



Department of  
Building and Housing  
*Te Tari Kaupapa Whare*

# **Technical Investigation into the Structural Performance of Buildings in Christchurch**

**Department Report to the Minister for Building and  
Construction**

September 2011



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# Introduction

The New Zealand Government, through the Department of Building and Housing (the Department), responded to public concern about damage sustained by major buildings, and identified for investigation four large multi-storey buildings in the Christchurch Central Business District which failed during the 22 February 2011 aftershock.

The buildings included in the investigation are the Canterbury Television building (CTV), the Forsyth Barr building, the Hotel Grand Chancellor, and the Pyne Gould Corporation building (PGC). Two of these buildings experienced collapse, while the other two experienced significant failure of building components, including stairs, columns and walls. Damage to these buildings is representative of many of the structural engineering effects that the earthquake and aftershocks have caused to commercial buildings in Christchurch.

The Panel's first report covers the PGC, Forsyth Bar, and Hotel Grand Chancellor buildings for which investigations have been completed. A second report will be issued covering all four buildings, including the CTV building, and finalised recommendations. This will be published once the CTV building investigation is completed. Further analyses have been found to be necessary for the CTV building in order to develop a full understanding of its behaviour in the 22 February 2011 aftershock, and the contributing factors that caused the building to collapse.

The recent earthquake series in Canterbury has been a unique event, both in New Zealand and internationally, and it is important to learn from this event to inform the future. The Department has the utmost confidence in the quality of the investigation, and considers the Panel's report to provide an authoritative and accurate account of the factors that contributed to the failure of the PGC, Forsyth Barr and Hotel Grand Chancellor buildings.

The Department endorses all of the Panel's recommendations, and is moving immediately to implement them, with a particular focus on the priority recommendations.

# Panel Recommendations and Department Response

The recommendations from the Panel are presented below in the order they appear in the report. They have been separated into priority recommendations that represent the need for more urgent action, and other recommendations.

The Department's immediate response will focus on the priority recommendations, and are outlined under each of the recommendations. In implementing the recommendations, the Department's approach will be to balance the need to address the issues highlighted in the Panel's first report, with practical solutions that will not burden building owners with excessive regulatory costs.

## Priority recommendations

### Stairs

#### ***Recommendation***

A Department Practice Advisory is urgently needed to warn owners of buildings, especially those built prior to 1992, to check that all egress stairs are designed to accommodate earthquake movement. Reviews are needed to check that:

- a. provisions for movement are in line with current standards. Buildings built before 1992 may have stairs with less allowance for inter-storey movement than currently required.
- b. support and separation details are such that they are not compromised by unintended restrictions to movement under earthquake actions.
- c. progressive collapse is avoided.
- d. appropriate allowances are made for normal variations in construction dimensions.

#### ***Department response***

The Department, with assistance from its Engineering Advisory Group, has developed a Practice Advisory under section 175 of the Building Act 2004. The Engineering Advisory Group includes representatives from the Structural Engineering Society of New Zealand (SESOC) and the New Zealand Society for Earthquake Engineering (NZSEE). The Practice Advisory provides guidance to structural engineers and was released on 30 September 2011.

The Department has written to the Chief Executives of all the Territorial Authorities (Councils) in New Zealand. This letter requests the help of Territorial Authorities, when sending out Building Warrant of Fitness reminder letters, to strongly recommend to multi-storey building owners to seek professional advice to check stair egress safety.

Further, when building consent applications are made to alter a multi-storey building, the Department has requested that Building Consent Authorities draw the Practice Advisory to the building owner's attention, with a strong recommendation that they check the stairs.

Building owners, who have concerns, are advised to obtain a report from a chartered engineer experienced in structural design, on the earthquake vulnerability of the stair system, with

particular reference to the issues raised in the Practice Advisory. This could include undertaking retrofit work.

The Department will also send the Practice Advisory to structural engineers advising them that when they are undertaking detailed assessments of buildings, to strongly recommend to clients that checking the stairs should be included in the building assessment. Engineers should advise on retrofit measures necessary to bring the stair earthquake safety performance in buildings, to as near as is reasonably practicable, to that of a stair in a new building.

