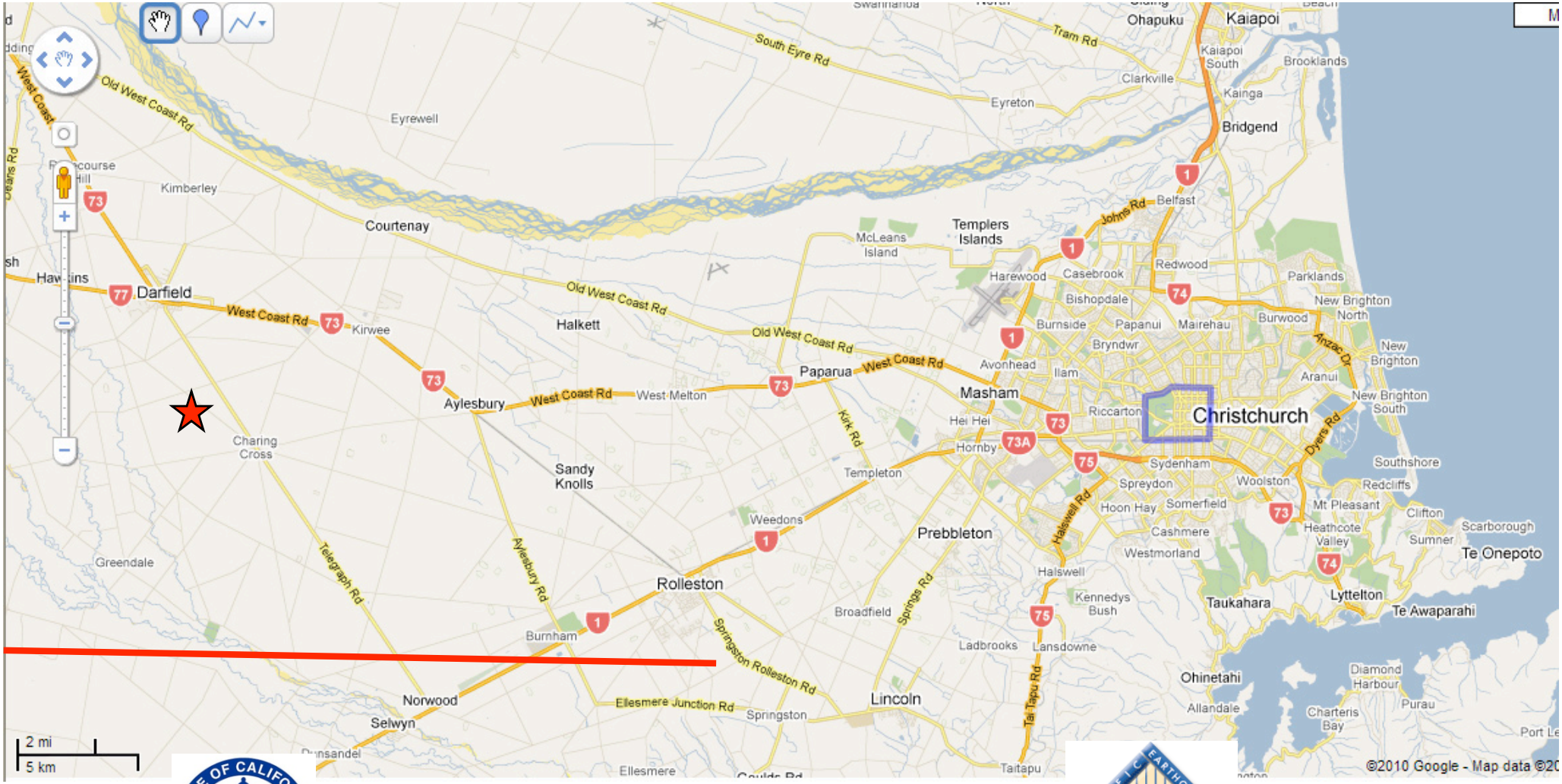
Unreinforced Masonry and Selected Modern Buildings and Port Facilities

