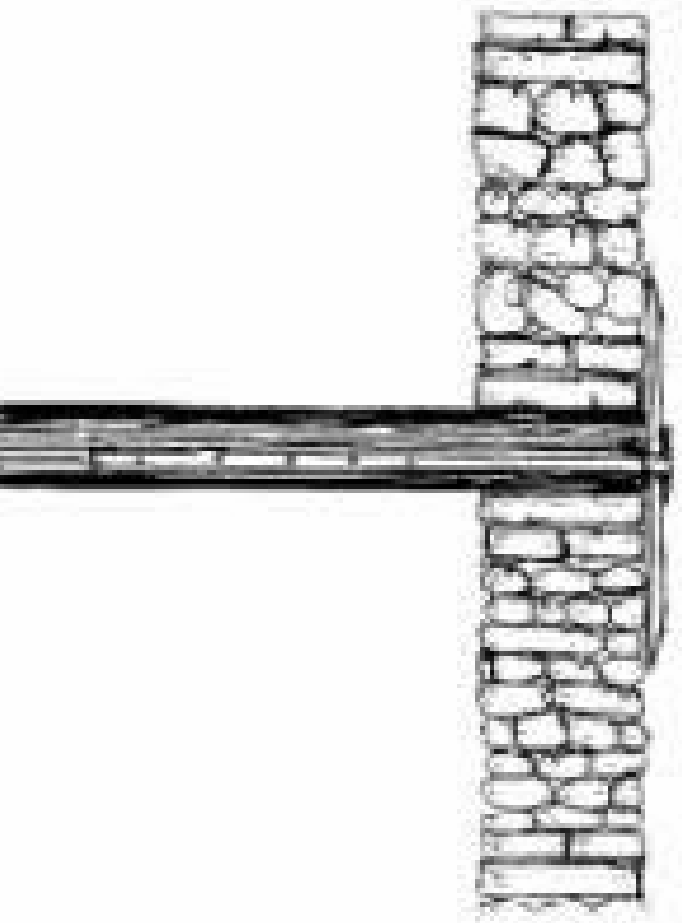
Why not in timber?

Unbonded Post-tensioned Precast Concrete Building

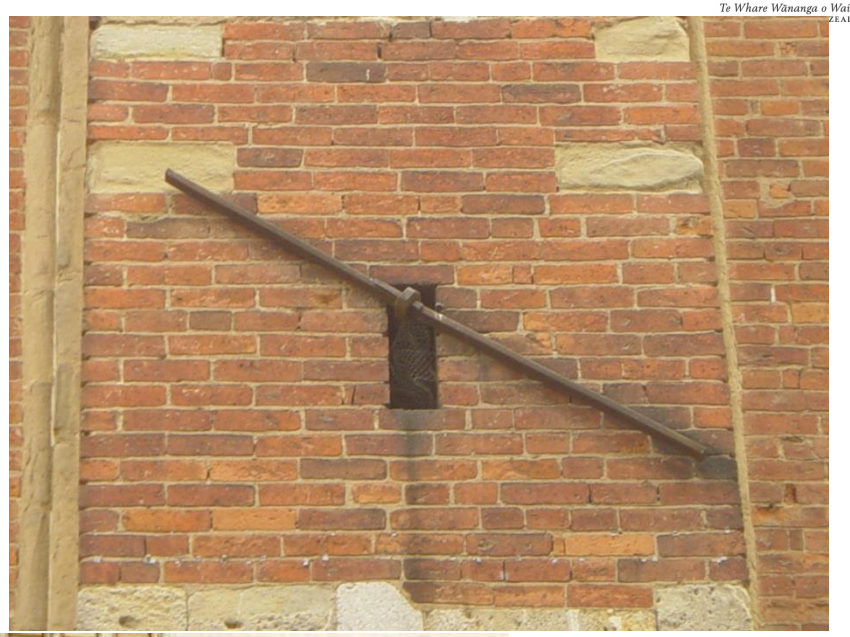
(Brooklyn System, BS Italia)

Pampanin, Pagani, Zambelli, 2004

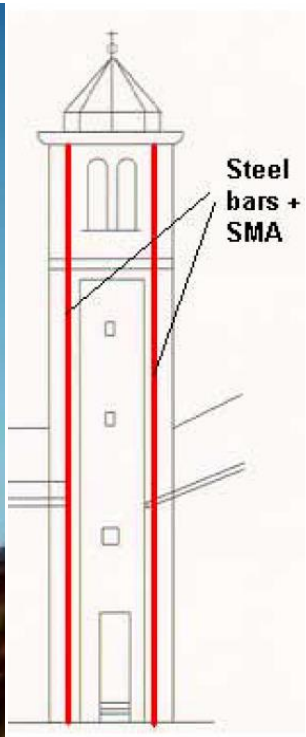
Use of post-tensioning for retrofit



Protection of facades using tie-back



Use of post-tensioning for retrofit/repairing (SMA)

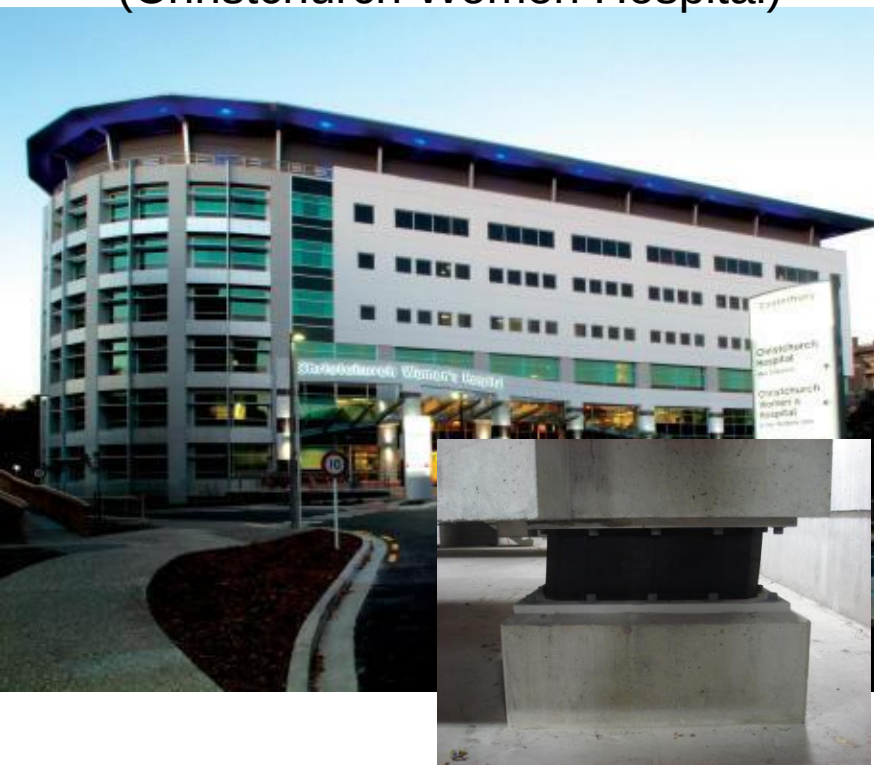


The Opportunity for the Future:

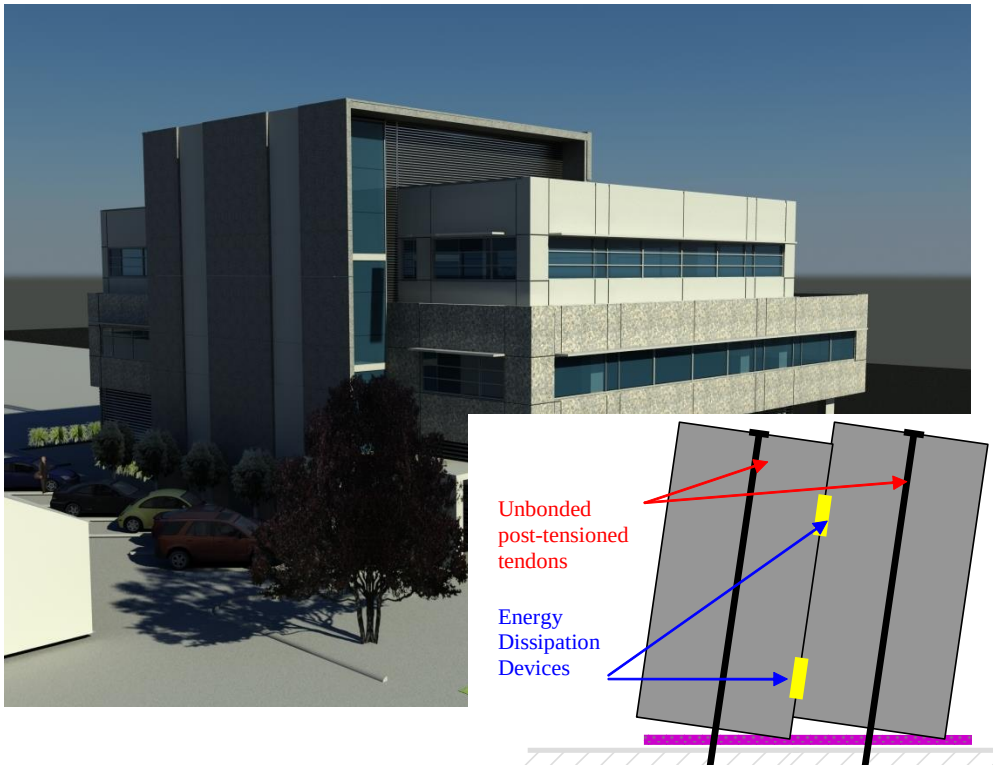
Cost-efficient low-damage technology

Base Isolation

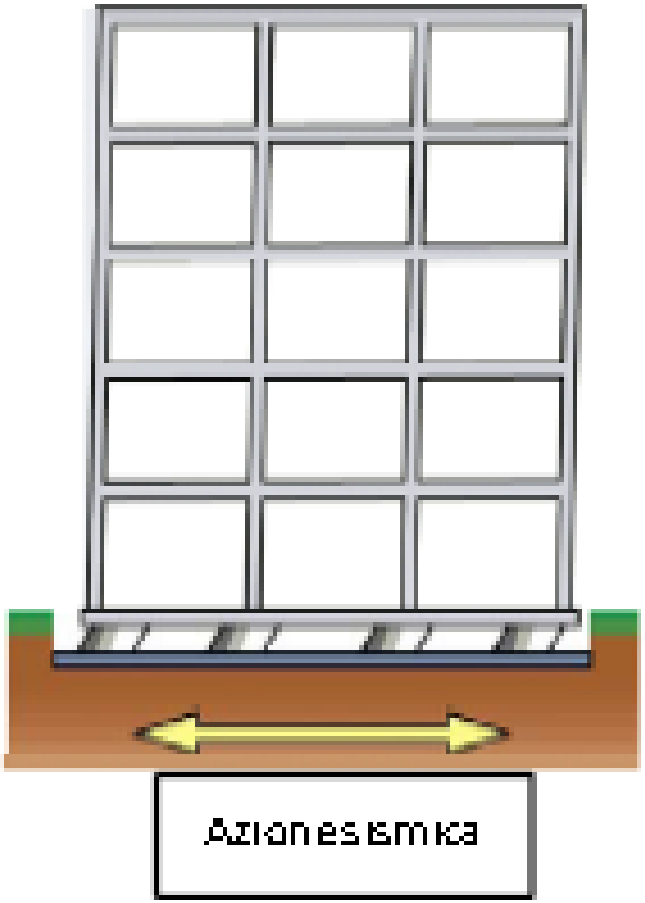
(Christchurch Women Hospital)

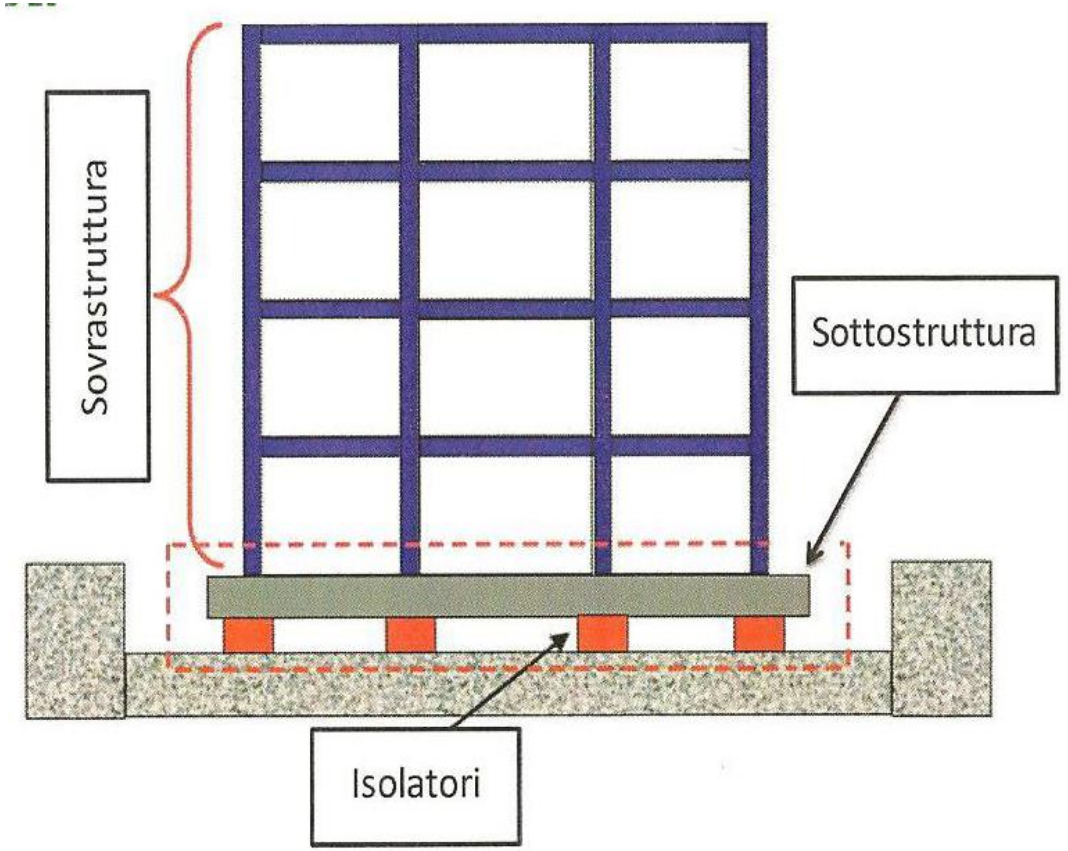


Rocking/Dissipating (PRESSS) Technology
(Southern Cross Hospital Endoscopy Building)



Basic Conceptof Base Isolation





“Base Isolation” in the ancient past

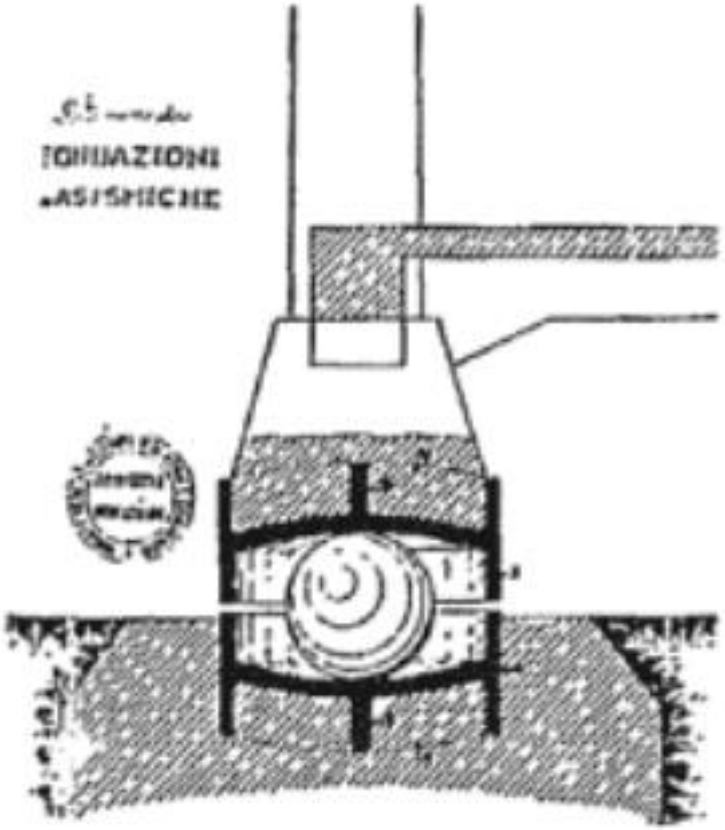
Temple of Diana (Artemis) in Ephesus

“ It was built on marshy soil, locating charcoal and woool furs under its foundations, to reduce its sensitivity to earthqukae and to avoid locating such a big mass on unsable soil”

by Pliny (in Naturalis Historia)

Base-Isolation Sliding system

(Patent from Viscardini, 1909)