The Practice Advisory, along with the other recommendations, will also be sent to the New Zealand Property Council, the Property Investors Federation, the Real Estate Institute of New Zealand (commercial buildings only), Registered Master Builders Federation, the Construction Industry Council, the Certified Builders Association of New Zealand, the New Zealand Institute of Architects, and the Architectural Designers of New Zealand, in order to raise awareness of the issues.

## **Walls and columns**

### ***Recommendation***

A review is needed of some aspects of the requirements for the design, detailing and construction of walls and columns. Improvements in ductility capacity and confinement steel may be needed to maintain load-carrying capacity in the face of unexpectedly large displacements and/or high vertical accelerations.

Changes in design requirements need to be considered, including the following:

- a. Further limitation on axial loads in columns and walls.
- b. More stringent detailing for ductility, whether or not walls or columns are intended to be part of the earthquake-resisting structure.
- c. Confinement, slenderness and reinforcement requirements for structural walls.
- d. The required detailing of walls subject to flexural yielding, particularly those with variable and/or high axial loads.

### ***Department response***

The Department is working with SESOC, NZSEE and universities to identify key aspects of current requirements that need to be amended, and to develop detailed recommendations to incorporate into standards and design practices.

It is anticipated that identification of these changes will be completed and advice circulated to designers by the end of 2011, and detailed requirements developed in mid-2012.

## **Earthquake-prone buildings**

### ***Recommendation***

There is a need to improve public awareness that buildings which are not classified as earthquake-prone under the Building Act 2004 could also collapse in a major earthquake. Changes to the approach should be considered that would promote early action to improve the seismic performance of existing buildings that are not up to current standards. Specific recommendations are outlined under 'Other recommendations.'

### ***Department response***

Although strictly outside its terms of reference, the Panel has recommended changes related to earthquake-prone buildings, and the Department recognises and shares the concern expressed by the Panel regarding this issue. The earthquake on 4 September 2010 and the subsequent aftershocks have highlighted the reasons why earthquake-prone building policies are necessary. Design and construction practices change and improve over time.

The Canterbury Earthquakes Royal Commission of Inquiry has included earthquake-prone buildings in the scope of its investigation. The Department is currently preparing a submission on this issue which will be submitted to the Royal Commission. The Department is actively engaged with the Royal Commission and will work with them as they consider this issue, including implementing any recommendations made in its final report.

In parallel with this, the Department will liaise with Territorial Authorities, building owners and designers to look for improved outcomes of legislative/regulatory approaches to buildings that are at risk in major earthquakes.

## **Lightly-reinforced shear walls**

### ***Recommendation***

Reinforced concrete shear walls like those in the PGC building are particularly vulnerable in severe earthquake shaking. Usually the reinforcing steel is a central layer and there is no confining steel. This type of construction could have been used in buildings built before 1965 and possibly as late as 1976. Such buildings are not usually classified as earthquake-prone under the Building Act 2004.

Owners of buildings built before 1976 need to be alerted to this vulnerability and urged to obtain advice from a Chartered Professional Engineer with experience in structural design.

Consideration needs to be given to these vulnerabilities in the NZSEE assessment guidelines.

### ***Department response***

The use of non-confined reinforcing steel was a construction practice in buildings constructed prior to 1965. The focus of the Department's response to this recommendation will be on the limited subset of buildings of this era.

The Department is working with SESOC and NZSEE to more closely define the range of buildings affected and their vulnerabilities, and to develop possible retrofit approaches. It will

advise building owners of potential vulnerability and recommend they seek structural engineering advice on possible remediation. This will be promulgated through networks such as Territorial Authorities, the New Zealand Property Council, and other building owner organisations. It is anticipated that this will be completed by mid-2012.

Regarding the NZSEE assessment guidelines, the Department proposes to reconvene the technical committee that developed the guidelines as soon as possible, to make the necessary changes recommended by the Panel.

