Department of
Building and Housing
Te Tari Kaupapa Whare

Structural performance of Christchurch CBD buildings in the 22 February 2011 earthquake

Summary

Following the Magnitude 6.3 earthquake on 22 February 2011 that caused severe damage to Christchurch city, the Department of Building and Housing decided to undertake a detailed investigation into the performance of four relatively modern multi-storey buildings in the central business district (CBD) that had serious structural failures.

These were the:

- Canterbury Television (CTV) Building
- Pyne Gould Corporation (PGC) Building
- Hotel Grand Chancellor Building
- Forsyth Barr Building.

The Department appointed engineering consultants to investigate each of the buildings. The Department also appointed an independent Expert Panel to oversee and review the findings of these investigations. On 30 September 2011, the Expert Panel issued an interim report covering three buildings (the PGC, Forsyth Barr and Hotel Grand Chancellor buildings), along with the technical investigation reports for each building. The investigation into the Canterbury Television (CTV) Building took longer because it was more complex.

This summary covers the main points of the investigation into the collapse of the CTV Building, drawing on the consultants' CTV Building Collapse Investigation Report and the summary in the final Expert Panel report. This document summarises the recommendations that have resulted from the investigations into all four buildings, and the Department's response to them.

EXPERT PANEL

The Department appointed professional engineering consultants to investigate the issues with each building and established an Expert Panel to oversee their work, provide guidance on the methodology of the investigations, and review and approve consultants' reports and report on their implications.

Expert Panel members were chosen to provide experience across the range of matters related to the planning, design, approval and construction of buildings.

For further information on the membership of the Expert Panel and its Terms of Reference turn to section 3.1 of the final Expert Panel report.

EXTREME EARTHQUAKE

The Magnitude 6.3 earthquake on 22 February 2011 was an extreme event and caused horizontal ground shaking which was much stronger than that used as the basis for the design of modern buildings in Christchurch. Exceptionally high vertical ground shaking and the proximity of the event to the central business district (CBD) were also factors. The peak vertical accelerations in this earthquake were among the highest ever recorded internationally in an urban environment. The intense ground shaking was a severe test for all buildings in the Christchurch CBD and was the fundamental contributing factor to all building collapses.

For further information turn to sections 4.1-4.3.2 of the final Expert Panel report.

SUMMARY: CANTERBURY TELEVISION BUILDING INVESTIGATION

The technical investigation into the reasons for the collapse of the Canterbury Television (CTV) Building was commissioned by the Department of Building and Housing and undertaken by Hyland Consultants Ltd and StructureSmith Limited. A separate report covering the Site Examination and Materials Testing undertaken for the investigation was prepared by Hyland Consultants Ltd.

Evaluating the collapse

The evaluation of the CTV Building was aimed at finding the most likely collapse scenario. To achieve this, structural analyses were undertaken to develop an understanding of the building's likely response to earthquake ground motions, and the demands placed on the key components in the building's structure.

These analyses were considered, along with information from eye-witness accounts, photographs, physical examinations and selective sampling and testing of building remnants.

For further information turn to section 5.9 of the final Expert Panel report.

Number of possible collapse scenarios

A number of possible scenarios for the building's collapse were identified. They ranged from collapse initiated by the failure of one or more columns on the east or south faces at a high level of the building, to collapse initiated by failure of a more heavily loaded internal column at a low level.

For further information turn to section 5.9 of the final Expert Panel report.

Likely collapse scenario

The common factor in all the possible scenarios was that one or more columns failed because of the forces placed on them by horizontal movement between floors.

The precise sequence of events in the collapse could not be determined because of the range of factors involved. However, a likely scenario identified in the investigation is that the collapse was initiated by failure of one or more columns in the mid-to-upper levels of the east face. Once one column failed, the building's load shifted to adjacent interior columns which were already heavily loaded at ground floor level, causing them to fail at the ground level. This was consistent with eye-witness accounts of an initial tilt to the east.

Once the interior columns began to collapse, the beams and slabs above fell down and broke away from the north core and the south wall, which then fell northwards onto the collapsed floors and roof.

The asymmetry of the stabilising walls meant the building would have twisted during the earthquake, placing extra strain on the columns. Further strain may have come from failure of the connection between the floor slabs and the north core.

