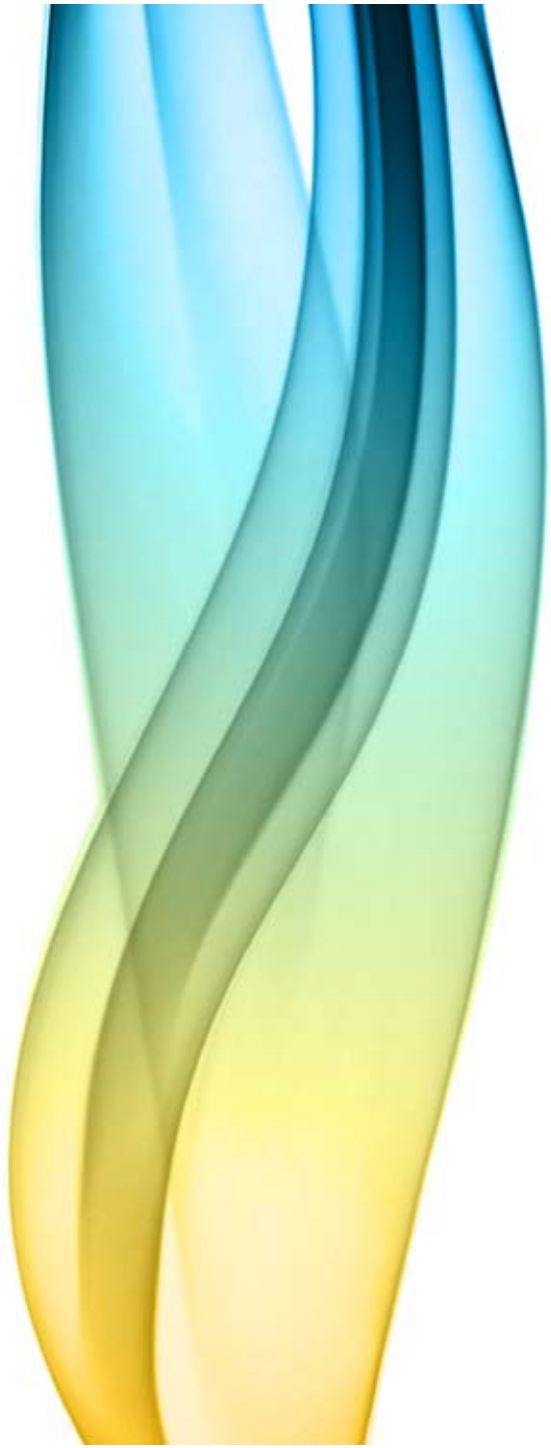


Investigation into the collapse of the stairs in the Forsyth Barr building

Mr Rob Jury and Dr Richard Sharpe

This Presentation Covers:

- Our investigations
  - History
  - The building and the stairs
  - The earthquakes and their effects
  - Design and construction issues
  - Analysis results
- Reason for collapse
- Conclusions
- Recommendations

Our Investigations

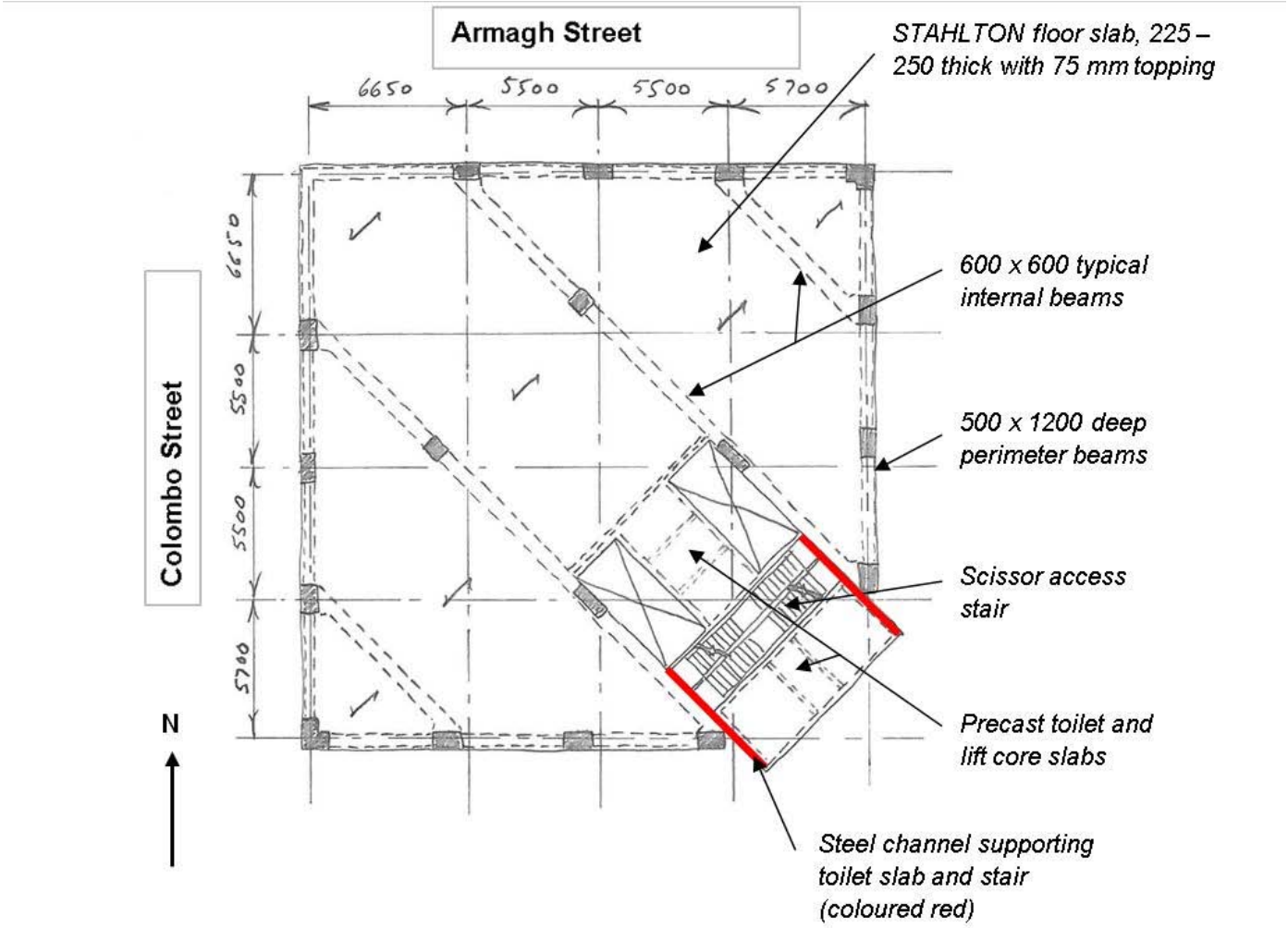
- Began in early April 2011
- All documents made available
  - Christchurch City Council files
  - Owner's structural engineers' files
  - Original drawings for construction of structure
  - Photos (including USAR)
  - Witness statements
- Earthquake records
- Simulation of building in earthquake (computer)
- Site Visit