## Other recommendations

The Department acknowledges the issues outlined in the seven recommendations below, and the need to raise awareness within the building and construction sector to improve building quality. Publication of the technical reports related to the investigation is a positive first step in the education process. The other recommendations made by the Panel include:

- 1 **Structural irregularity:** There is a need for greater design rigour for buildings with irregularity (horizontal or vertical) resulting from architectural requirements. While current design standards impose stricter requirements for irregular structures, greater recognition is needed of the special demands on critical members (for example walls, columns, beams) that can result from structural irregularity. There is a need to detail these members accordingly.
- 2 **Displacement demand:** In the design of new buildings, and the assessment of existing buildings, greater emphasis should be placed on the displacement demands on the structure and the capacity of the structure to accommodate those demands. There is a need for increased design rigour for displacement-induced actions. For example, greater attention is needed to detail secondary (i.e. non-seismic) structural elements to withstand the induced displacements that may occur during seismic actions.
- 3 **Progressive collapse:** Failures of the stairs in the Forsyth Barr Building and the Hotel Grand Chancellor underline the need for more rigorous design approaches to avoid progressive collapse due to the failure of one member. Consideration should be given to requiring designers to identify the measures taken to avoid progressive collapse.
- 4 **Cantilevers and vertical accelerations:** The high demands on the failed shear wall in the Hotel Grand Chancellor and the recording of high vertical accelerations is a reminder that the design of cantilevers requires consideration of vertical accelerations.
- 5 **Stair supports:** Changes in approach to stair support design are required. Stair supports must be designed to have a sufficient displacement capacity so that stair collapse is not expected to occur before building collapse. This will require allowances for displacements well above those expected at the ultimate limit state of the structure.
- 6 **Structural integrity:** Greater emphasis on overall structural integrity is needed, including the following:
  - a. Methods for determining the required connection forces between the floor diaphragm and structural walls and shear cores should be re-examined.
  - b. Design and design reviews need to focus more on the detailing necessary to achieve structural integrity (tying together of main structural elements).
  - c. Columns, beams and joints must be detailed to achieve a high degree of resilience.

### ***Department response to other recommendations 1 - 6***

As this is the first report of a two-stage technical investigation, the Department is committed to implementing the Panel's priority recommendations in the first instance. The Department is developing a programme of response in relation to the remaining recommendations, which will be confirmed in the Panel's second report with the final recommendations.

- 7 **Earthquake-prone buildings:** The consultant's findings that the PGC Building could have been classified as earthquake-prone, has caused the Panel to consider the need for changes in the legislation to earthquake-prone buildings. The Panel recognises that this topic will be covered by the Royal Commission, and across a wider range of buildings, and that it is strictly outside the Panel's terms of reference, but the Panel makes the following observations aimed at effecting improvements:
- a. The level of 33% of New Building Standard (NBS) used in regulations to the Building Act 2004 to define an earthquake-prone building has been wrongly interpreted as meaning that buildings above this level are relatively safe in a major earthquake. This is in spite of clear messages to the contrary that the legislation was set to cover only the worst of buildings.
  - b. Action is needed to address this misunderstanding. Strong education initiatives are needed to improve public awareness of the danger represented by older buildings which do not meet current design requirements.
  - c. The Panel believes that consideration should be given to promoting measures that would develop a stronger appreciation of the value of good seismic performance of buildings, and so lead to more improvement action.
  - d. Consideration should be given to changing the approaches for defining earthquake-prone buildings and the requirements for their strengthening. Particular consideration should be given to buildings with the potential to fail in a brittle manner.
  - e. Territorial authorities should consider adopting active policies to identify and deal with earthquake-prone buildings. Policies should promote early action to improve the seismic performance of existing buildings that are not up to current standards.
  - f. Consideration should be given to changes to the Building Act to give territorial authorities the power to require earthquake strengthening when significant alterations are made to a building or when significant increases are made to occupancy levels.

### ***Department response to other recommendation 7***

The Canterbury Earthquakes Royal Commission of Inquiry has included earthquake-prone buildings in the scope of its investigation. The Department is currently preparing a submission on this issue to be submitted to the Royal Commission. The Department is actively engaged with the Royal Commission and will work with them as they consider this issue, including implementing any recommendations made in its final report.

The Department is also working with Territorial Authorities, building owners and designers to look for improved outcomes of legislative/regulatory approaches to buildings that are at risk in major earthquakes.

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