in the Darfield, NZ Earthquake 9-4-2010

Fred Turner, SE

CA Seismic Safety Commission

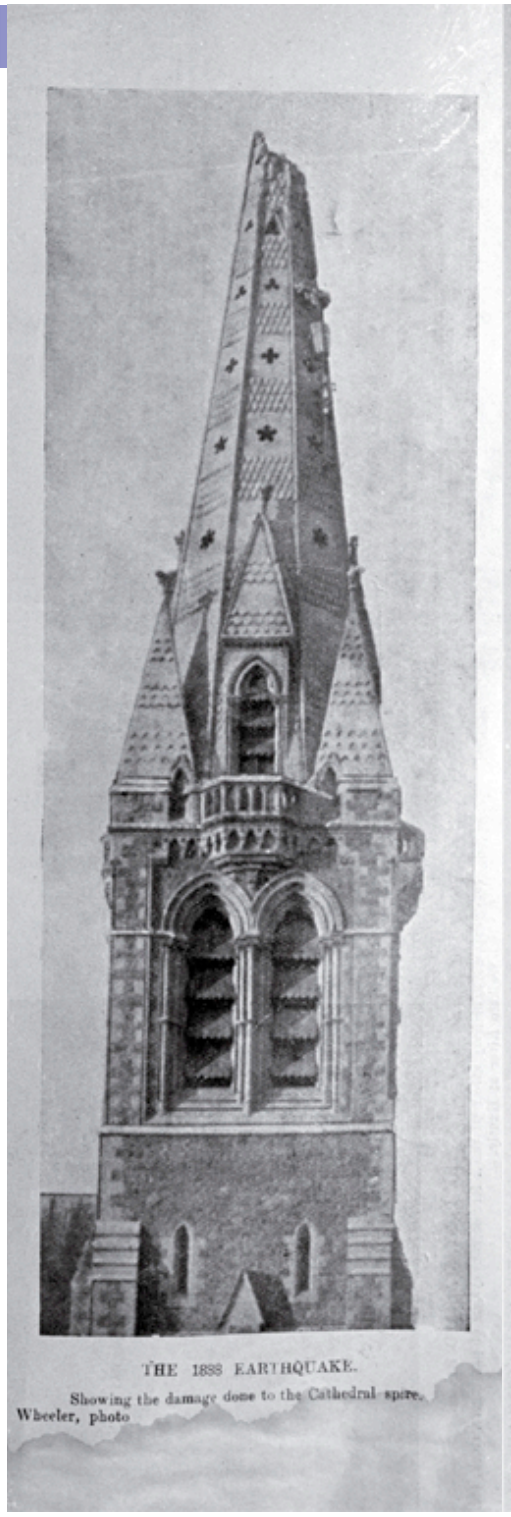
Darfield Earthquake, Canterbury Region



Christchurch in 1877

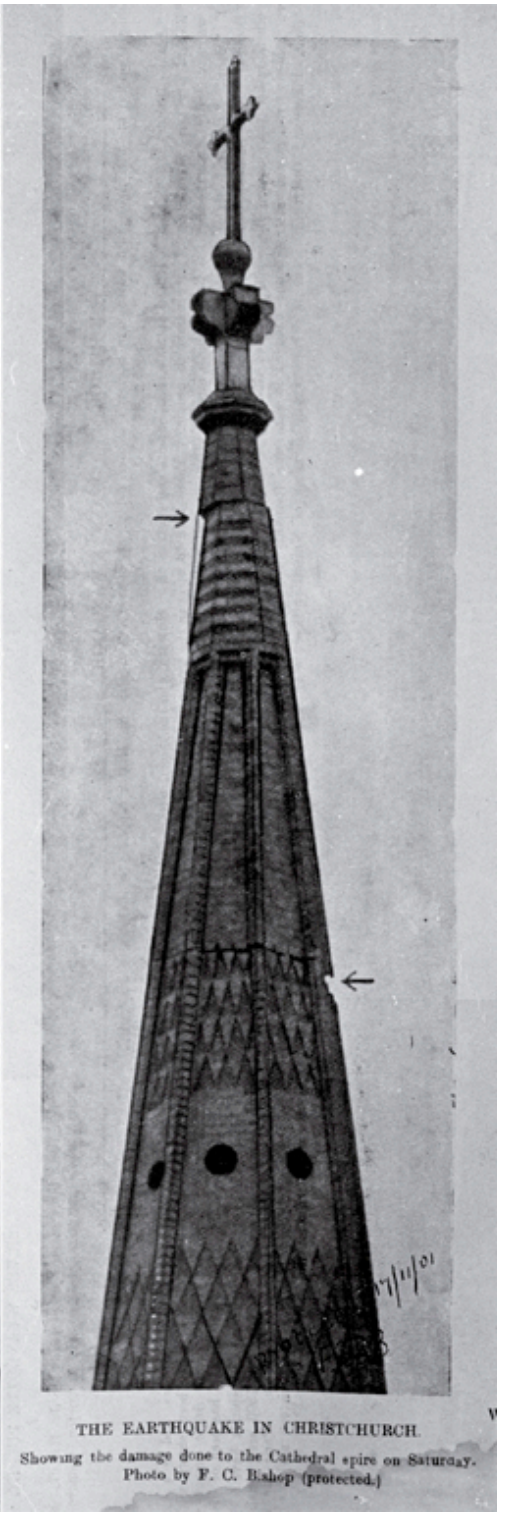
Anglican Cathedral in 1880's

Anglican Cathedral Damage to Spire 1888 and 1901 Earthquakes



THE 1888 EARTHQUAKE.

Showing the damage done to the Cathedral spire. Wheeler, photo



THE EARTHQUAKE IN CHRISTCHURCH.

Showing the damage done to the Cathedral spire on Saturday. Photo by F. C. Bishop (protected.)