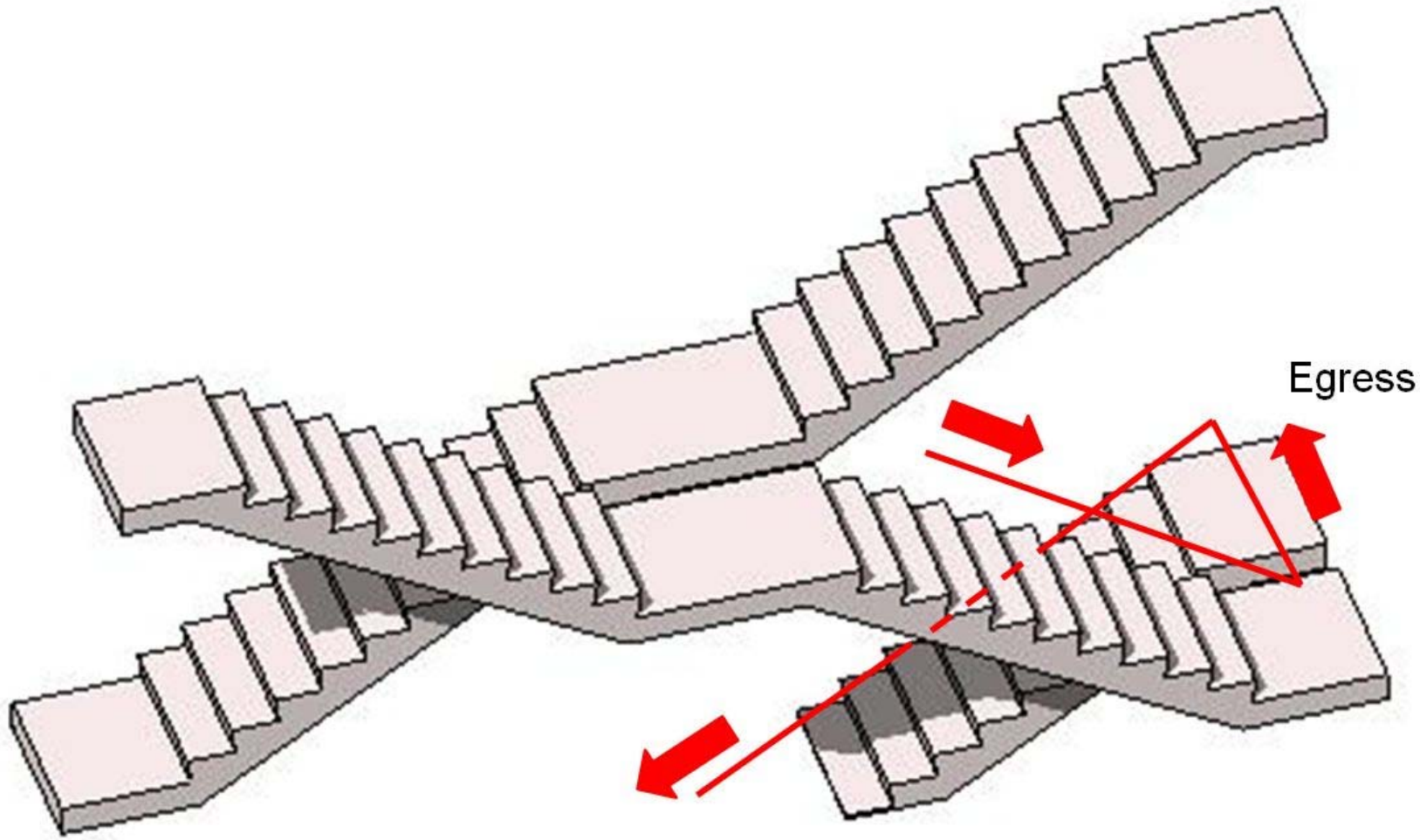
History of the building

Date	Event	Comment
1988	Designed as Robert Jones House	
1988	Constructed	Building Consent 1988
5th Sept. 2010	Level 1 Rapid Assessment	Unsafe (Red)
5th September 2010	Level 2 Rapid Assessment	Restricted Access (Yellow)
6th September 2010	Level 2 Rapid Assessment after inspection of stairs and propping completed	Inspected (Green)
15th September 2010	Level 2 Rapid Assessment after inspection of in-filled slab at floor level 7.	Confirmed as Inspected (Green)
Oct 2010-Feb 2011	Repairs to floor coverings on stairs and landings	
Nov 2010 – Feb 2011	Repairs to structural elements	

The Building and the Stairs

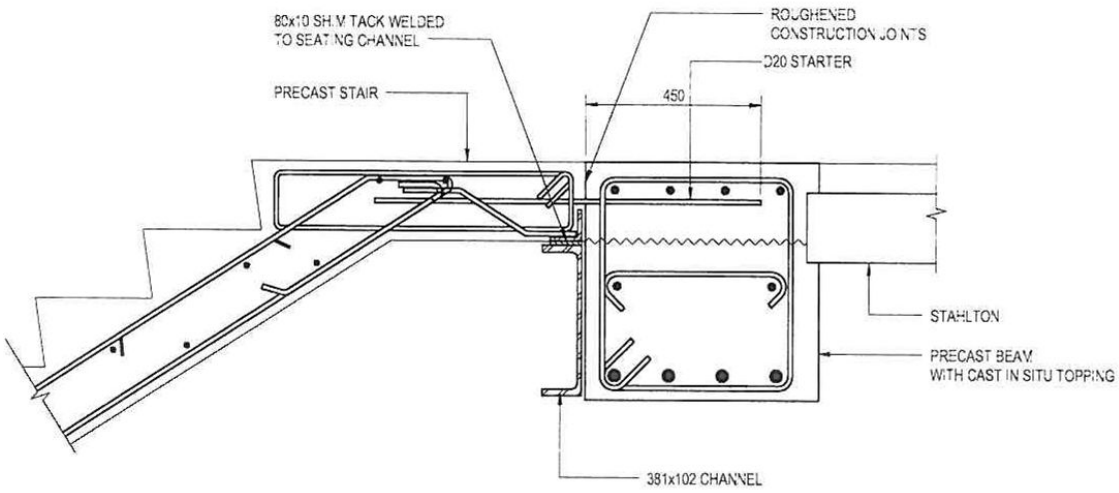

SMITH

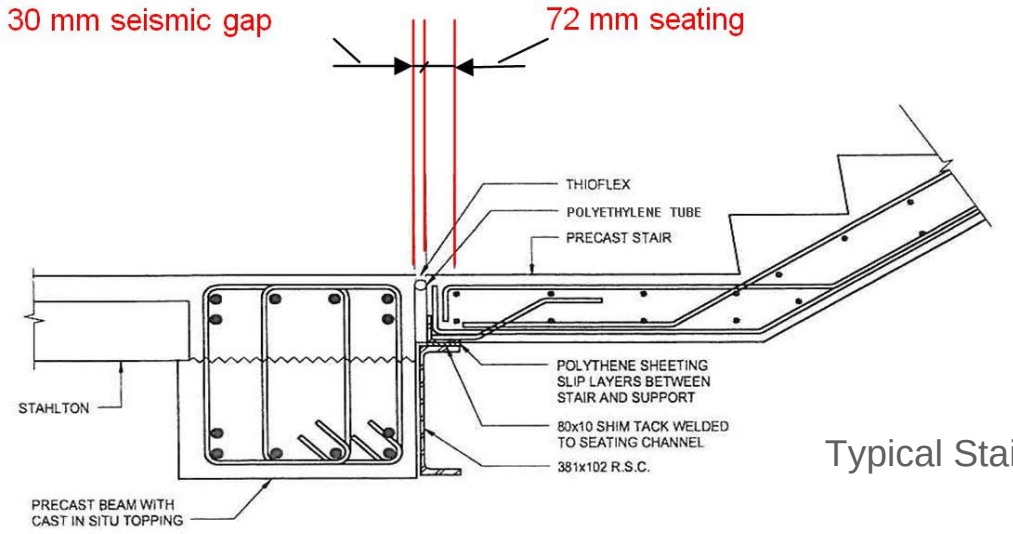

Armagh Street
Colombo Street
N
6650
5500
5500
5700
6650
5500
5500
5700
STAHLTON floor slab, 225 – 250 thick with 75 mm topping
600 x 600 typical internal beams
500 x 1200 deep perimeter beams
Scissor access stair
Precast toilet and lift core slabs
Steel channel supporting toilet slab and stair (coloured red)