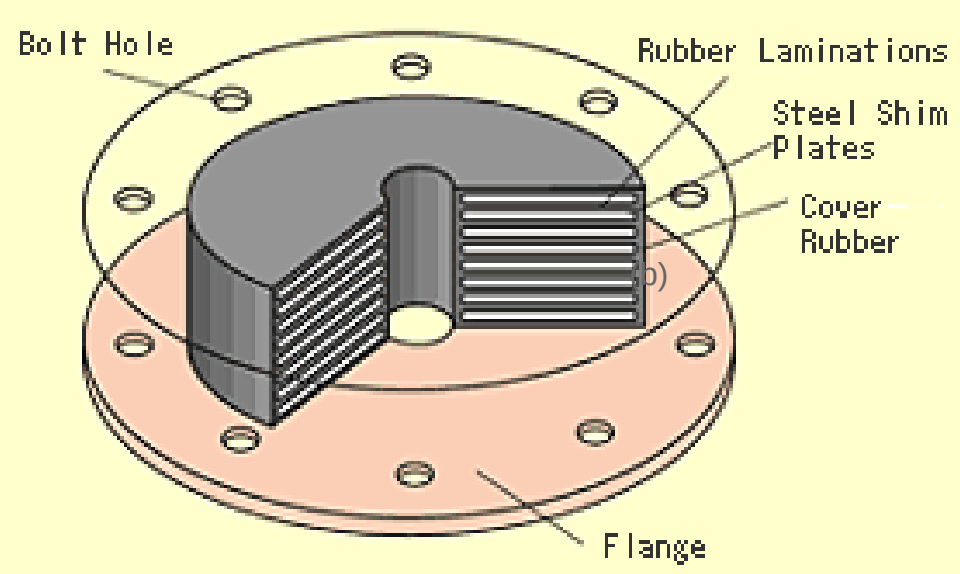


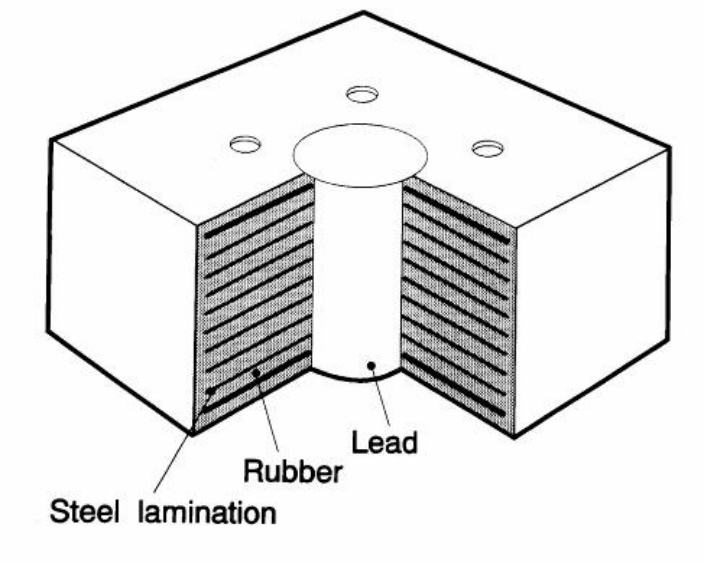
First(?) patent of base-isolation system in modern times

Viscardini, Italy, 1909

Lead-Rubber Bearing Isolator

Bill Robinson, New Zealand





Experimental test on Base Isolation

Base Isolated

“Normal”

E-defence Experimental test

on Base Isolation (click externally)

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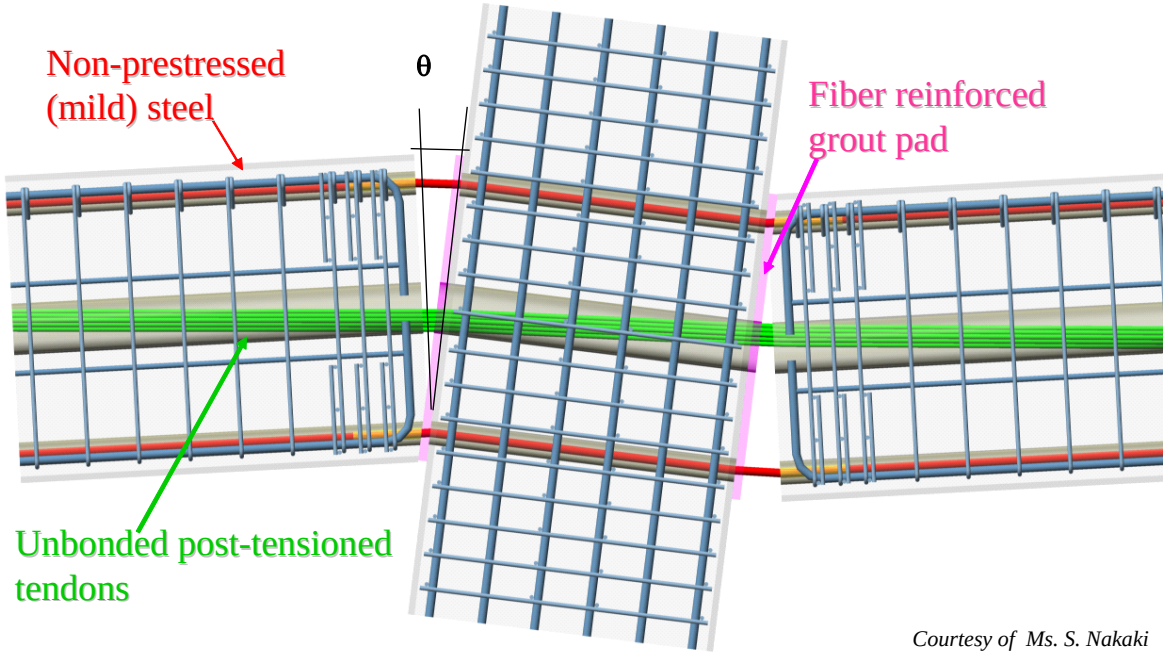
MODERN “ROCKING’ SYSTEMS
“An internal isolation” mechanism

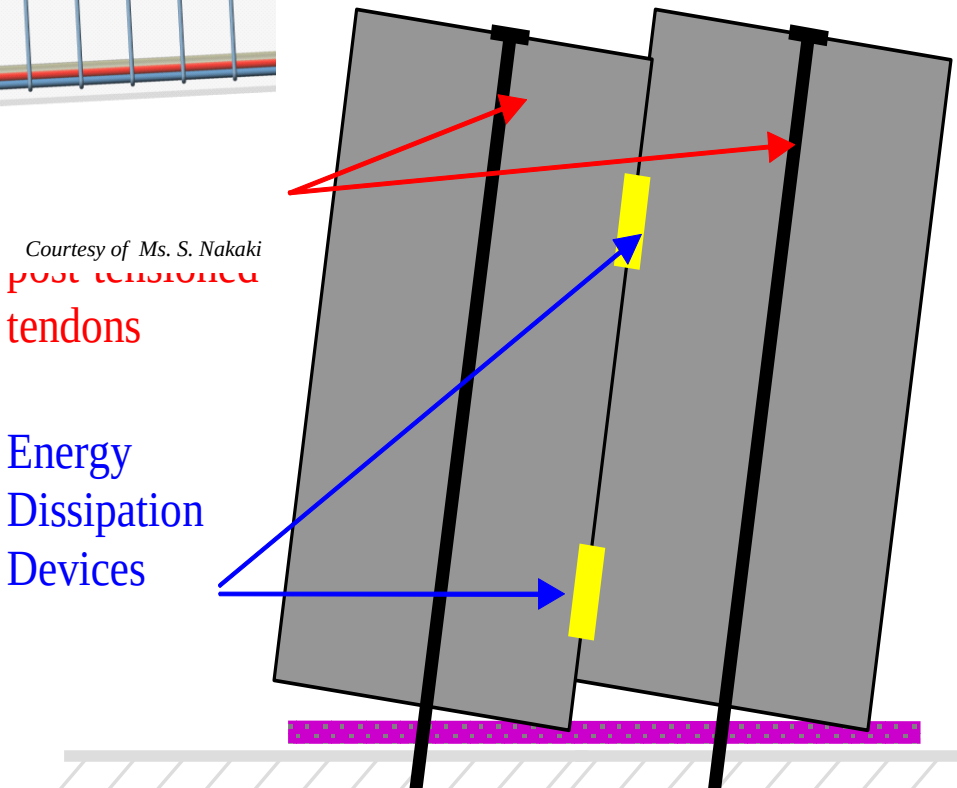
An internal isolation system: PRESSS-Technology (PREcast Seismic Structural System)

Five-Storey Test-Building (UC San Diego, Aug 1999, coordinator Prof. M.J.N. Priestley)

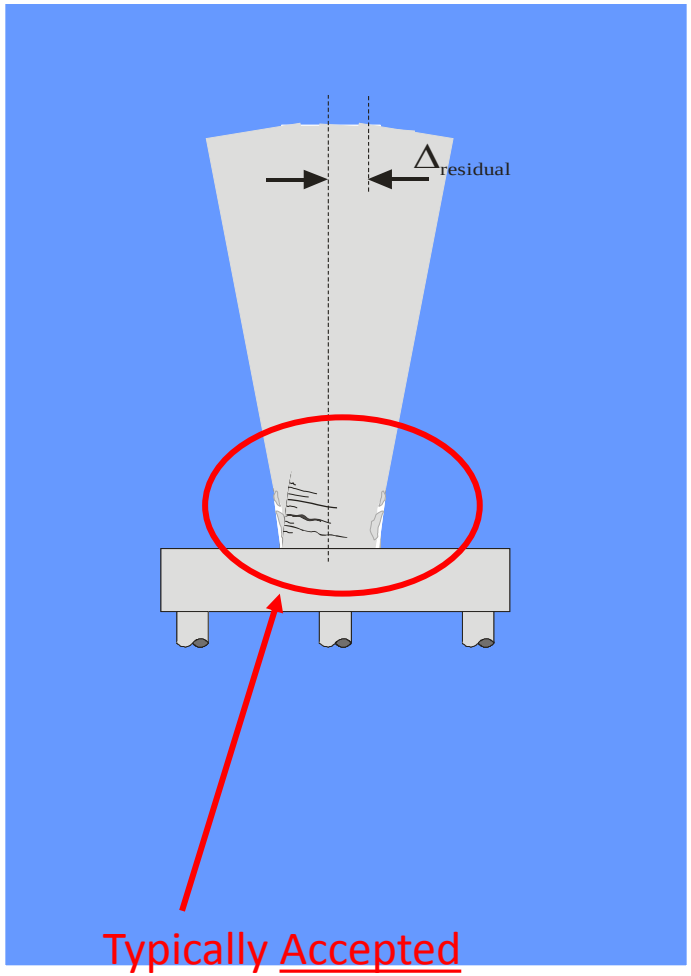
PRESSS-technology
Controlled Rocking-dissipation