Anglican Cathedral in 2010

0.26 g, 41 cm/sec

Christchurch Cathedral Square

0.26 g, 41 cm/sec

Types of Unreinforced Masonry (URM): Chimneys

0.26 g, 41 cm/sec

URM Type: Fire Separation Walls

0.26 g, 41 cm/sec

0.21 g, 50 cm/sec

URM Type: Cavity Walls

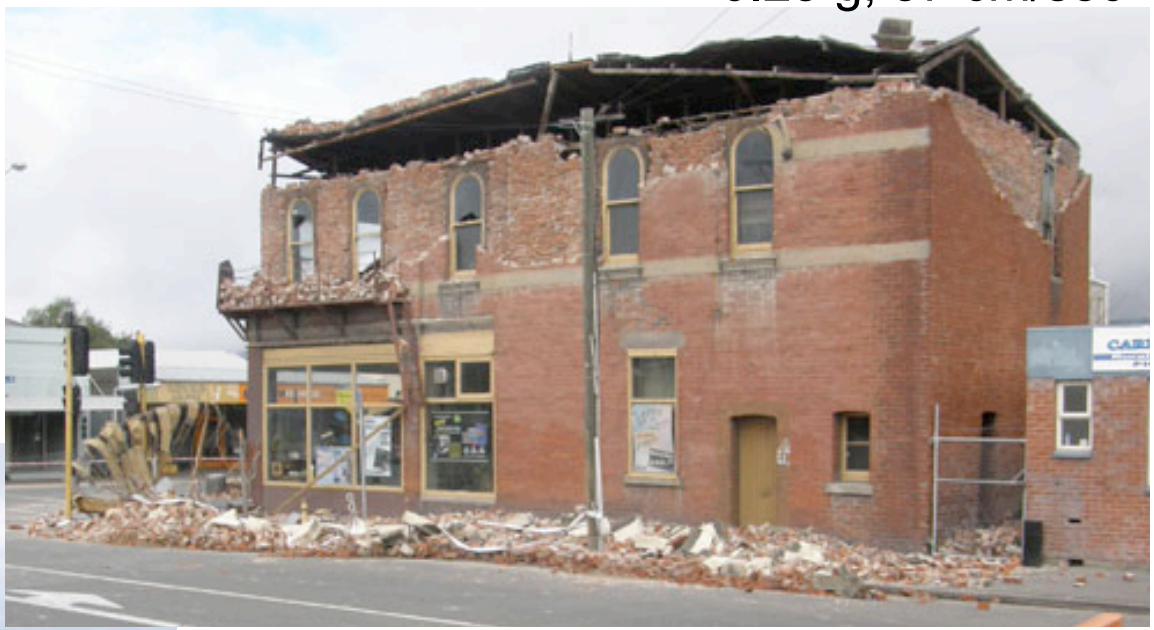
0.26 g, 41 cm/sec

URM Type: Multi-wythe Walls

0.26 g, 41 cm/sec

URM Parapet & Upper Wall Collapses

0.23 g, 57 cm/sec



0.36 g, 31 cm/sec

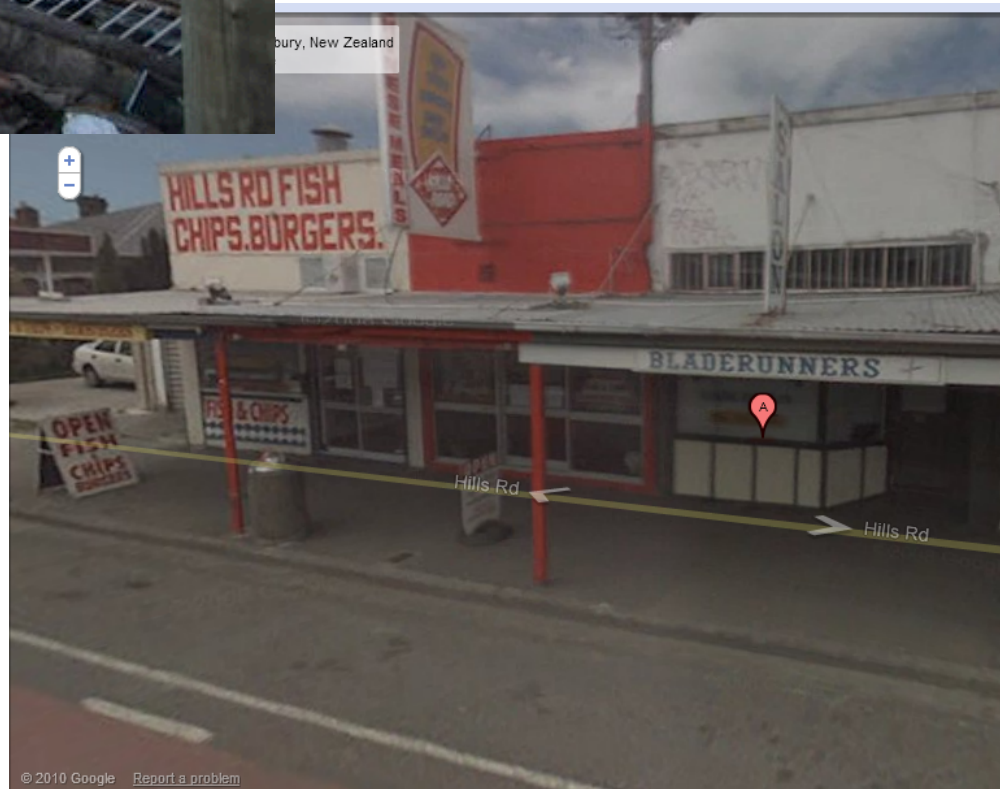
0.26 g
41 cm/sec

URM Parapet & Upper Wall Collapses

0.26 g, 41 cm/sec

After: Twitpic

Before: Google Maps



0.26 g, 41 cm/sec

After: Twitpic

Before: Google Maps

0.23 g, 57 cm/sec

Stone Bell Tower Collapse St. John's Latimer Square

0.23 g, 57 cm/sec

Image Credit: Corey Stewart

Taller URM Buildings

0.21 g, 50 cm/sec

Taller URM Buildings

0.23 g, 57 cm/sec

Image Credit: Myrto Anagnostopoulou

URM Gable Walls

0.21 g,
50 cm/sec

0.26 g, 41 cm/sec

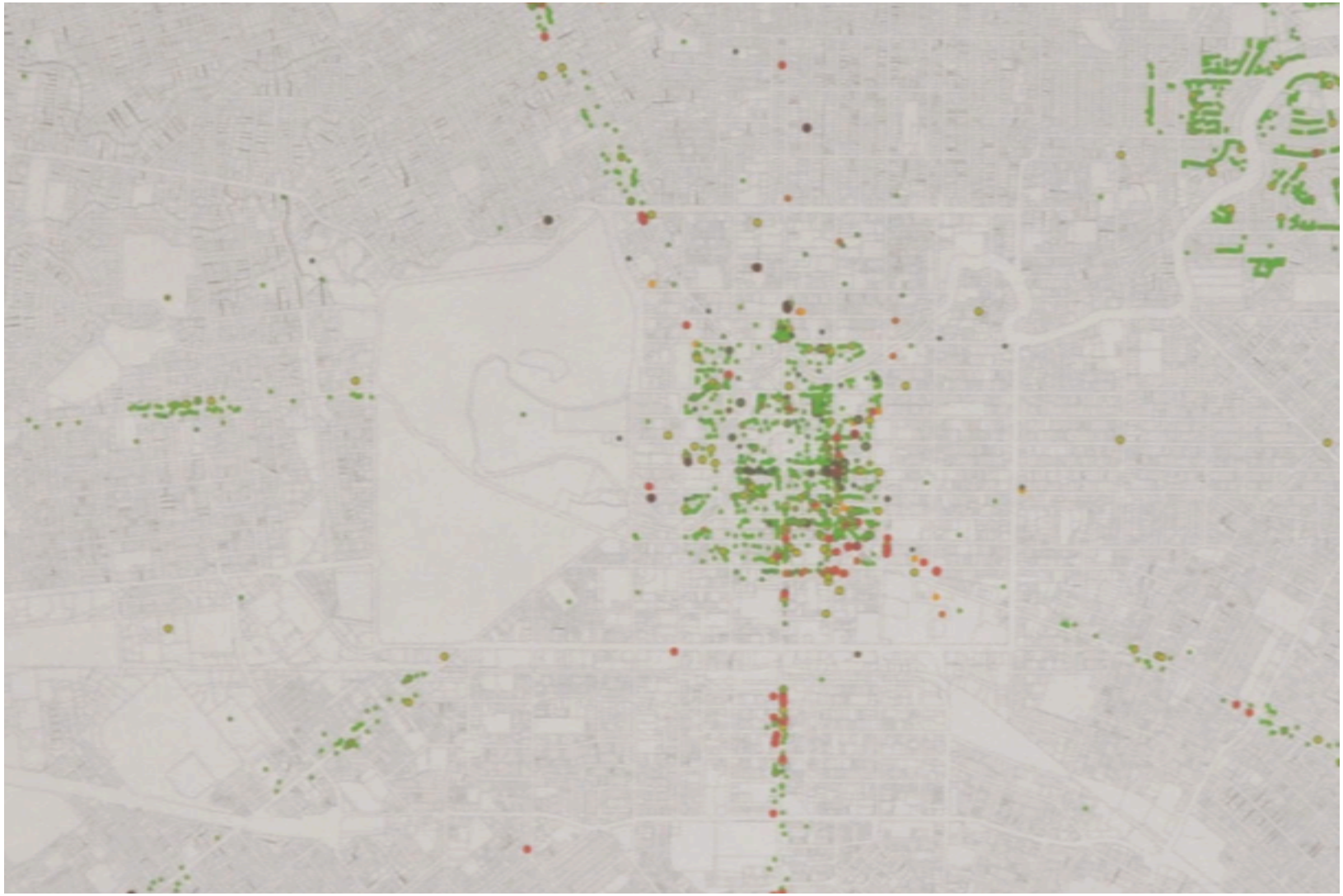
Fire Following Restoration of Electricity

Corey Stewart

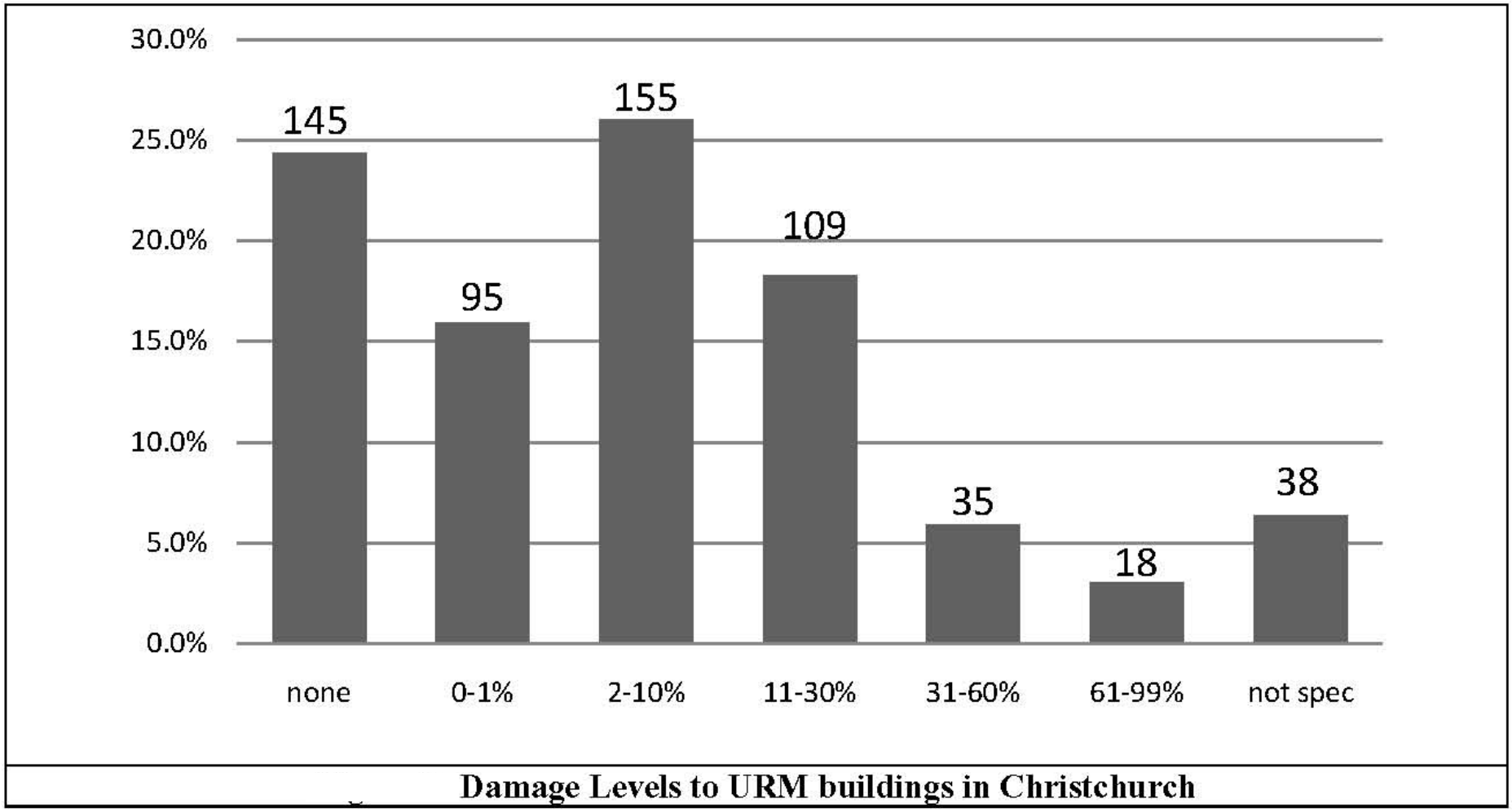
0.26 g, 41 cm/sec

Indirect Impacts of Collapsed URM Buildings

Safety Assessments in Christchurch's Central Bus. Dist.