For more information and diagrams explaining this scenario, turn to sections 5.9 and 9.2.1 of the final Expert Panel report.

Previous damage

Damage to the CTV Building structure was observed and reported after the 4 September 2010 earthquake. This reported damage appeared to be relatively minor and not indicative of a building under immediate stress or having a significantly impaired resistance to earthquake shaking.

Demolition of the building to the west of the CTV Building began almost immediately after the 4 September 2010 earthquake and continued until a week before the 22 February 2011 earthquake. The demolition work caused noticeable vibrations and shuddering in the CTV Building, which was a significant concern to the tenants.

The Expert Panel said that, based on a general description of the demolition operation and photos of the demolition process, the demolition would have been unlikely to have caused significant structural damage to the CTV Building.

There are no reports available on the condition of the building after the 26 December 2010 earthquake but no further significant damage was reported.

For further information turn to section 5.5 of the final Expert Panel report.

Range of factors that contributed to the CTV Building collapse

The Expert Panel identified a range of factors that may have contributed to the CTV Building's collapse.

Three critical factors were identified:

- intensity of horizontal ground shaking
- lack of ductility in the columns
- asymmetrical shear wall layout.

The following factors added to or may have added to the effects of the critical factors:

- low concrete strengths
- vertical ground accelerations
- interaction between the columns and the spandrels
- separation of the floor slabs from the north core
- structural influence of masonry walls.

The limited robustness and integrity of the tying together of building components was not the cause of the collapse, but was not sufficient to hold the building together when the collapse started.

Aspects for which standards of the day were not met

There were three factors where standards of the day (1986) were not met. These were:

- column ductility
- asymmetrical wall layout of shear walls
- column shear strength.

Tests on 26 columns (21% of all columns in the CTV Building) after the collapse found that the concrete in many columns was significantly weaker than expected.

GLOSSARY

A full Glossary is provided in Appendix C of the report. Some terms used in this summary are explained below.

Asymmetrical	A shape which is not like the opposite side if you flip or turn it.
Axial load	Tension or compression force pushing on the long axis of a structural element of a structure such as a beam or column.
Cantilever (structure)	A structure that is supported at one end only.
Columns	A slender, upright structure, supporting the structure in a building.
Confinement steel	Reinforcing steel, usually in the form of rectangular hoops or spirals, that are used to hold the concrete inside the core of a reinforced concrete column or beam.
Cover concrete	Concrete on the outside of a reinforced concrete column or beam, which is used as protection from corrosion and fire, and is not normally relied on to carry loads in columns.
Diaphragm	A diaphragm is a structural element that transmits earthquake loads stabilising walls and frames. In buildings, floors usually act as diaphragms.
Displacement	The amount of movement of the building or building element.
Drift	The amount of lateral (sideways) movement of any point in the building due to earthquake effects. 'Inter-storey drift' is the displacement of one floor relative to the one below or above.
Ductile	Bends like wire. The ability to sustain additional load capacity when subject to movement.
Flexible-frame buildings	Buildings stabilised by structural frames (beams and columns). They are flexible in comparison to buildings stabilised by walls.
Floor slabs	A broad flat thick piece of material forming the floor of a building, usually a concrete reinforced structure.
Horizontal ground shaking	Horizontal ground shaking is sideways (rather than up and down) ground motion produced by sudden pressure or force.
Non-ductile	Brittle – snaps like a piece of chalk.
Redundancy	An alternative load path or paths in the event of failure of one or more structural component such as a column or beam and is aimed at limiting the extent of collapse.
Shear walls	Walls that support the building's structure and are capable of withstanding lateral movement.
Spandrel panels	Panels on the external face of the building. Spandrel panels can be used to provide fire separation between floors and are used as architectural features.
Vertical acceleration	Acceleration of the ground or building measured in the vertical (up and down) direction.

Expert Panel recommendations relating to the CTV investigation

The Expert Panel made a series of recommendations resulting from its investigations into the failure of the four buildings including the CTV Building.

The full list of these recommendations can be found in section 9.3 of the final Expert Panel report.

EXPERT PANEL RECOMMENDATIONS AND DEPARTMENT RESPONSES FOR THE FOUR INVESTIGATED BUILDINGS

The Department of Building and Housing accepts all of the Expert Panel's recommendations. It has already taken action on some, and plans have been made to implement the other recommendations.