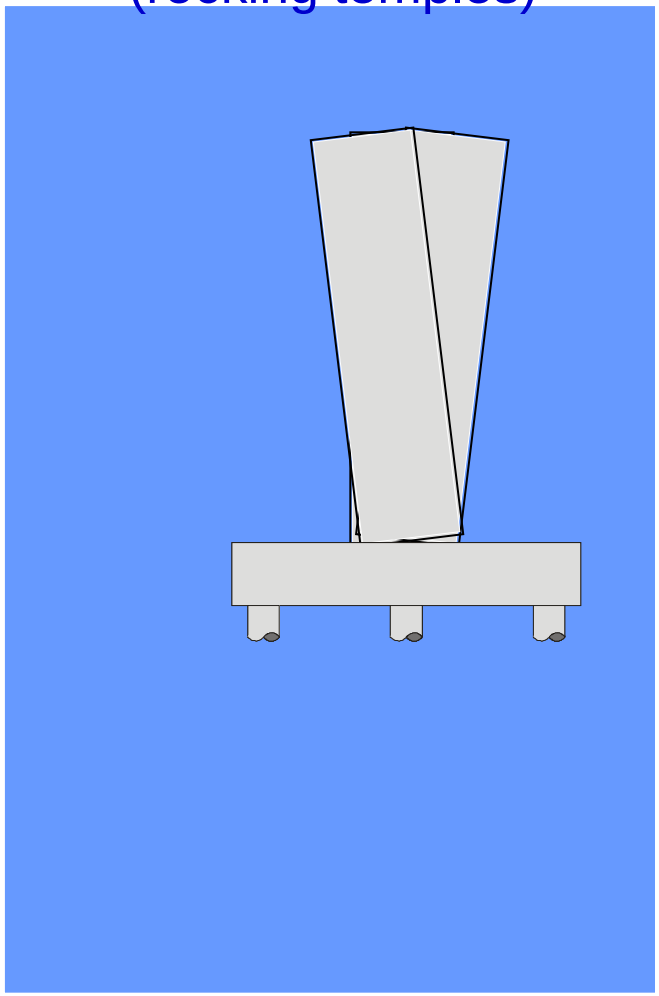
Courtesy of Ms. S. Nakaki



Traditional (monolithic)

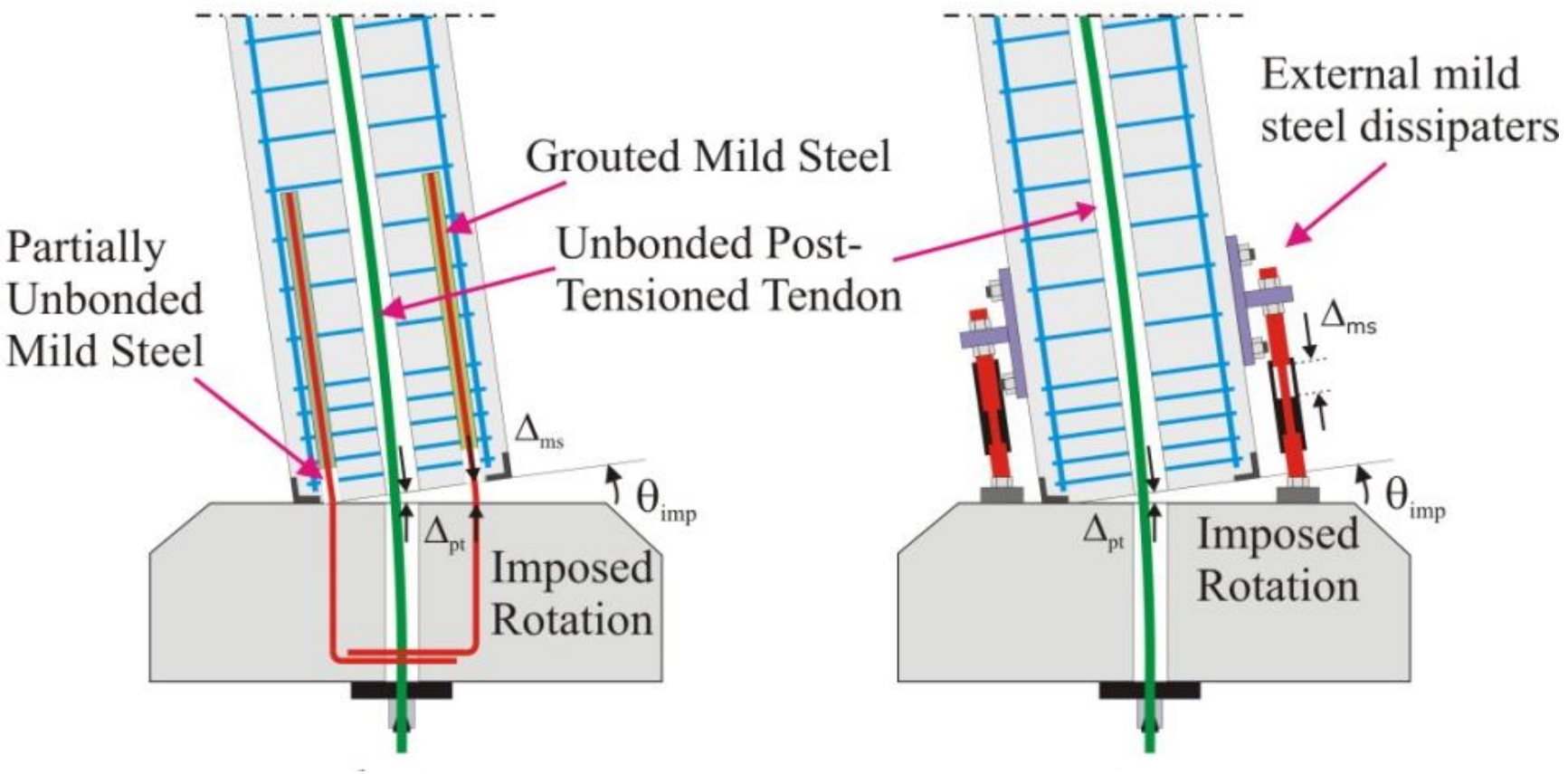


New generation
(rocking temples)



courtesy of Dion Marriott

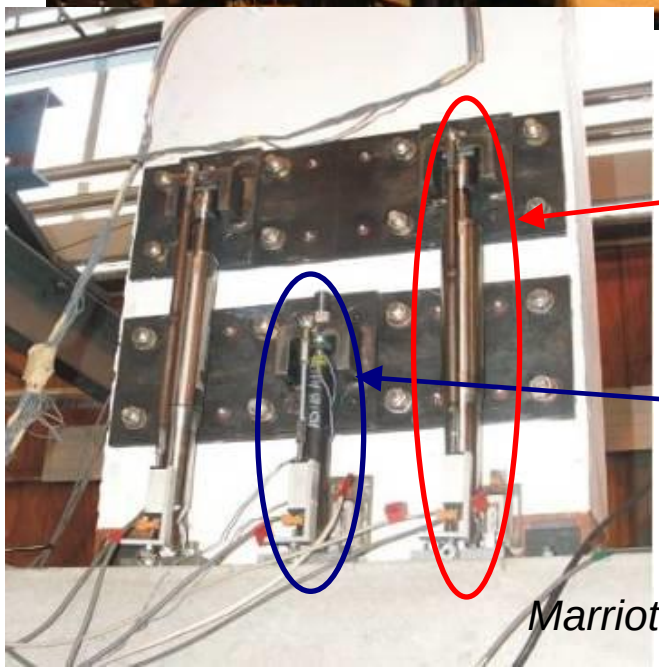
External &Repleacable Dissipaters ("Plug & Play")



Marriott et al., 2008

Alternative "architecture" Configurations

Amaris et al. 2006



Viscous

+

Hysteretic

Marriott et al., 2007

Big Aftershock?