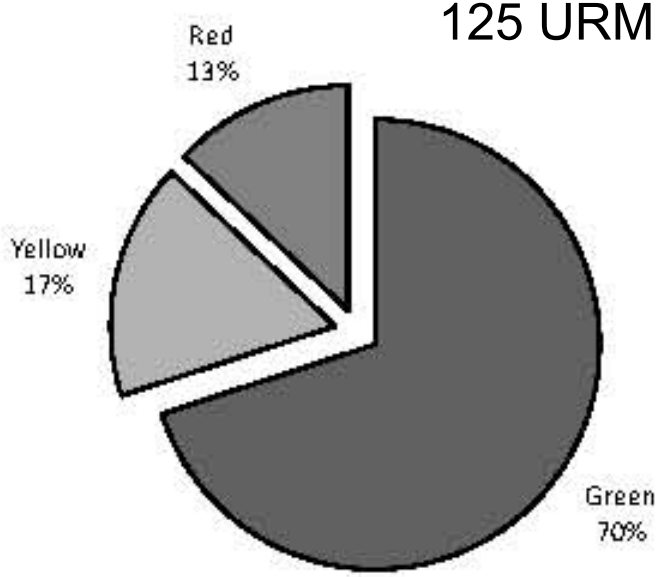
Damage Levels in URM Bldgs in Christchurch



From Jason Ingham and Mike Griffith

Damage Distribution of URMs in Christchurch

125 URM Buildings Red-Tagged



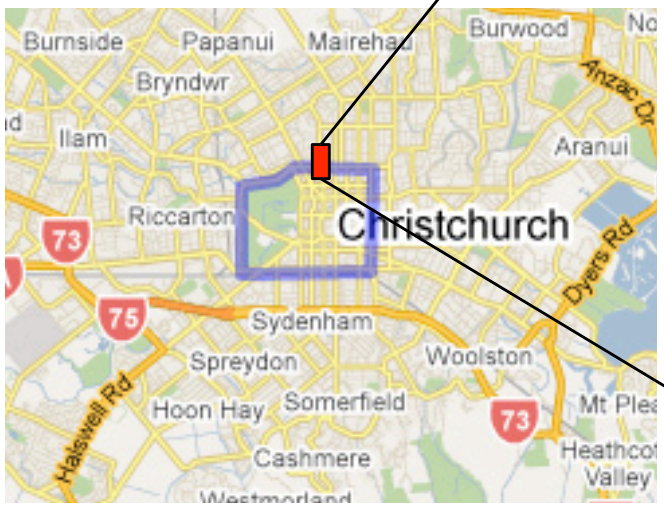
(b) Theorised damage distribution for entire building stock (958 entries)

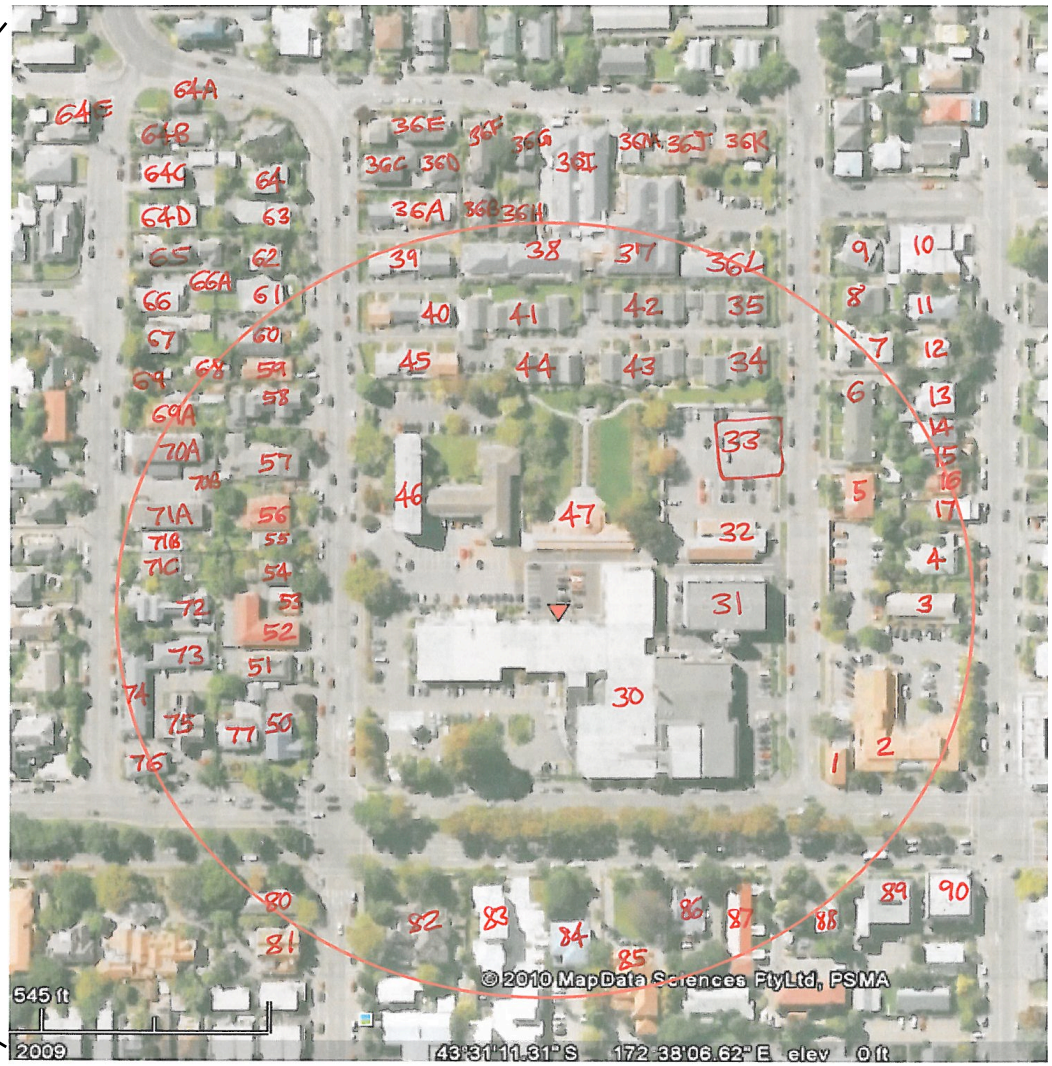
From Christchurch City Council, Jason Ingham and Mike Griffith

Christchurch Resthaven Pod of

Buildings and their Earthquake Performance Evaluation

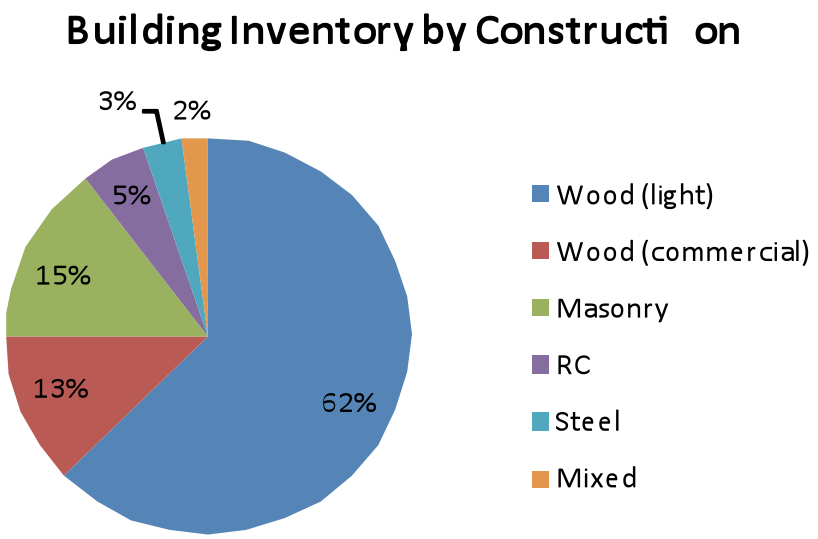
- 26%g PGA, 41 cm/sec
- 100 or so buildings