The Expert Panel's recommendations are summarised below, and the Department's responses are indicated as 'Action'.

1. Ground-shaking building response

Bring together a range of studies that examine the seismic response and performance of buildings in the Canterbury earthquakes, aimed at improving the effectiveness and efficiency of earthquake-resistant design in New Zealand and elsewhere.

ACTION
The Department will lead a multi-disciplinary research programme to learn from the building performance in the Canterbury earthquakes and follow through on any necessary changes to the Building Act, Building Code, education, training and professional practices.

2. Geotechnical

Review geotechnical information standards required for development in urban areas in New Zealand and promote consistency through the development of national guidelines for minimum standards of information.

ACTION
The Department is leading a programme with the New Zealand Geotechnical Society and its members to review geotechnical information standards. Minimum geotechnical information requirements and standards for commercial buildings will be developed.

3. Post-earthquake inspections

Review current methods for inspecting and reporting information on the structural condition of buildings following an earthquake.

ACTION
The Department, working with the Ministry of Civil Defence and Emergency Management and other experts, will lead a review of methods for post-earthquake inspection of buildings. In consultation with relevant industry groups, the Department will decide on and action practical measures to ensure that there is a common approach and understanding across New Zealand.

4. General structural design issues

Reassess approaches to and general requirements for earthquake resistance in buildings and see that necessary changes are made.

ACTION
The Department will lead a programme of work to help practitioners keep up to date with the latest developments and requirements for seismic design of buildings, including the changes that will be made as a result of the learning from the Canterbury earthquakes. The Department already has underway a review of the Earthquake Prone Buildings policy settings. This includes considering the need for changes to current legislation to require a higher level of structural strengthening when buildings are altered or their use is changed.

5. Specific structural design issues

Review detailed design requirements for structural design and amend them as necessary to resolve concerns identified in relation to:

- strength and resilience ('ductility') of walls and columns
- vulnerability of lightly reinforced concrete shear walls
- limits on axial load levels in columns
- vulnerability of buildings with cantilevers
- strength and integrity of diaphragm connections.

ACTION
The Department will drive the development of the strategically important building standards by working with researchers and practitioners to make revisions to the current standards. This will be followed by training and continuing professional development for practitioners.

6. Stair design

Issue a Practice Advisory to warn owners of buildings, especially those in flexible-frame buildings, to check that the stairs are designed to accommodate appropriate levels of earthquake-induced displacements. Develop revised criteria for stair support and protection of egress ways and incorporate them into the requirements for new designs and retrofits.

ACTION
On 30 September 2011 the Department issued a Practice Advisory under section 175 of the Building Act 2004 to provide guidance to structural engineers and territorial authorities.

7. Construction quality and compliance

Review quality assurance processes in all phases of building design and construction. Implement tighter controls and enable more designer involvement to provide confidence that design intentions are achieved and that the work complies with the requirements of the approved design documents.

ACTION
The Department will work with industry groups and implement necessary changes in the sector to bring about the greater involvement of designers throughout construction. This will be reinforced by the introduction of Design Features Reports and a stronger focus on quality assurance in building consenting processes.

8. Concrete quality

Work with the concrete industry to review in-situ strength of concrete in a representative range of buildings around New Zealand and recommend any measures required to provide confidence that specified concrete strengths have been used and achieved.

ACTION
The Department has already agreed to work with the Cement and Concrete Association of New Zealand and leading building contractors to review the level of in-situ concrete strength and agree on changes to practice if required. The Department will also draw the issue of concrete strength to the attention of building owners.

9. Earthquake-prone buildings

Promote and implement measures, and associated enforcements and incentives, that would result in improvements to earthquake-prone buildings.

ACTION
The Department is leading a comprehensive review of the policy settings for earthquake-prone buildings, and in October 2012 will be providing options to change the settings having had regard to cost and benefits.

The Department's report (Technical Investigation into the Structural Performance of Buildings in Christchurch – Final Report) notes the Expert Panel's findings and recommendations and provides the Department's response to each recommendation.

Further information

If you have any questions about the technical investigation, please contact the Department of Building and Housing:

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