(simply check and replace your Plug&Play dissipaters)

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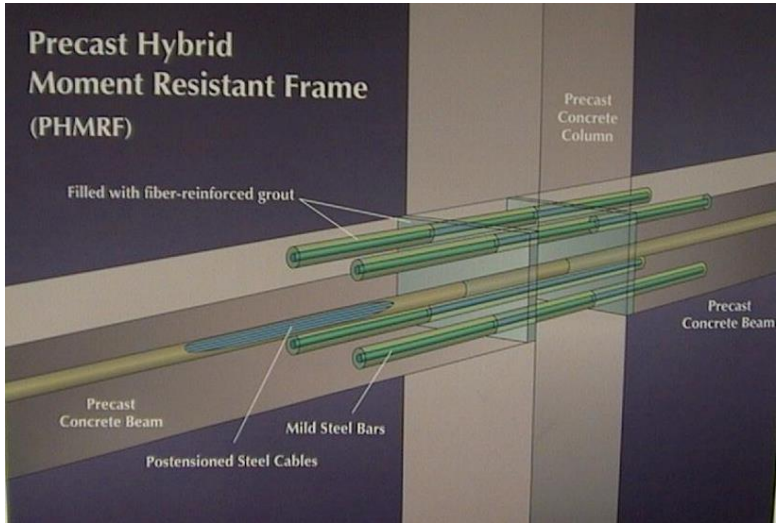
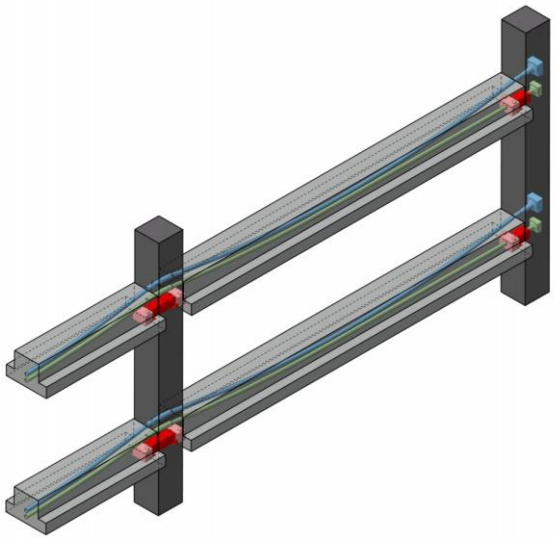
From theory…
to Practice

On-site Applications (1)

Paramount Tower, San Francisco (Englekirk, 2002)



On-site Applications (2)



Brooklyn System – Italy
(Pampanin, Pagani, Zambelli, 2004)

Speed of Construction: a “LEGO System”

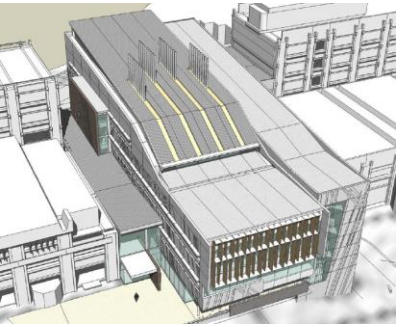
On-site Applications (3)

Hotel Virgo
(Mendoza, Argentina)
courtesy Pretensados Argentinos

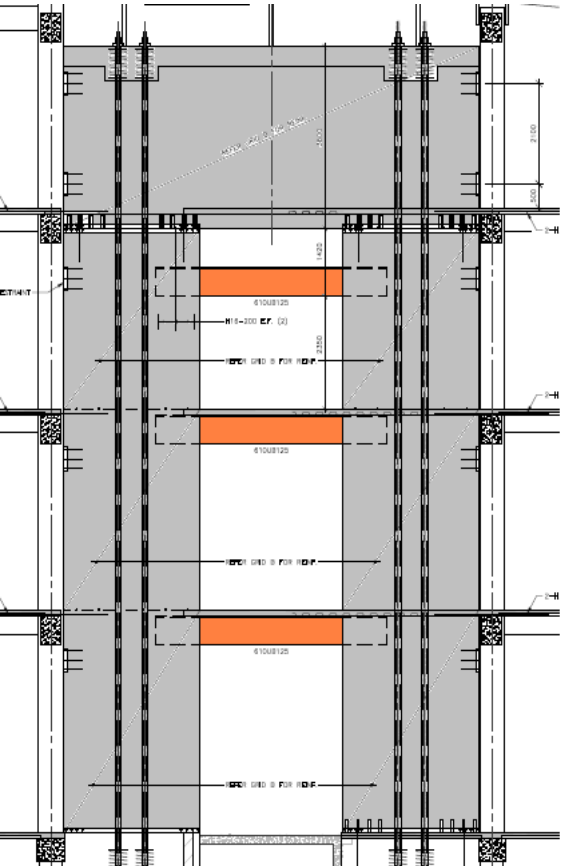
On-site Applications (4)

Zona Franca America, Costarica, Holcim Producto de Concreto

On-site Applications (5)



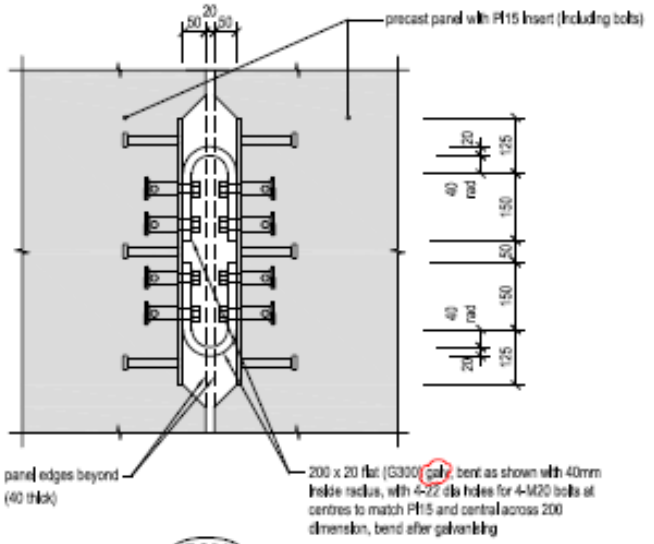
Alan MacDiarmid Building
Victoria University, **Wellington**



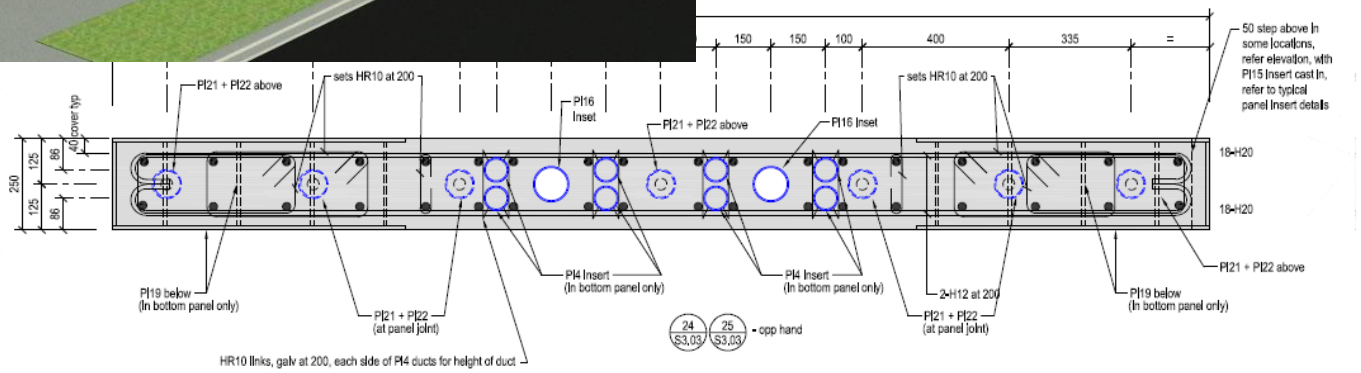
Alistair Cattanach

Adam Thornton

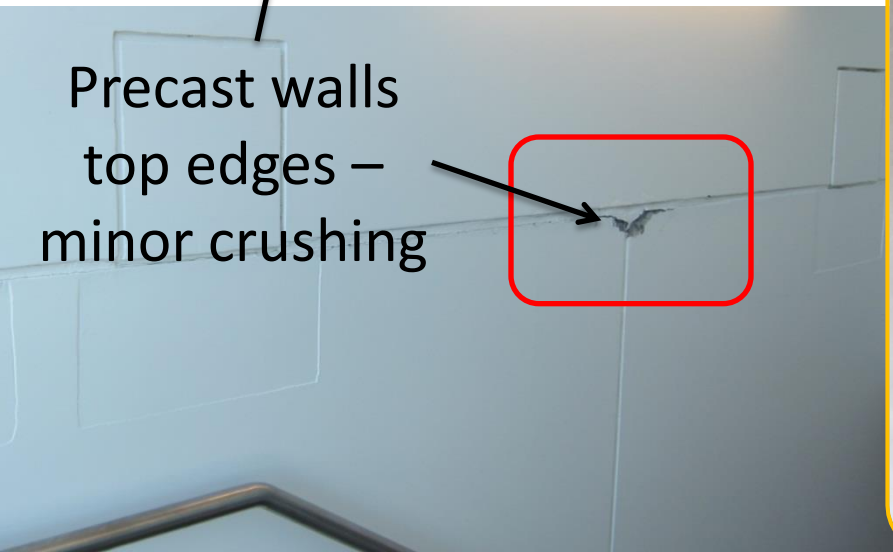
NZ's second PRESSS Building (6)



Coupled PRESSS walls



Performance after Feb 22

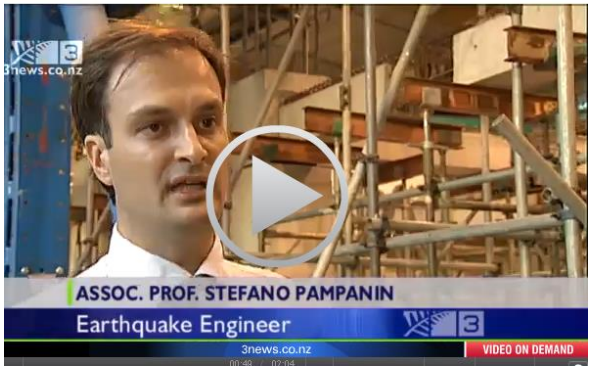


Precast walls top edges – minor crushing

Continuous functionality and immediate re-occupancy

Isn't this the GOOD NEWS

that our Society deserves to receive?