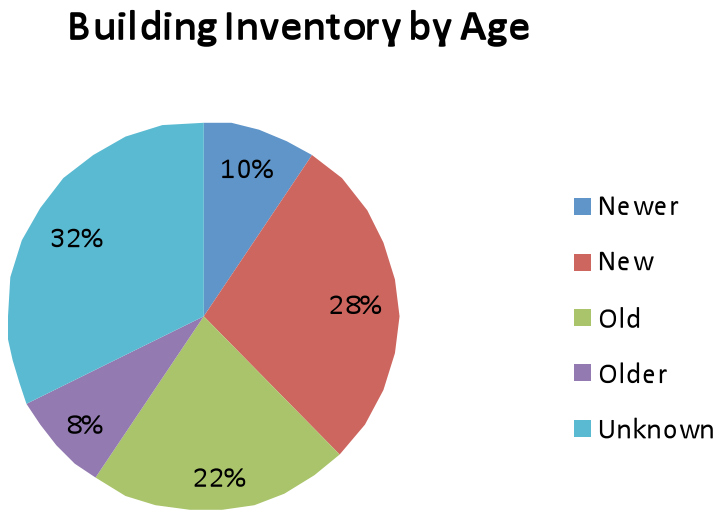




Per Structural Engineers Association of California's Earthquake Performance Evaluation Program

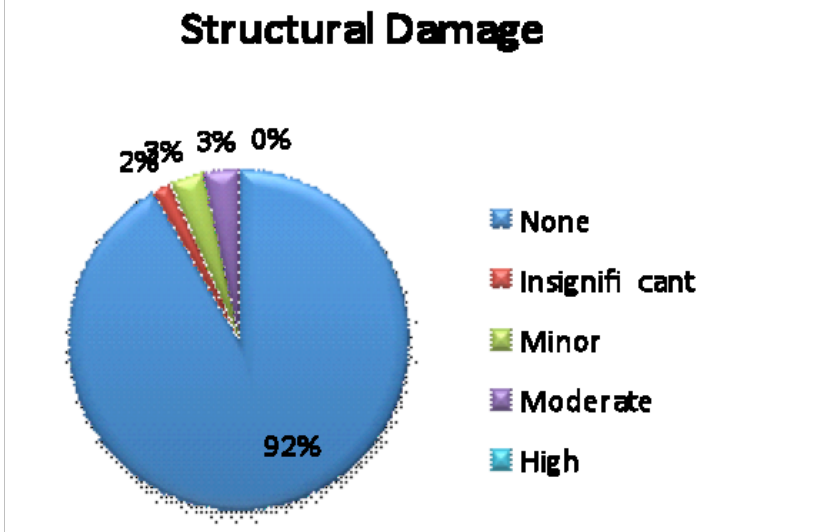
Building Inventory Distribution (Preliminary)

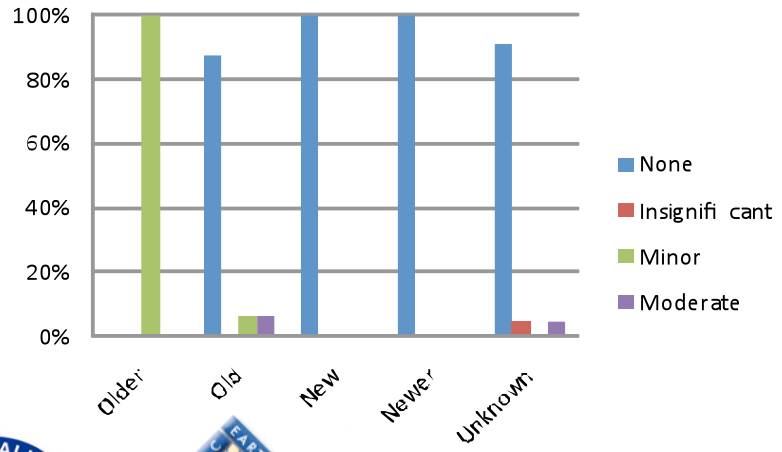


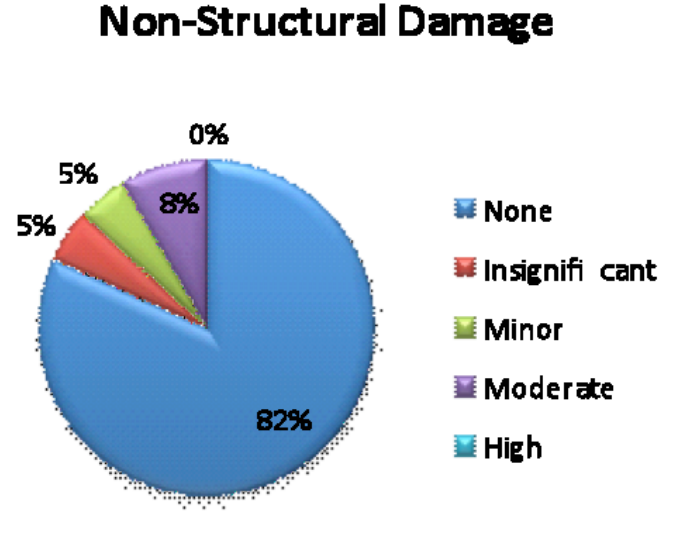


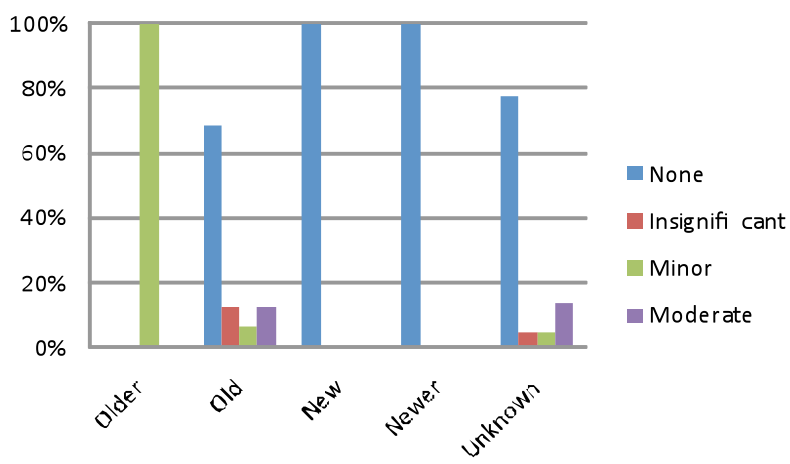
From Tao Lai AIR, EERI Team

Structural and Non-Structural Damage Statistics (Preliminary)









From Tao Lai AIR and EERI Team

URM Gable Wall Retrofits

0.26 g, 41 cm/sec

URM Parapet Retrofits

Earthquake Architecture

0.21 g, 50 cm/sec

Earthquake Architecture

0.21 g, 50 cm/sec

Less Intrusive Retrofits

0.21 g, 50 cm/sec

Use of Fibre Reinforced Polymers

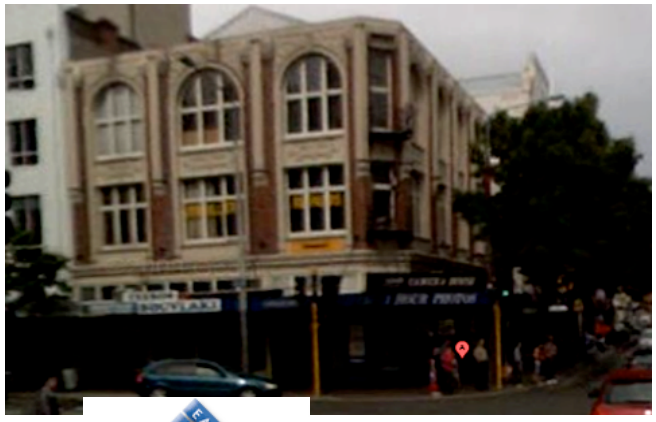
Lincoln University

Ivey Hall Retrofitted

Memorial Hall Unretrofitted

0.46 g, 80 cm/sec

Systematically Retrofitted Commercial URM Buildings



0.26 g, 41 cm/sec

NZ's Comprehensive Earthquake-Prone Building Law of 2004

Table 2.2 NZSEE Risk Classifications and Improvement Recommendations

Description	Grade	Risk	%NBS	Existing Building Structural Performance	Improvement of Structural Performance	
					Legal Requirement	NZSEE Recommendation
Low Risk Building	A or B	Low	Above 67	Acceptable (improvement may be desirable)	The Building Act sets no required level of structural improvement (unless change in use) This is for each TA to decide. Improvement is not limited to 34%NBS.	100%NBS desirable. Improvement should achieve at least 67%NBS
Moderate Risk Building	B or C	Moderate	34 to 66	Acceptable legally. Improvement recommended		Not recommended. Acceptable only in exceptional circumstances
High Risk Building	D or E	High	33 or lower	Unacceptable (Improvement required under Act)	Unacceptable	Unacceptable