Scissor Stair Arrangement

Typical Stair Top Support Detail

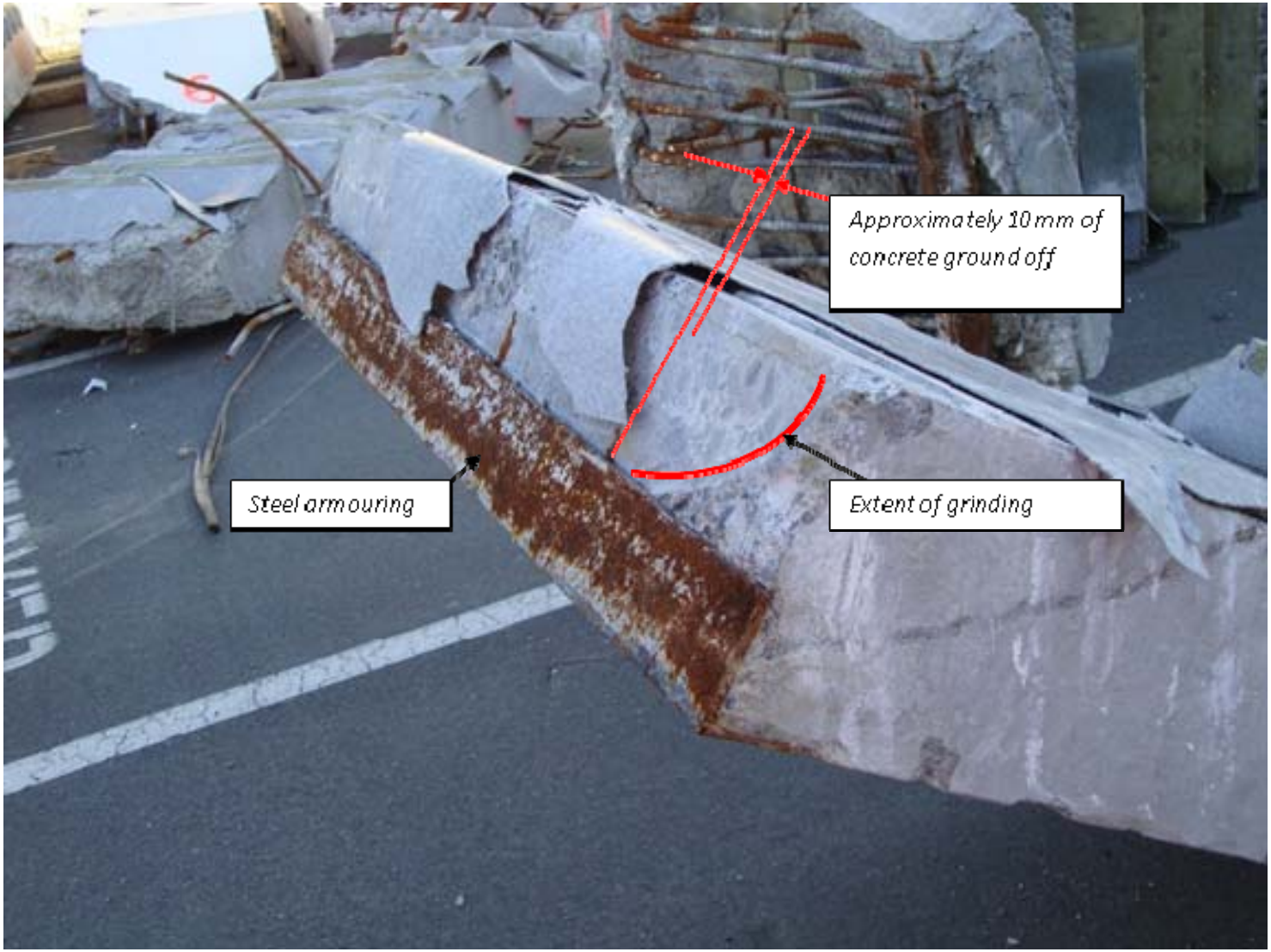




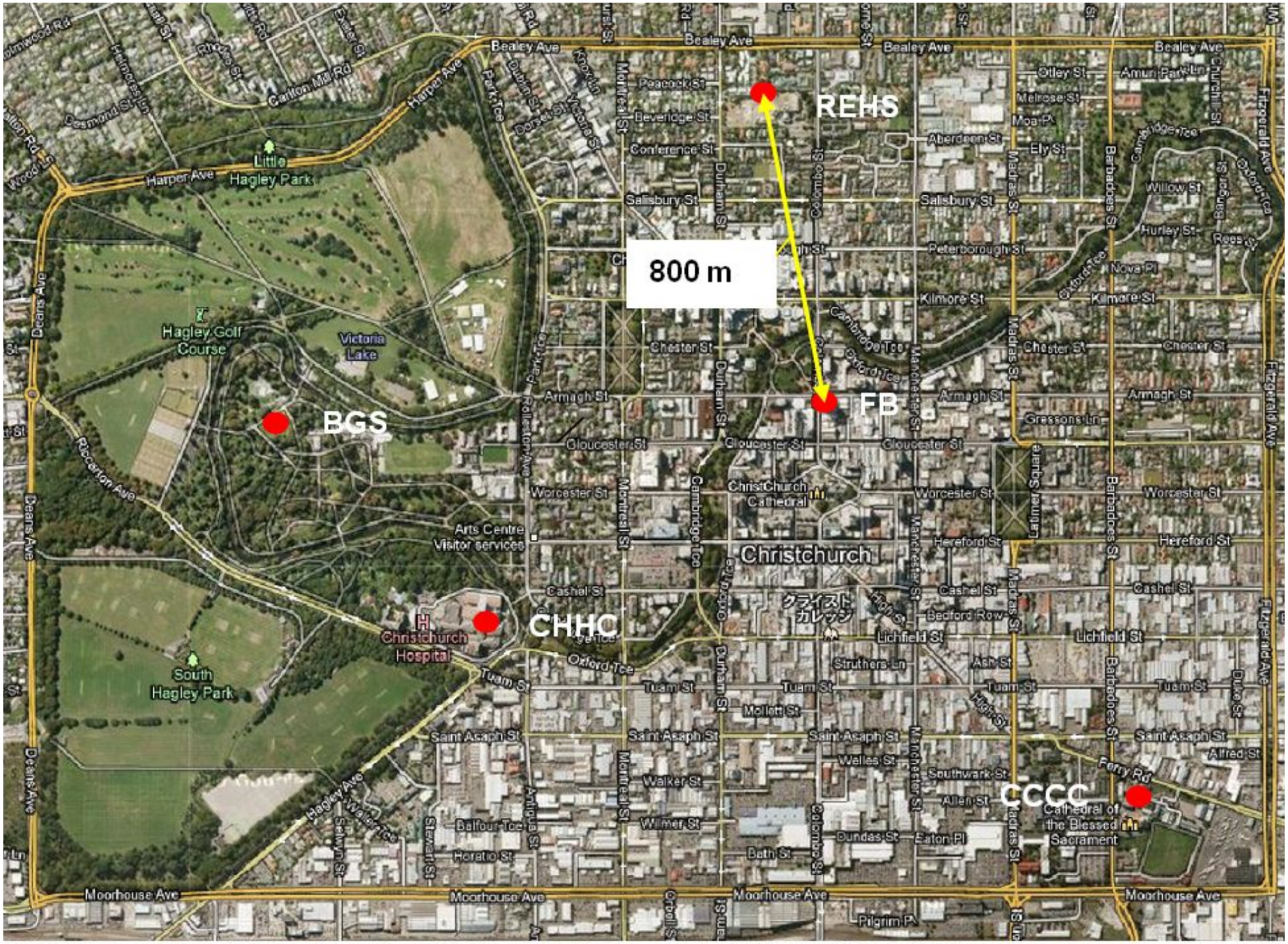
Typical Stair Bottom Support Detail

Design & Construction Issues

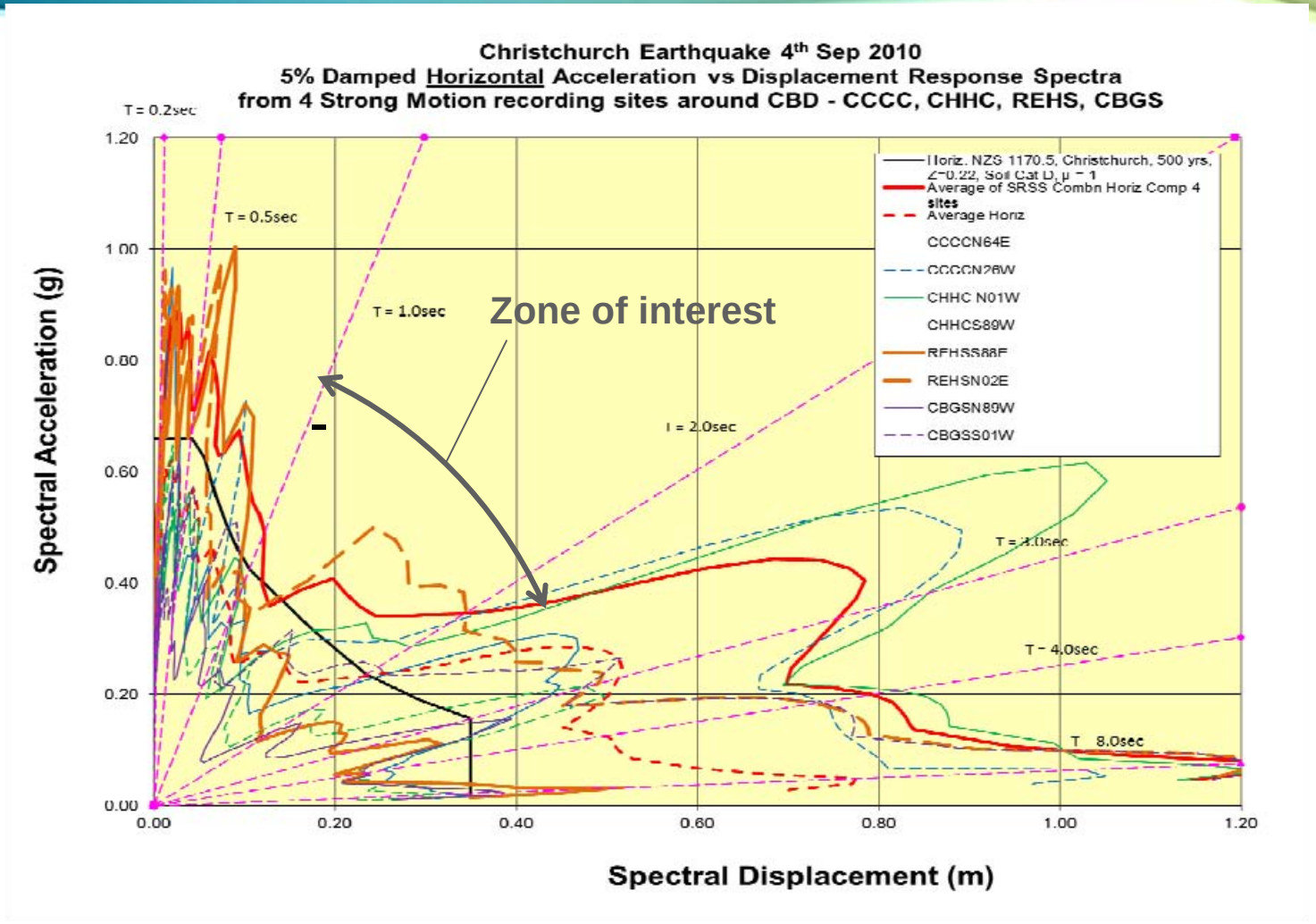
- The building appears to have been designed in accordance with the standards of the time (1988).
- The construction of the stairs appears to have been in general accordance with the design, but with some exceptions.