2500 years later…….

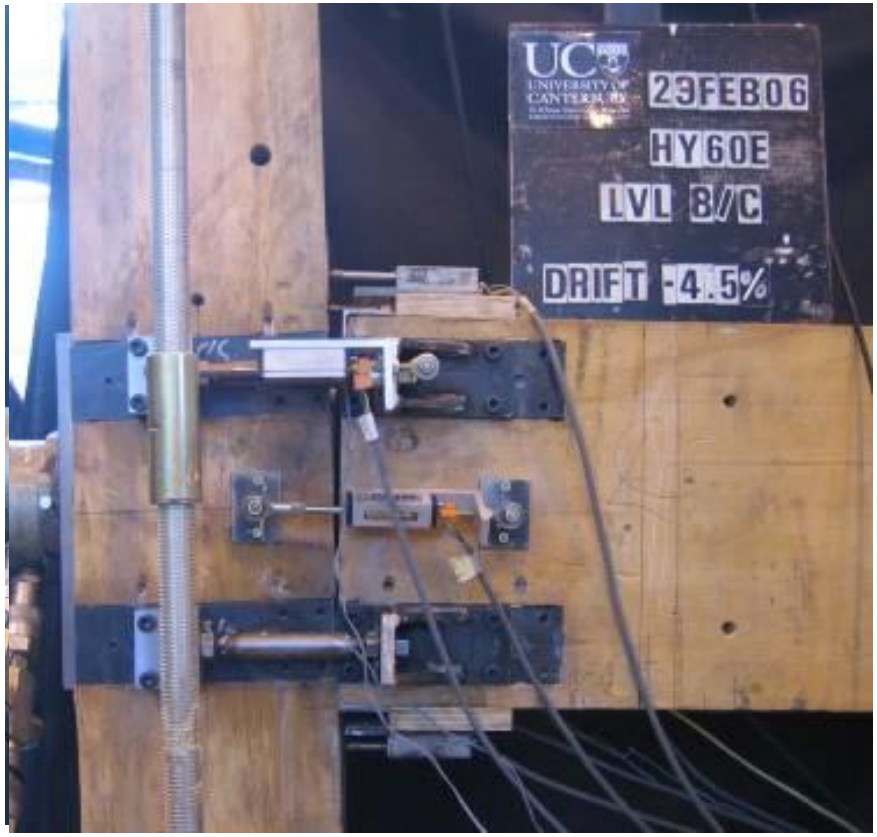
Why not in timber?

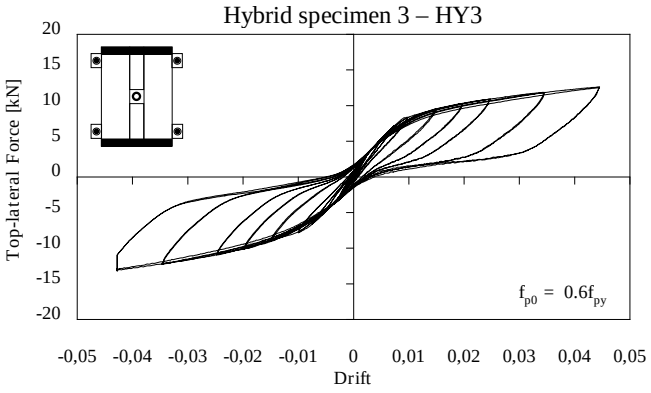
Unbonded Post-tensioned Precast Concrete Building

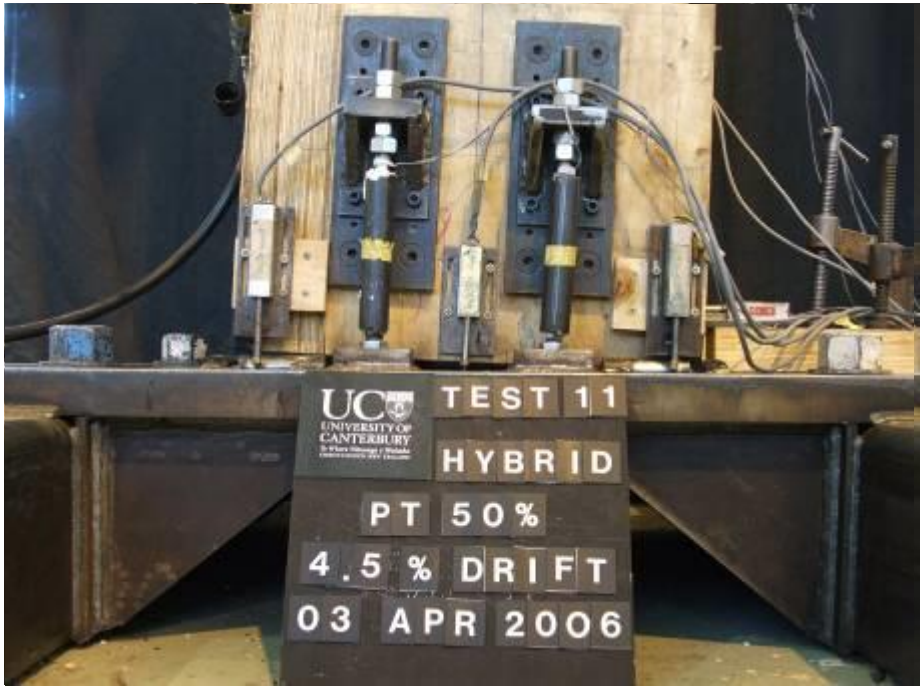
(Brooklyn System, BS Italia)

Pampanin, Pagani, Zambelli, 2004

The Timber revolution







Engineered Wood Products

Laminated Veneer Lumber - LVL

Glued Laminated - GluLam

Cross Laminated - X-Lam

Prestressed Laminated

University of Canterbury Test-Building

(Pres-Lam technology)

PRES-LAM

Demounted and remounted into a real building

EXPAN building with Pres-Lam technology

EXPAN/STIC CEO's office

Architect: Thom Craig

Engineer: Holmes Consulting

Builder: Mainzeal

NZ Wood - TV Commercial

From theory..
to Practice

Parma Project
c.o. Archest

c.o. Irving-
Smith-Jack

World's First Pres-Lam Building:

Nelson Marborough Institute of Technology (NMIT), Nelson (2008)