From NZSEE's Advice on How to Assess and Improve Buildings in 2006

All NZ Local Governments must adopt a Policy on Earthquake-Prone Buildings

- Christchurch had adopted a passive policy triggered upon significant alterations prior to the Darfield Earthquake
- 6 days after the earthquake, Christchurch expanded its policy to include mandatory 15 to 30 year milestones for assessments and if warranted retrofits or demolitions

Summary of URM Issues

- Cumulative Impacts of Passive Retrofit Policy
- Many most vulnerable buildings not systematically addressed, some severely damaged
- Partial retrofits vs. Systematic retrofits
- Too early to tell how effective, but very promising – documentation critically relevant to NZ, US, Canada particularly regions of moderate seismicity
- Performance somewhat inconclusive due to moderate intensity short period ground motions
- Many buildings on verge of collapse
- Expect much more damage & casualties other times of day

Westpac Bldg

0.23 g, 57 cm/sec

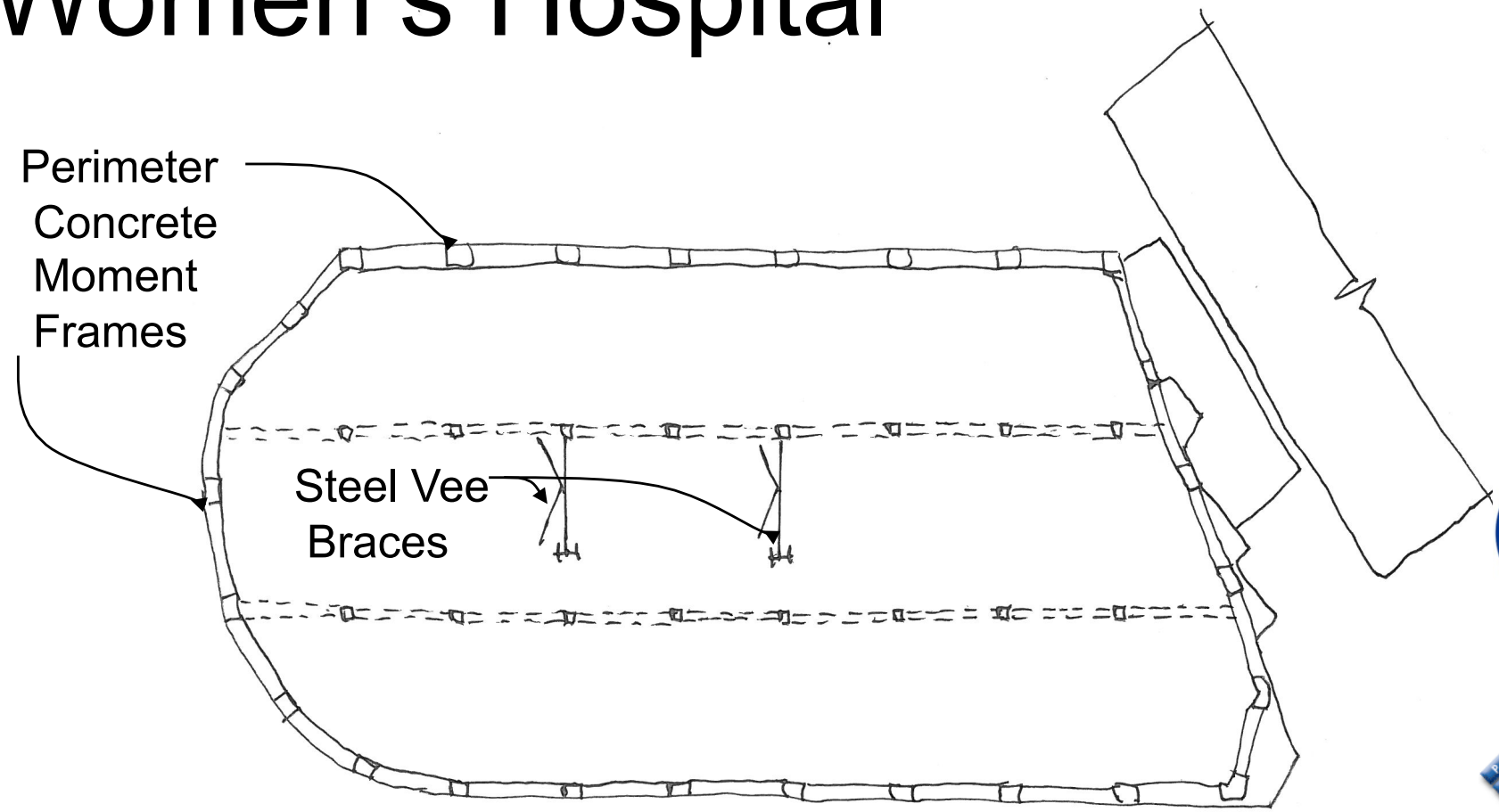
Before

After

Women's Hospital Seismically Isolated

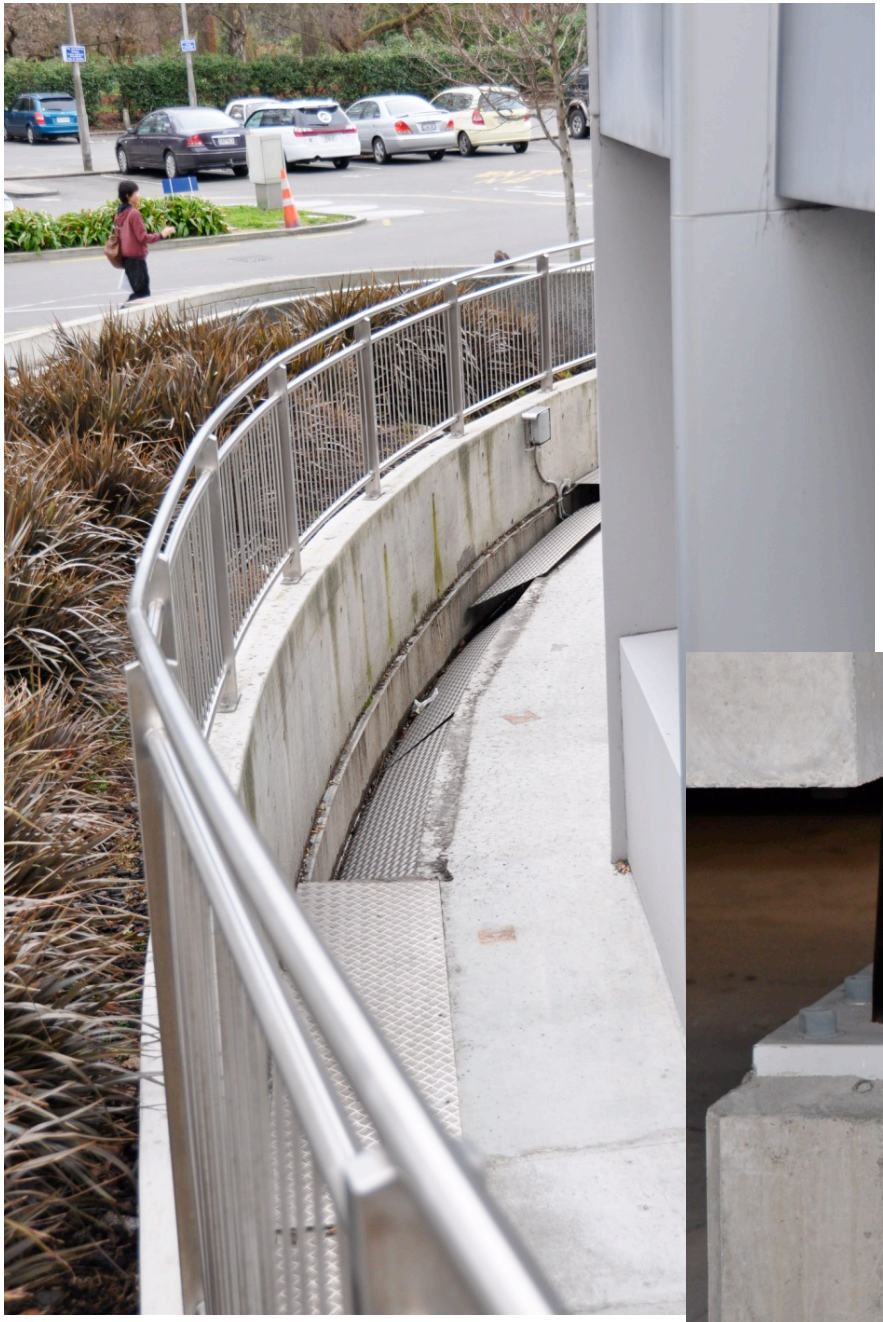
0.21 g, 50 cm/sec

Women's Hospital

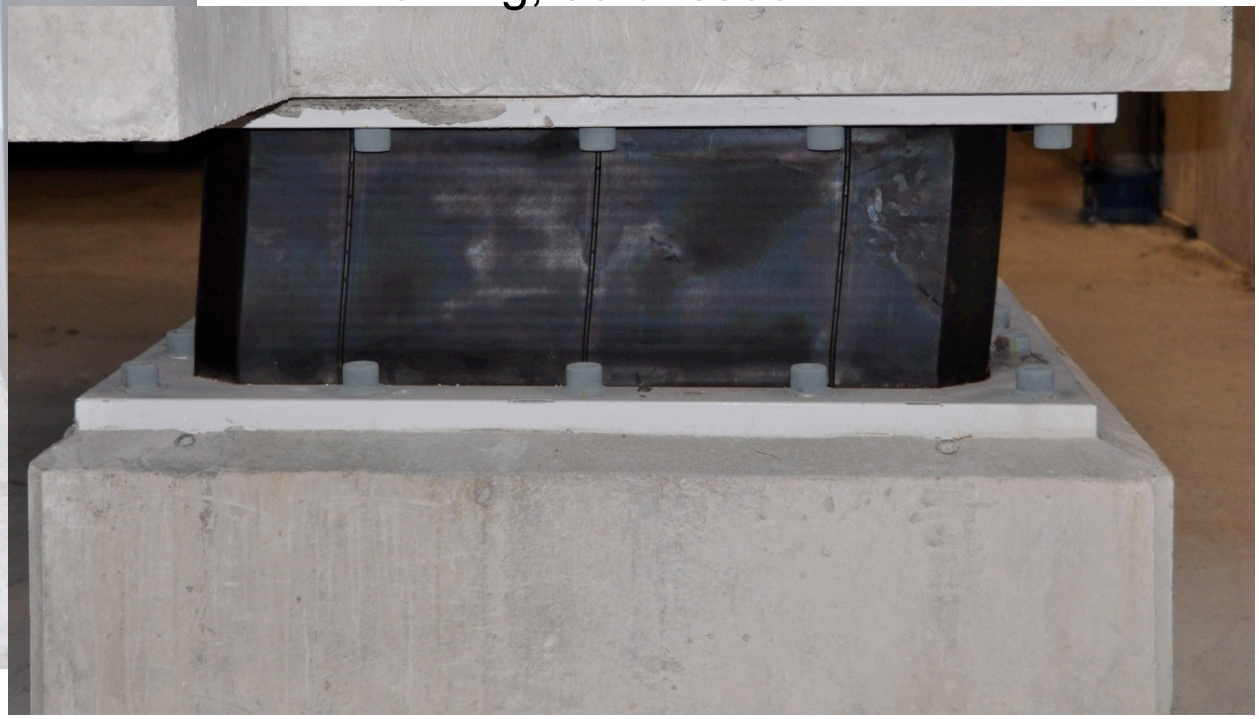


Sketch of Typical Lower Floor Framing Plan

0.21 g, 50 cm/sec

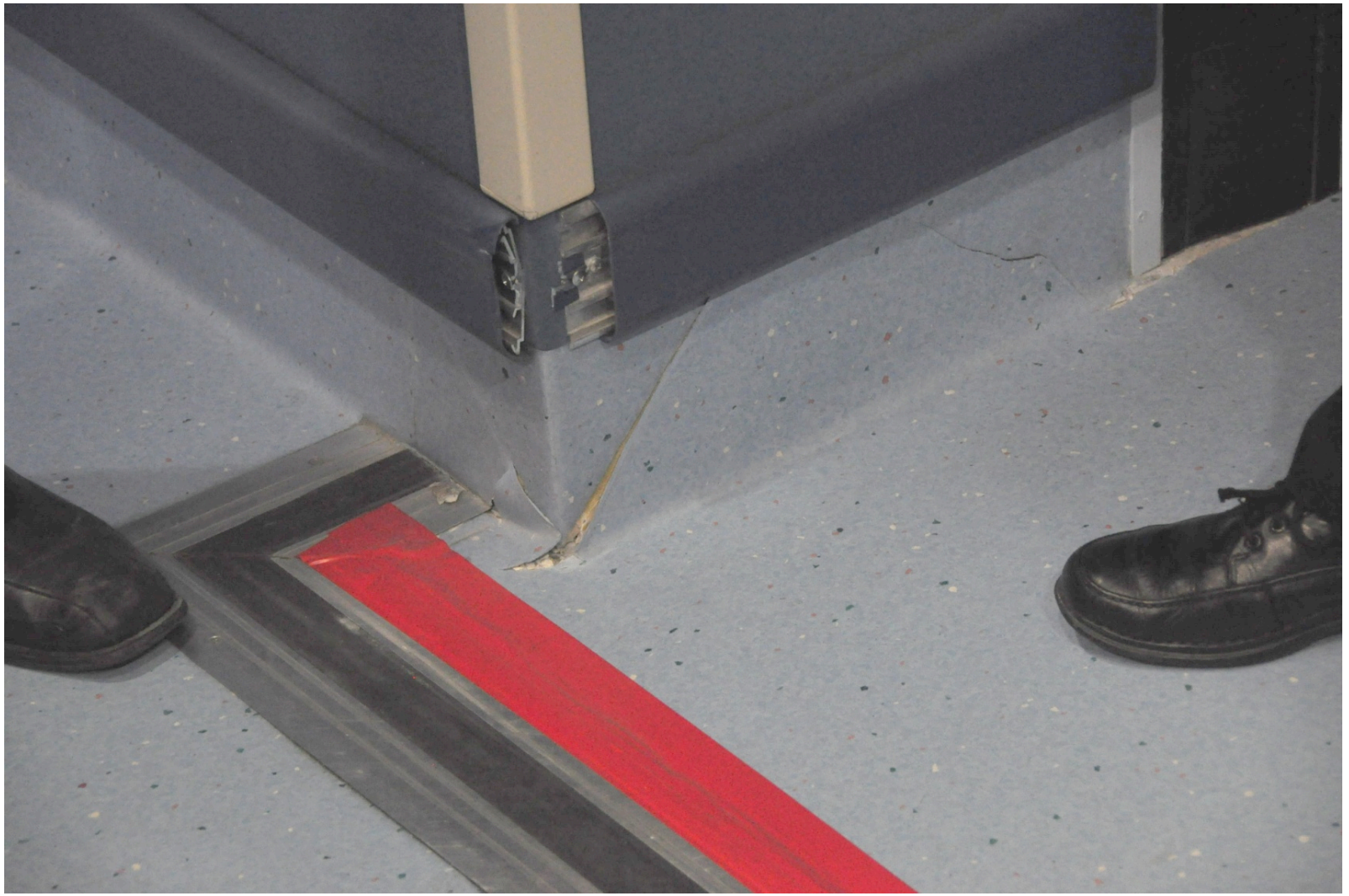


0.21 g, 50 cm/sec



Women's Hospital Damage to Finishes at Structural Separation

0.21 g, 50 cm/sec



Parking Garage with EB Frame

0.21 g, 50 cm/sec

Parking Garage EB Frame 0.21 g, 50 cm/sec

Parking Garage EB Frame 0.21 g, 50 cm/sec

Parking Garage with Precast Concrete Columns & Steel Eccentric Braced Frames

0.21 g, 50 cm/sec

Port of Lyttleton