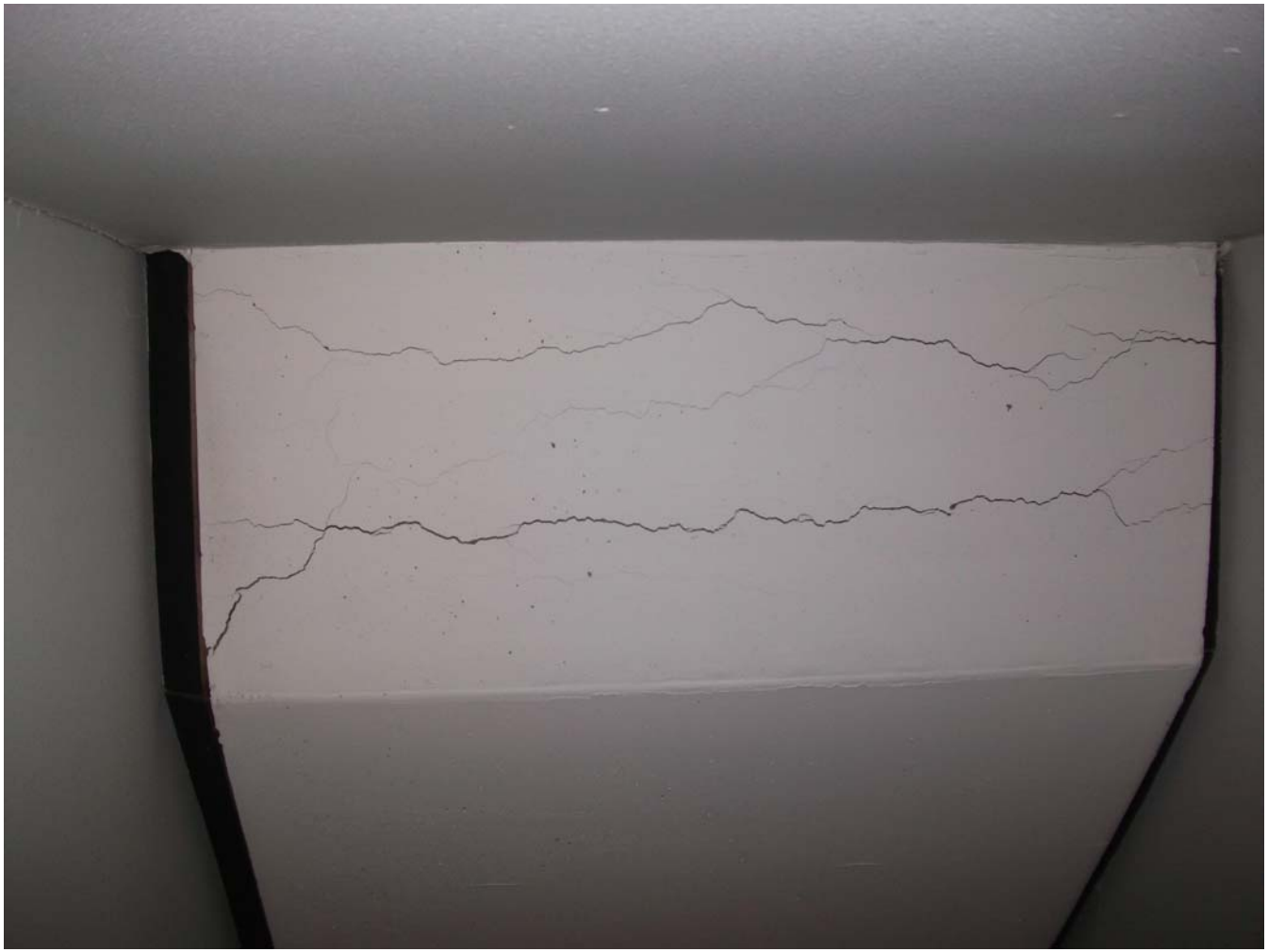

Approximately 10 mm of concrete ground off
Steel armouring
Extent of grinding

The Earthquakes and Their Effects

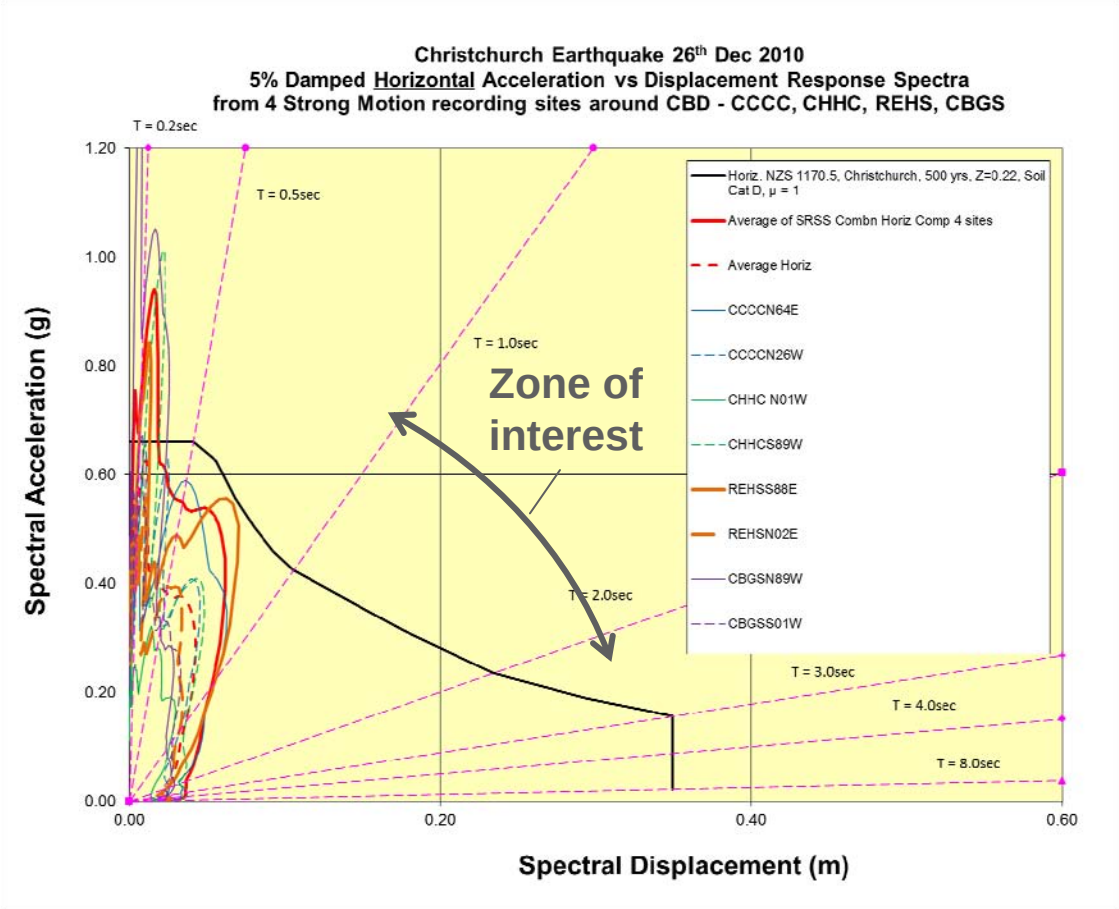


The Shaking on 4th September 2010

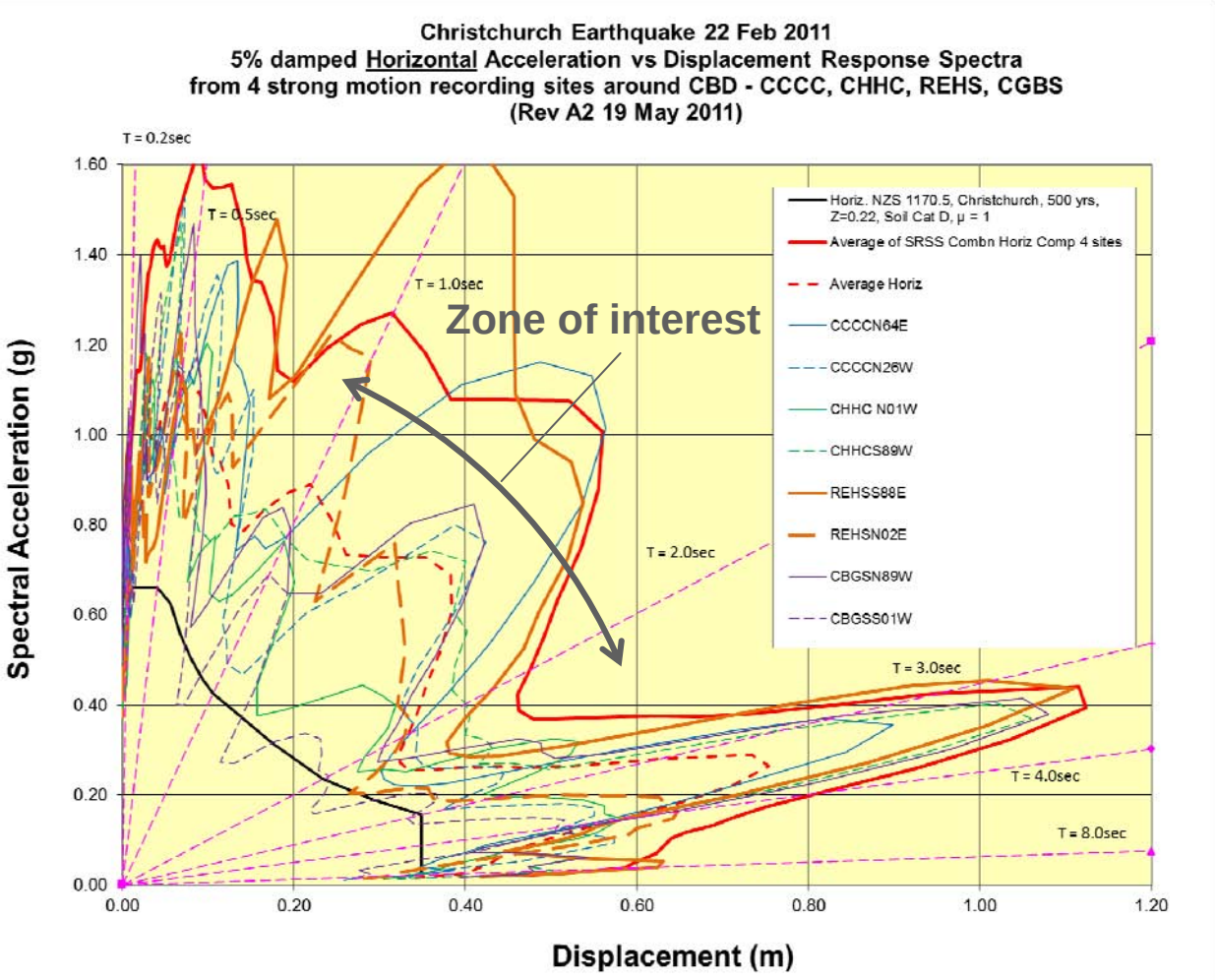