NMIT, Nelson

Carterton Events Centre

Architect: Opus

Engineer: Opus

QS: David Langdon

Builder: Holmes

BRANZ offices, Wellington

Architect: Warren & Mahoney

Engineer: Aurecon

QS: Rider Levett Bucknall

Builder: Fletchers

Massey University, Wellington

Architect: Athfield Architects

Engineer: Dunning Thornton

QS: Rider Levett Bucknall

Progetti

Concorsi

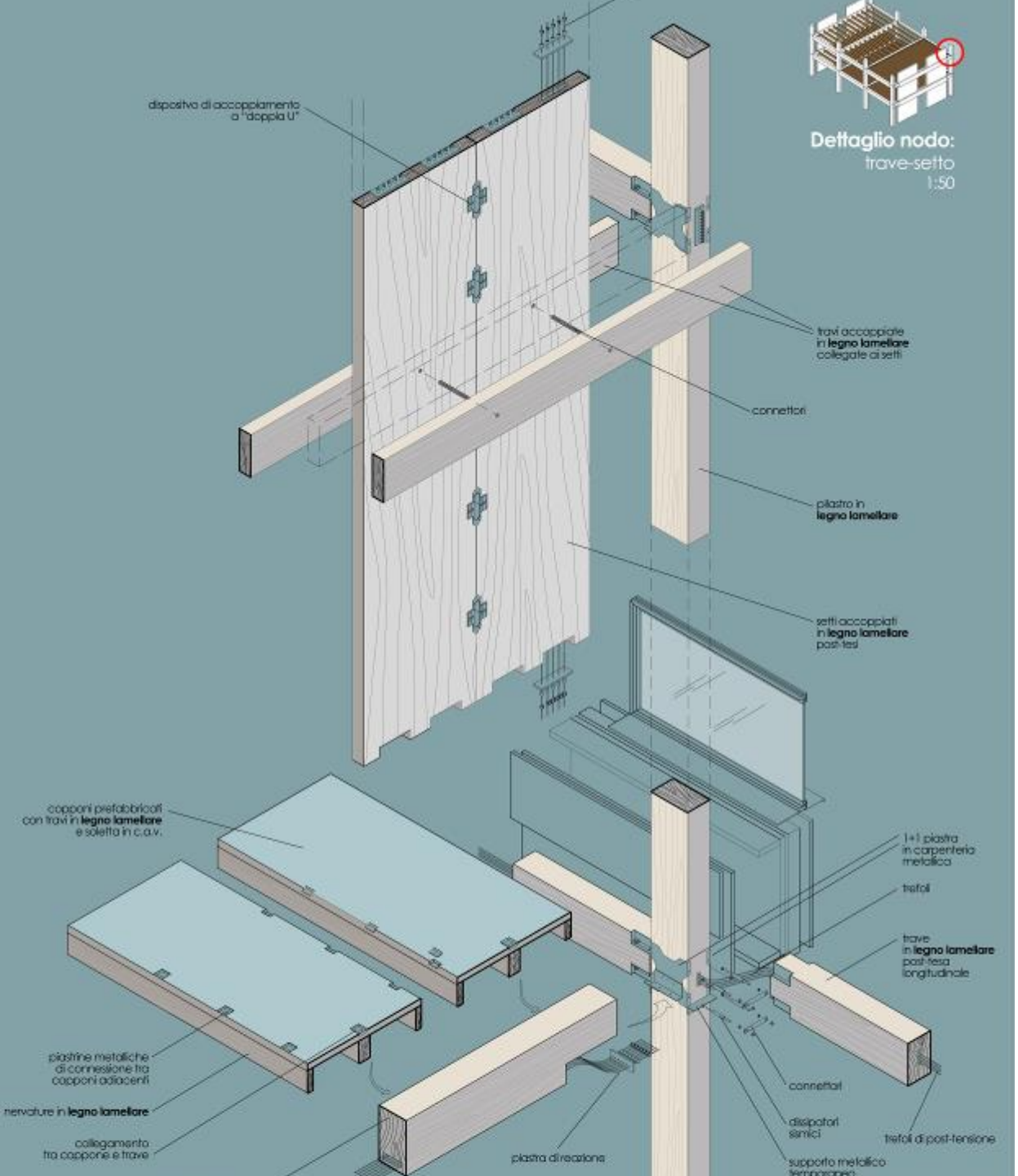
6

Il sistema Pres-Lam debutta in Europa con il Palazzo dell'Ambiente visto da Archet

Provincia di Parma, uffici in legno hi-tech

First Pres-Lam Building that could have appeared in Europe


Next Slides/Rendering from Archest



Courtesy of Archest

Christchurch Vision 2050: Re-building with damage-resisting technology

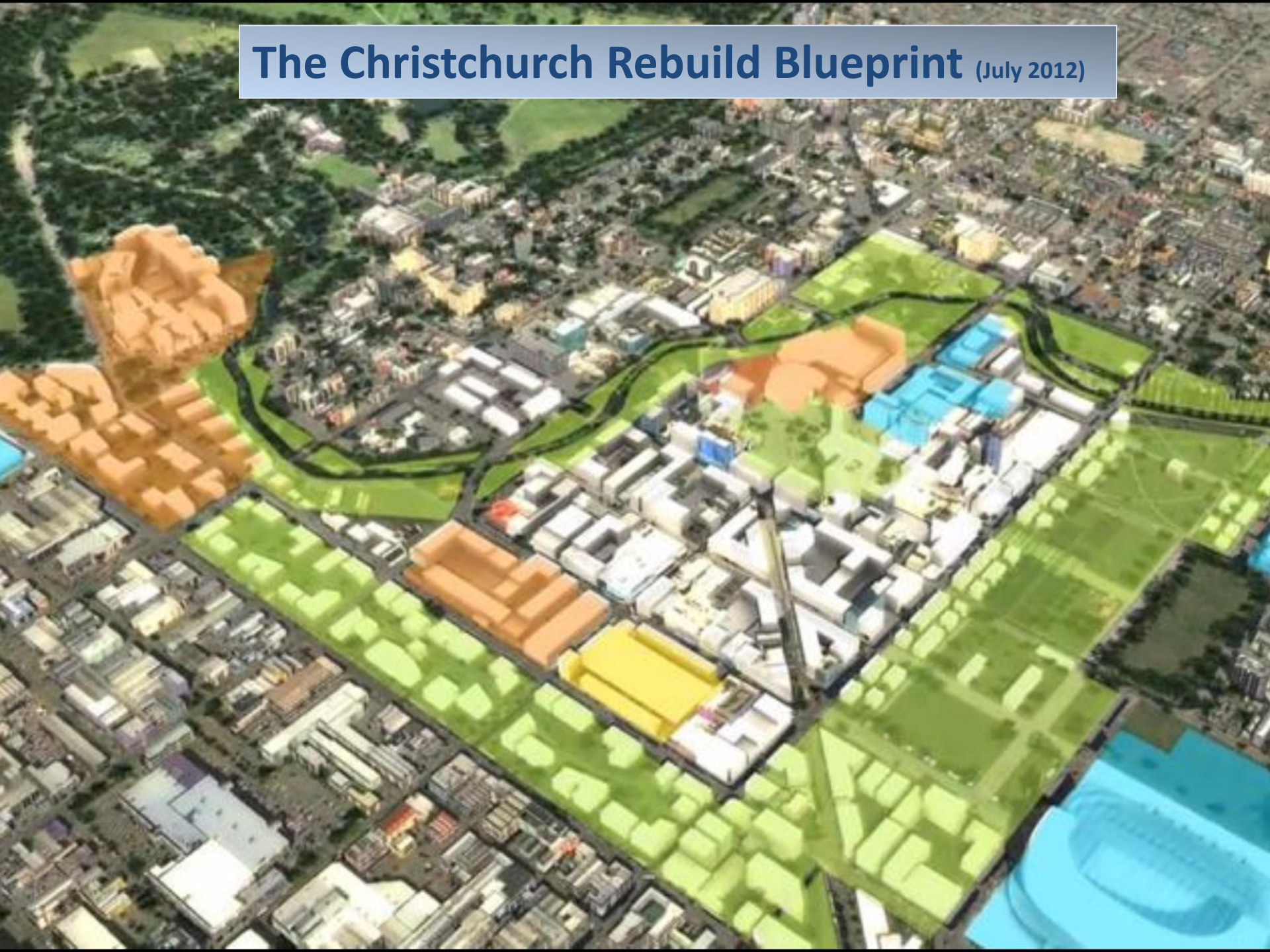
How would WE like this to look like?

(April 2011)

Photos courtesy of Weng Y Kam

(August 2012)

The Christchurch Rebuild Blueprint (July 2012)



Next Slides courtesy of Warren and Mahoney

VIBRANT STREETS AND COURTYARDS

PERMEABLE CITY BLOCKS - PEDESTRAIN FREINDLY CITY

WORKPLACE INTERIOR - SHOWING STRUCTURAL COMPONENTS

live

GREEN COMMUNITY SPACE

INTERIOR APARTMENT - SHOWING STRUCTURAL COMPONENTS

Warren & Mahoney

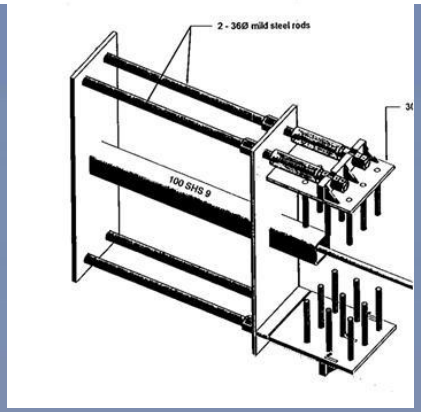
Low-Damage Concrete+Timber

St. Elmo Court (1930, RC frame with infills) damaged & demolished

St Elmo Courts
(Artist impression -Ricky Proko/Ruaumoko Solutions)


The “New” St. Elmo
Base isolation+
PRESSS/Pres-Lam Superstructure
St Elmo Courts
(Artist impression -Ricky Proko/Ruaumoko Solutions)

Low-Damage Post-tensioned Timber (Pres-Lam)

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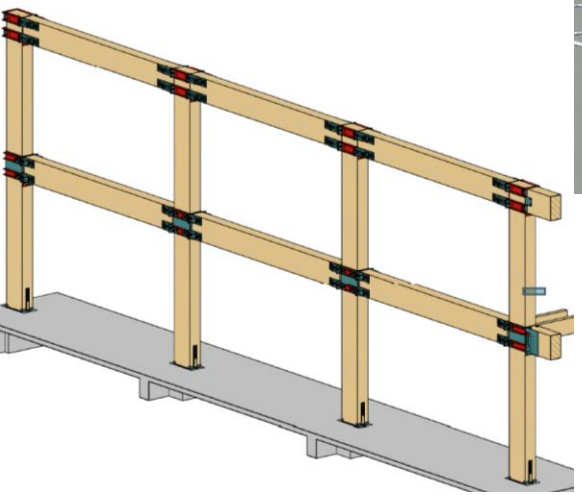
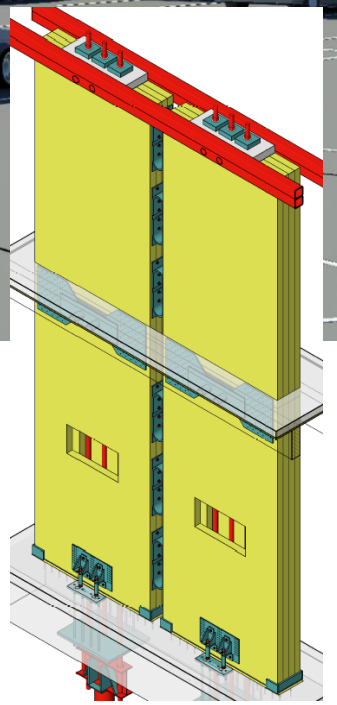
CONSTRUCTION SITE
CARTERS
SHEPPARD & ROUT