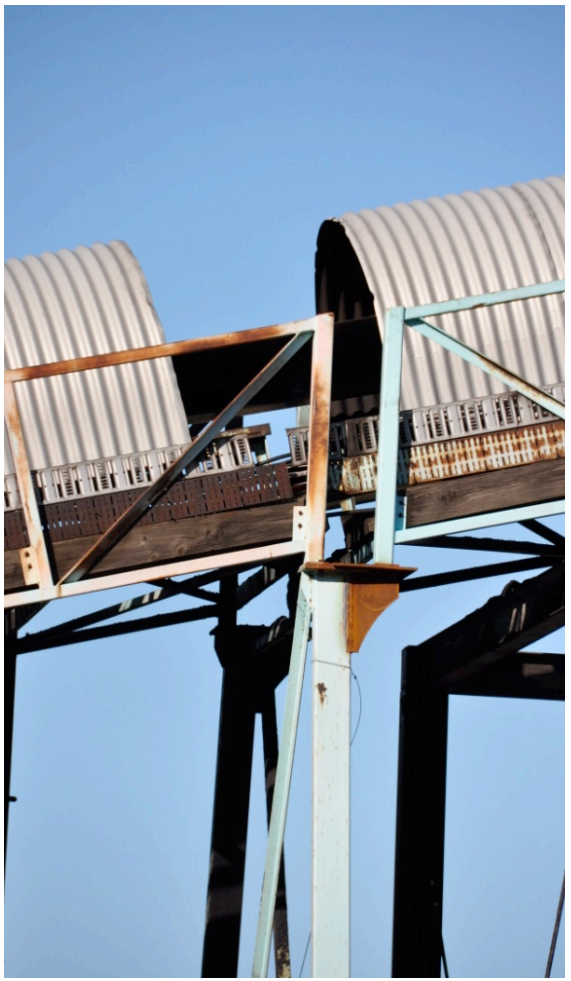
0.36 g, 19 cm/sec on rock

Port Lateral Spreading

0.36 g, 19 cm/sec on rock nearby

Port Damage to Bulk Coal Conveyor

0.36 g, 19 cm/sec on rock nearby



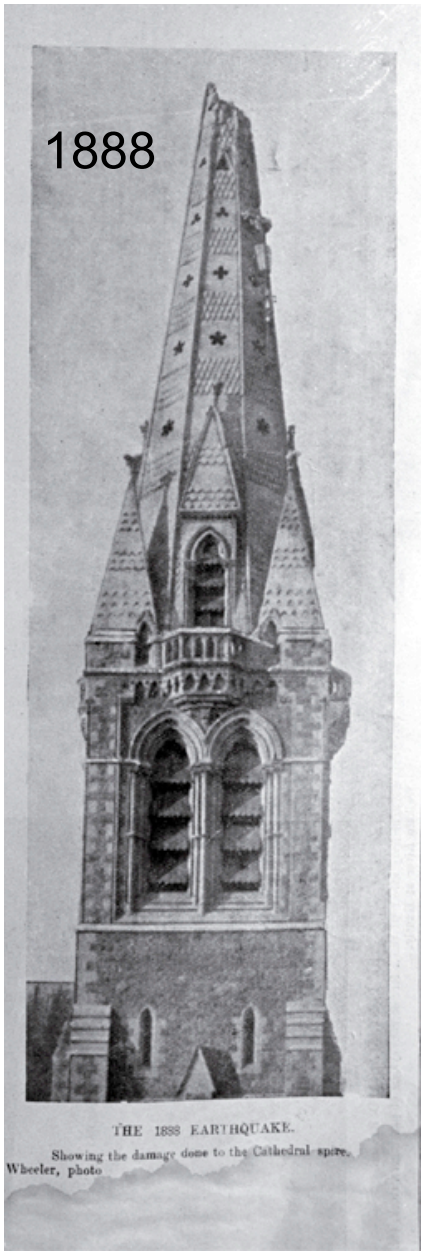
Port Cranes Still Operable

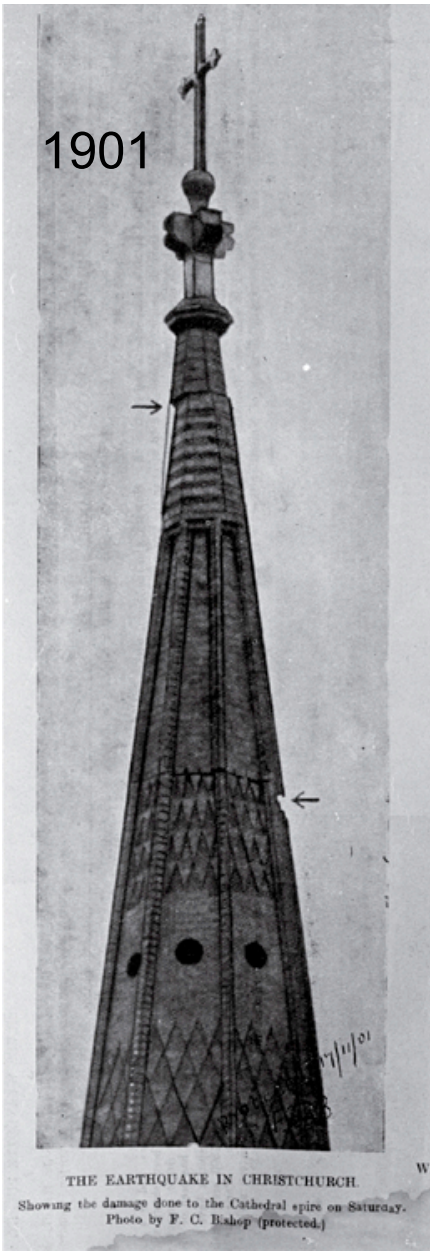
0.36 g, 19 cm/sec on rock nearby

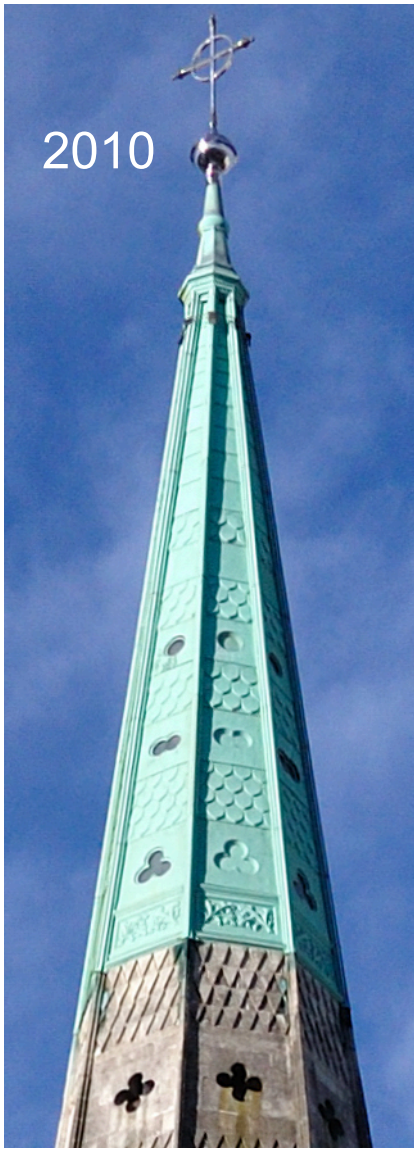
Image Credits

- Jason Ingham, Mike Griffith & Ismail Najif, Univ. of Aukland
- Myrto Anagnostopoulou, MCEER, EERI Team
- Corey Stewart
- Tao Lai, AIR, EERI Team
- Twitterers in Christchurch
- GNS Science, Te Pu Ao
- Google and Bing Maps and Aerials
- Structural Engineering Society of NZ
- NZ Society of Earthquake Engineering
- Christchurch City Libraries
- Christchurch City Council

Cathedral Spire Reflects Progress







0.26 g, 41 cm/sec