The Shaking on 26th December 2010



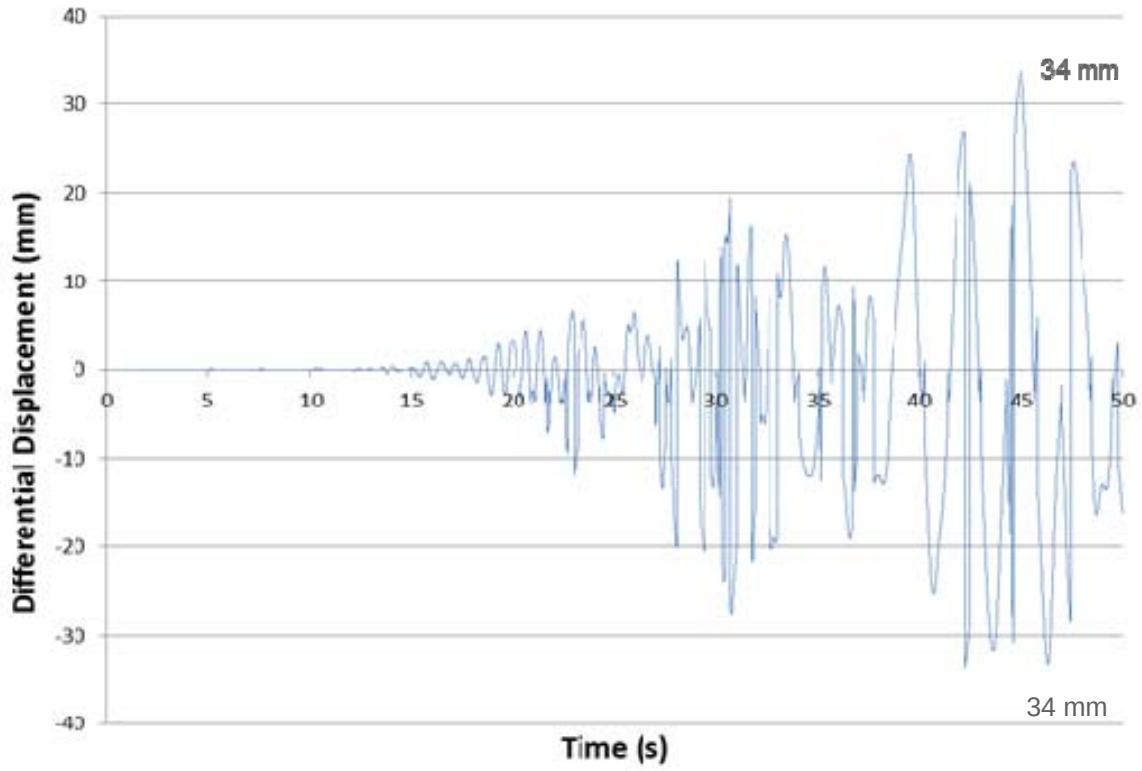
The Shaking on 22nd February 2011




THIS AREA IS FOR THE USE OF
AUTHORISED PERSONS ONLY!
BRENNER MEATS

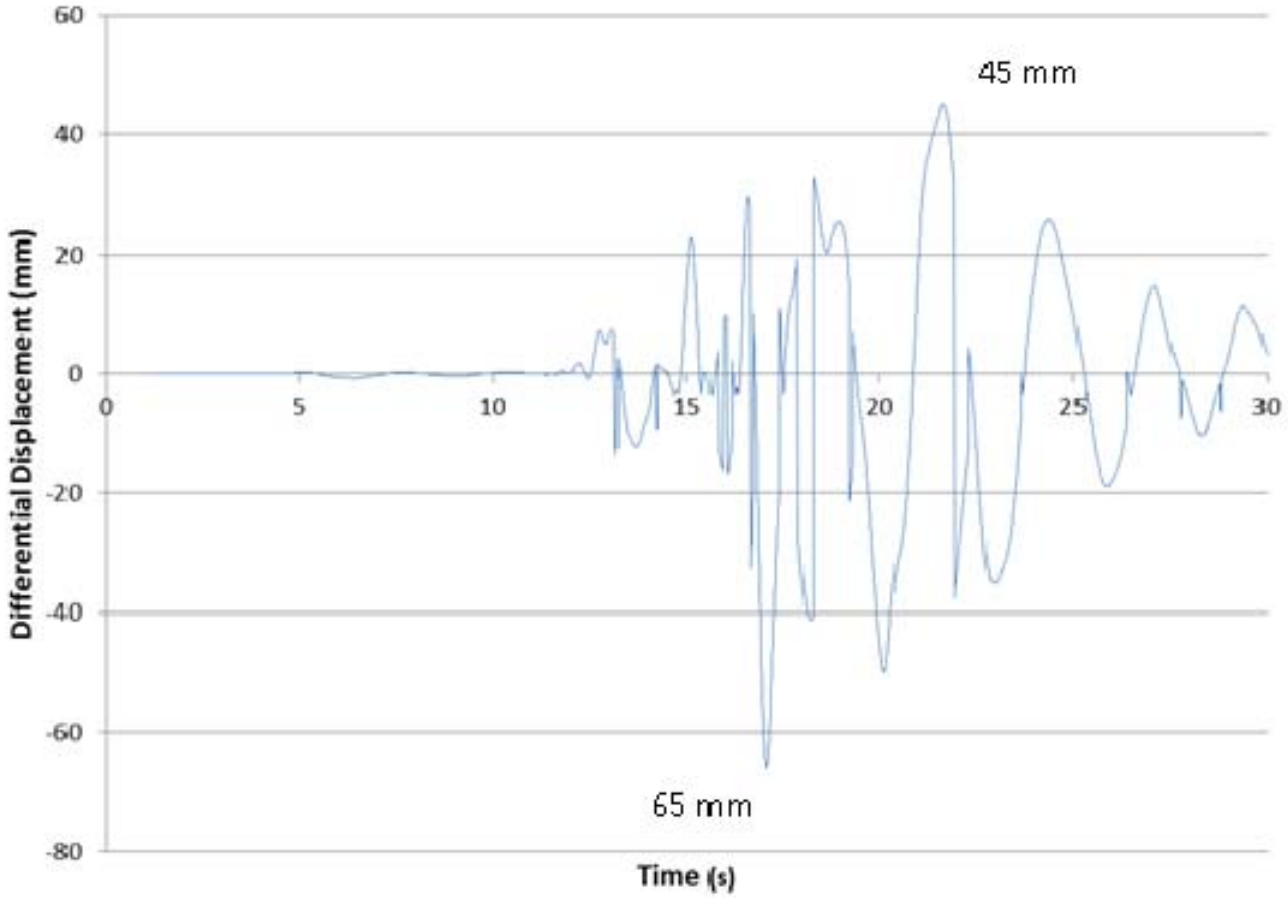

04/03/2011
FROM
MEASUREMENTS
LENGTH