COMING S
Brynn Burrows
021 375 917
CBRE

Low-Damage Post-tensioned Timber (Pres-Lam)





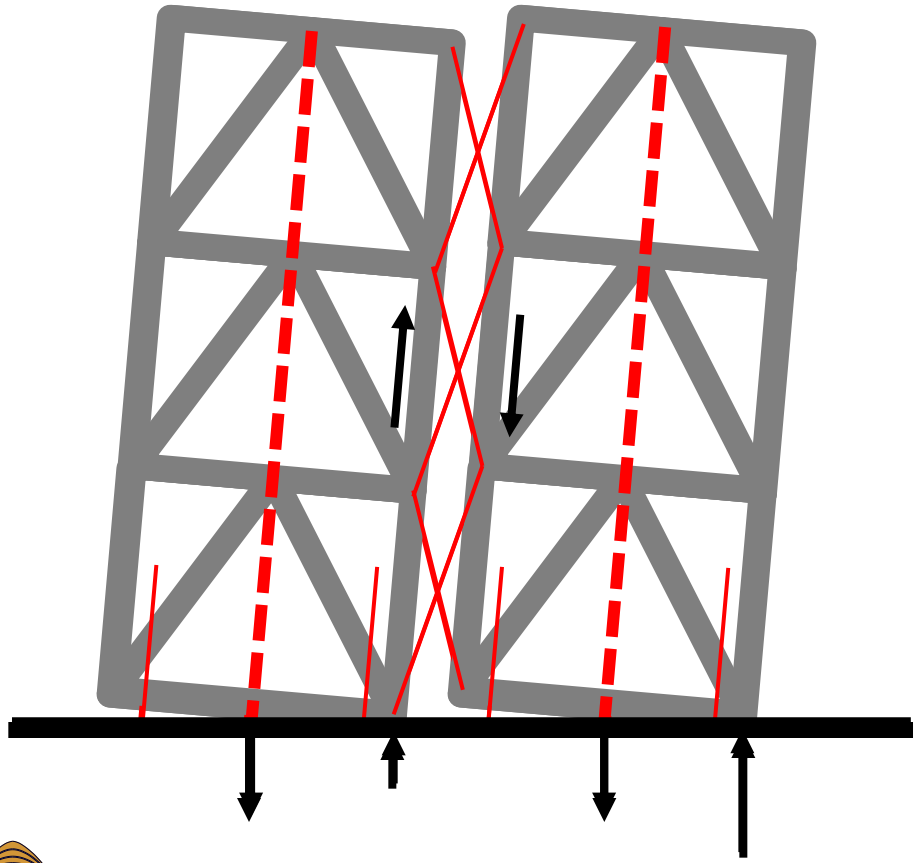
Architecture and Engineering: Opus International

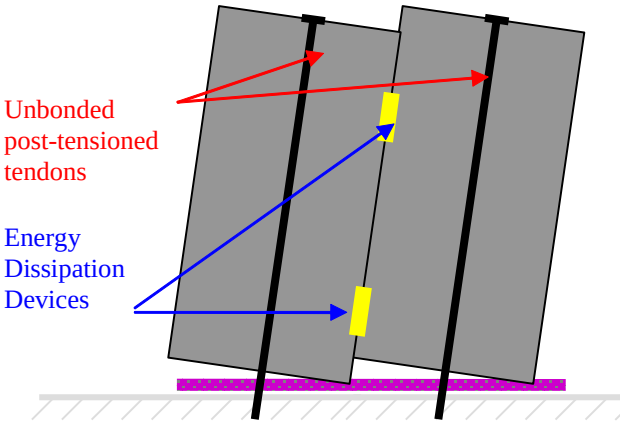
Low-Damage Post-tensioned Steel braced frames

Architects: Wilson & Hills
Structural Engineers: ARCL

Alan Reay Consultants

Post-tensiond Steel "Walls"





"The concept is to allow controlled rocking of the structure to reduce damage to the primary structural elements."

Alan Reay Consultants

UC UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

SEISMIC 'PRESSS' FRAMES

Alan Reay Consultants

UC UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

FROM THE LAB…

TO PRACTICE

A PROJECT OF MANY FIRSTS…

A willing client

Design team prepared to innovate

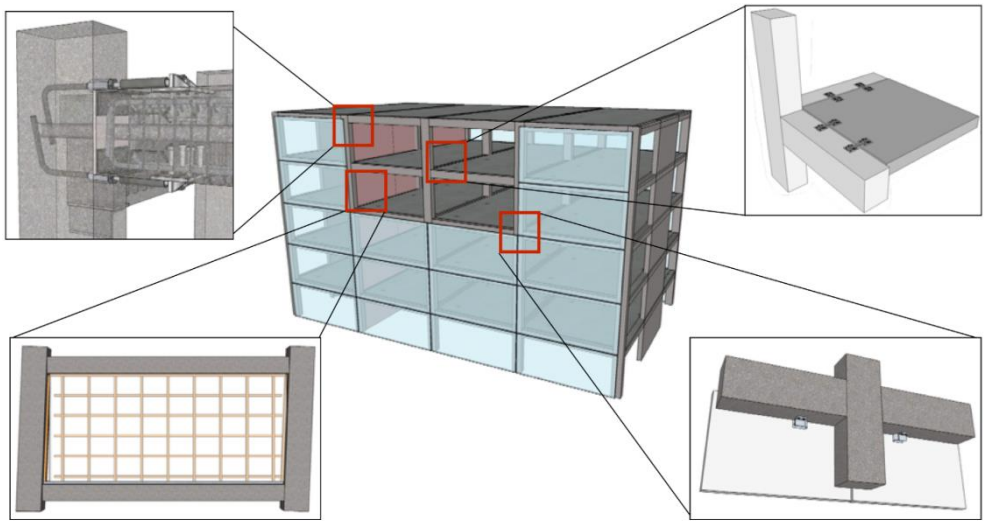
Research and Development

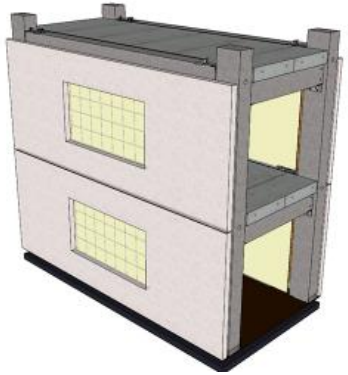
A capable contractor

The next step up towards the “ultimate” Earthqauke-Proof Building

Shake-table testing of an integrated (structure+non-structural) low-damage frame

(Johnston, Watson, Pampanin, Palermo, NZSEE 2014)



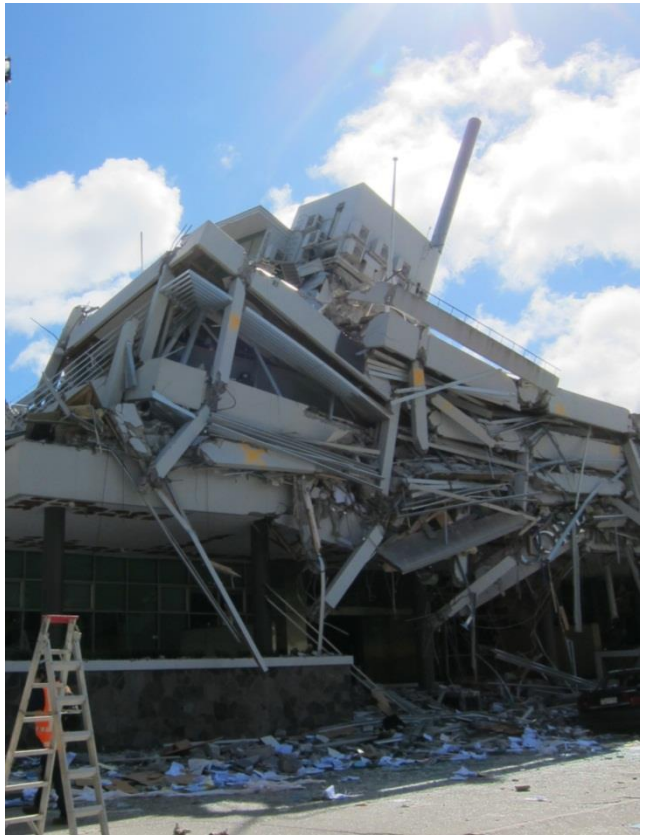


How many **"Lessons"** do we still need?

1999 → **2009** → **2011**

Izmit-Kocaeli, 1999
(photo courtesy: Berkeley Library)

L'Aquila, 2009
(photo courtesy: Anna Brignola)



Christchurch, 2011
(photo courtesy: Kam Weng)

Time to step up.
A common international challenge

Local/International Collaborators/Teams:
EERI (US), AIJ/JAEE (Japan), EEFIT (UK), NCEER (Taiwan), UoAuckland, European unis