FACE
TO FACE

Analyses of the Building



Interstorey drifts during 4 September 2010 Earthquake

Analyses of the Building - 2

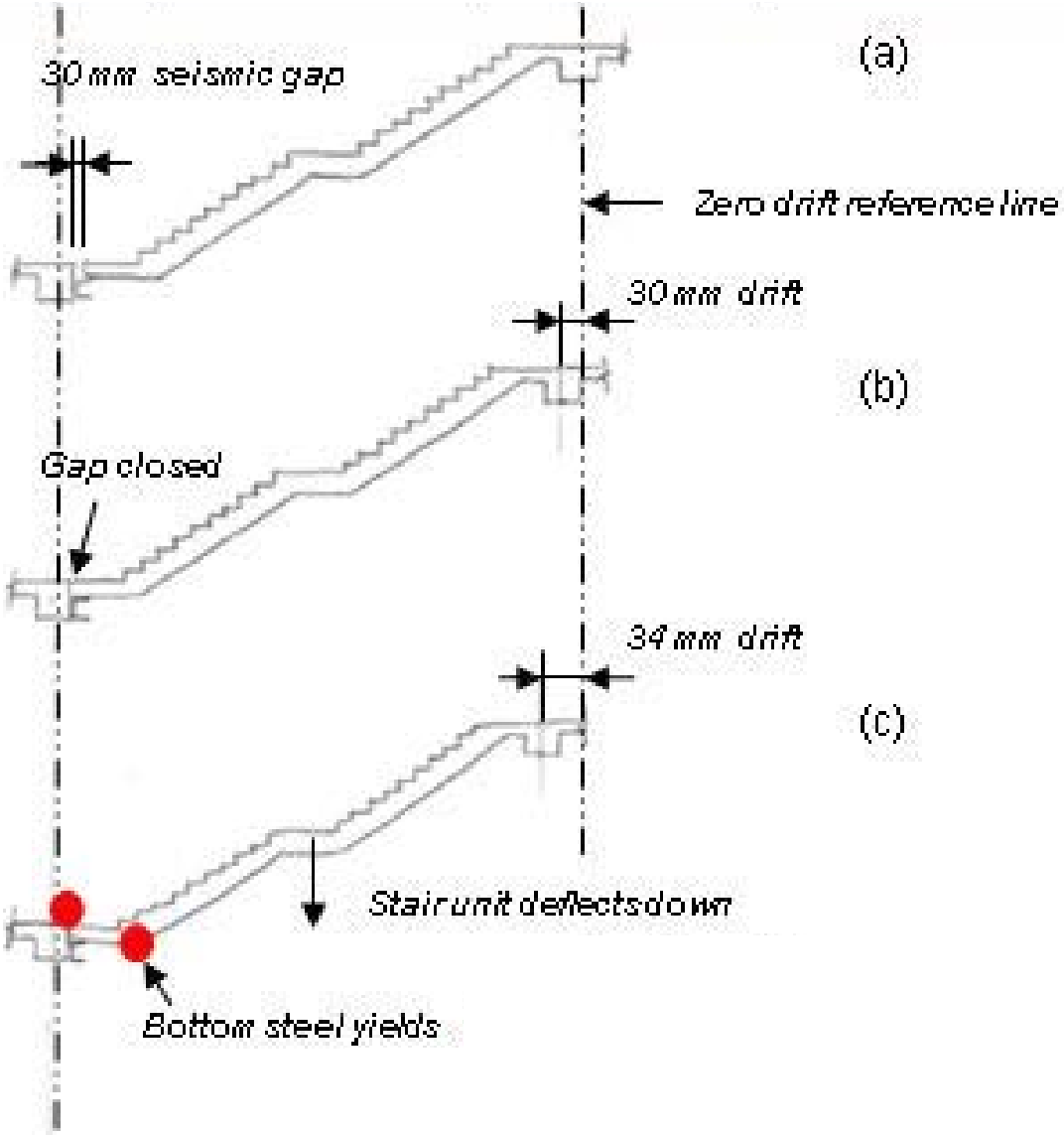


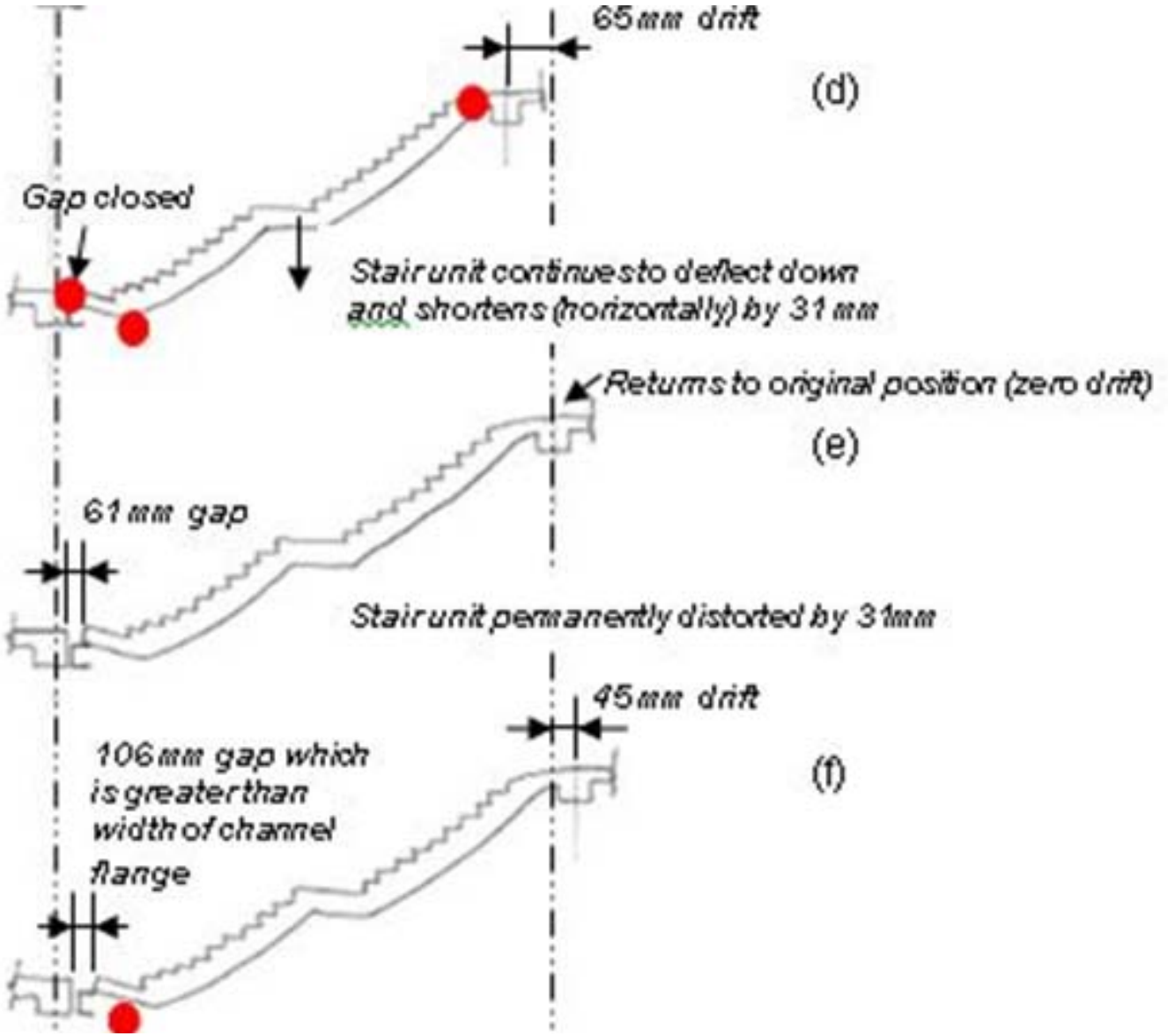
Interstorey drifts during 22 February 2011 Earthquake

Analyses of the Stair

- Yield in the bottom reinforcement at lower knee joint occurs under a restrained storey drift of approx 4mm
- Horizontal and vertical displacements at the lower knee joint are sensitive to horizontal displacements once the stair is “locked in”. E.g. 10mm locked in drift is predicted to cause permanent distortions of 25mm vertical and 15mm horizontal.
- Modal analyses under vertical excitation did not indicate resonant response
- The observed shear failure in the stair unit is consistent with our calculations of the stresses resulting from compression

Inferred Collapse Sequence




65mm drift
(d)
Gap closed
Stair unit continues to deflect down and shortens (horizontally) by 31 mm
Returns to original position (zero drift)
(e)
61 mm gap
Stair unit permanently distorted by 31mm
45mm drift
106mm gap which is greater than width of channel flange
(f)

(g)

Reason for Stair Collapse

- The shaking experienced on 22nd February led to between-floor displacements that were larger than those for which the the stairs were designed.
  - One or more stairs fell off their lower seating at around the 15th floor.
  - A domino effect collapsed stairs below.

Previous investigations

- University of Canterbury Masters Research Report, July 2000, '*The safety of single storey straight stair flights with mid height landings under simulated seismic displacements' by Peter Simmons*
- Prompted by interest of original designer in the seismic performance of the Forsyth Barr stair and designers of other similar stairs and in particular the ability of such stair units to take compression.
- Concluded that the seismic gaps should be maintained to ensure that the stair was not subjected to compression
- Did not consider the significance of the ledge support length

Conclusions

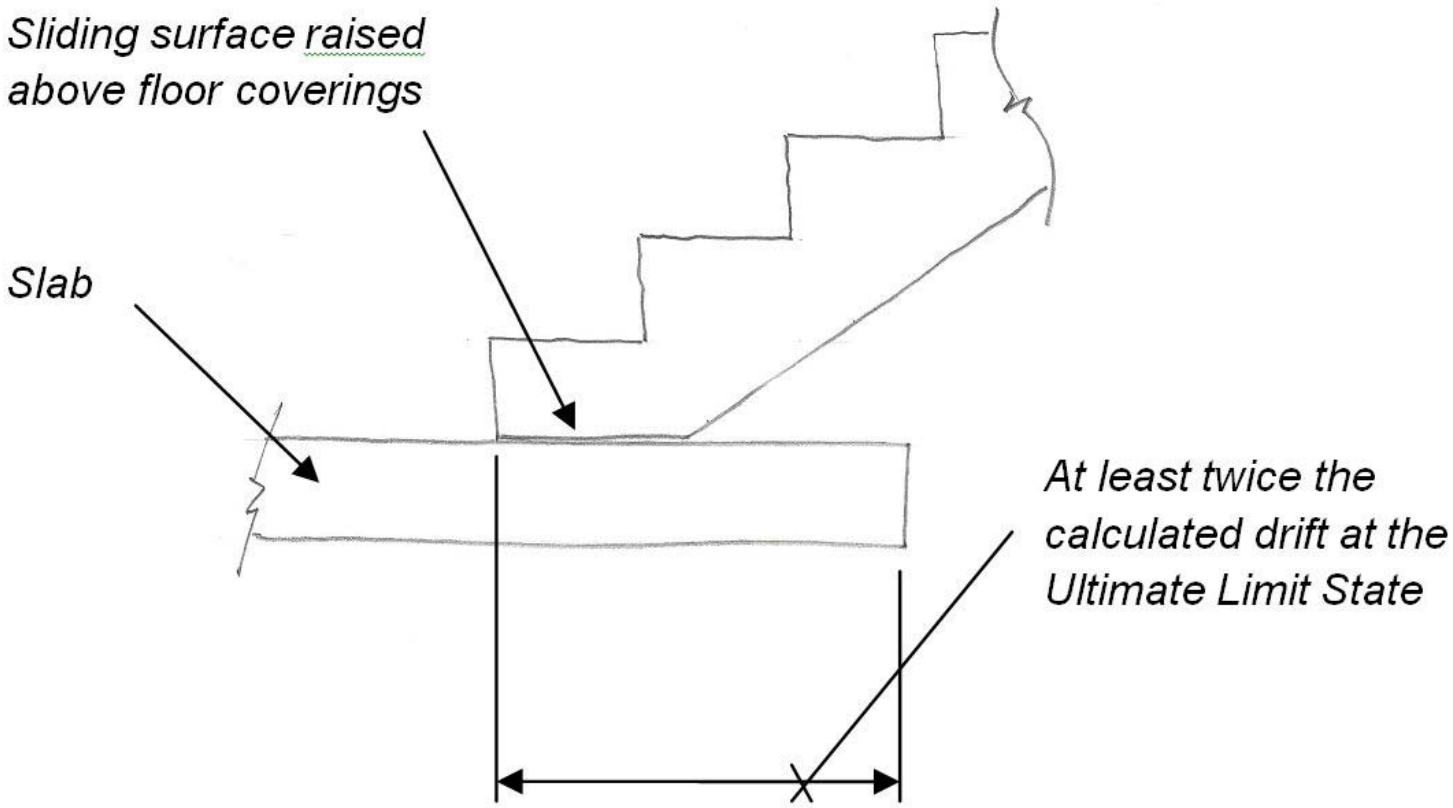
- Interstorey drifts in 22 Feb earthquake predicted to exceed original code requirements by 80% and current code requirements by 60%
- The specified stair seismic gap met code requirements of the day but was insufficient with respect to current code
- There was evidence of filling of the seismic gap which would increase the likelihood of support loss but collapse was still predicted in 22 Feb earthquake even if gaps were clear
- Although the stairs may have survived if the drifts required by the current code had been allowed for, collapse was still possible if the gaps had been compromised.

Conclusions cont…

- Once one stair unit was lost there was the potential for progressive failure of all stair units below

Recommendations

- Known alternatives to the gap detail should be used on all new buildings


Sliding surface raised above floor coverings
Slab
At least twice the calculated drift at the Ultimate Limit State

Recommendations

- Known alternatives to the gap detail should be used on all new buildings
- DBH should issue an advisory note warning of potential issues –DONE
- To improve resilience and to recognise that the performance of egress stairs should better building performance consideration should be given to requiring seating lengths at least twice the ULS interstorey drift – RECOMMENDATION ISSUED
- Seismic Gaps should not be compromised under any circumstances.