The effectiveness of post-earthquake building safety evaluations carried out in the Canterbury earthquake sequence

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Canterbury Earthquake Sequence

The Canterbury earthquake sequence was relatively unique

- Occurred in area with low probabilistic seismic hazard
- M7.1 Darfield earthquake of 4th September 2010 generated moderate shaking in Christchurch (37km away)
- M6.3 Christchurch earthquake of 22nd February 2011 centered just 8km from the CBD and resulted in severe ground shaking
- Events were very short, but the severity of shaking was well outside expectations of typical aftershock sequences
NZSEE guidelines were published in 2009

- Based on ATC-20

- Describe Level 1 and 2 rapid assessments to be carried out during state of emergency

- Discuss detailed engineering evaluation to be carried out beyond state of emergency

- Under revision at the time of the Canterbury earthquakes

- Relatively limited number of engineers trained in the post-earthquake evaluation of damaged buildings
Evaluations carried out in Christchurch

Rapid building safety evaluations
• Carried out under the direction of Civil Defence
• Took several days to complete

Private building owners and/or tenants
• Engaged engineers to carry out rapid assessments to inform re-occupation

Detailed engineering evaluations
• Commenced following response phase
• Approx 1100 submitted to date of a total of 8000
• Expected to take several years to complete
Effectiveness of Rapid BSE’s

Rapid building safety evaluation process
  • Damage focused
  • Based on assumption that aftershocks will reduce in severity

Many re-inspections were required due to aftershocks
  • Seismograph network could inform intensity rather than magnitude
  • Concept of indicator buildings utilized

Royal Commission process showed that damage from previous events was generally not a significant factor in the subsequent collapse
  • Actions (or lack thereof) prior to September 2010 were primarily responsible for poor performance
  • However, lucky to escape 26th December 2010 aftershock
Placards

NZSEE placards used were similar to ATC-20 – generally effective but some minor issues observed;

- Propose use of white, rather than green placards
- Placards need to distinguish between L1 and L2 assessment
- Hazard observed must be recorded (eg rockfall) as means of communication with future re-assessors
- Status must be recorded by individual building rather than site
Proposals for Rapid BSE’s

Objective is to assess significance of damage sustained with regards to immediate occupation or need for public cordons

- Level 1 rapid assessments only suitable for gaining an understanding of overall scale of disaster

- Level 2 rapid assessments effective for assessing damage sustained, provided structural systems are understood

- Some forms of hidden damage not easily identified without intrusive investigation

- Need to better communicate to the public the objectives and outcomes of a rapid assessment
The scope of a DEE was undefined at the time of the Canterbury earthquakes

- Objective to define the scope of repairs required and to quantify expected seismic performance
- Requires assessment of overall building capacity and critical structural weaknesses
- Understanding of these key deficiencies used to inform extent of detailed observations
- Detailed guidelines have since been developed
Detailed Engineering Evaluation (DEE)

DEE guidelines provide both qualitative and quantitative procedures.

Key development is the assessment of the resilience provided by a building.

Brittle collapse mechanisms considered by;

$$\% NBS_{element} = \frac{capacity}{K_d \times demand}$$

Where $K_d$ is a factor between 1.0 and 2.0 reflecting the resilience of the assessed brittle mechanism.
What to do between Rapid BSE and DEE

It takes a substantial period of time to carry out a detailed engineering evaluation - CCC and MoE aim to complete their DEE’s by mid 2014

Requiring a full DEE for re-occupation and public cordons after the September 2010 event;

- would have resulted in a cordon around CBD for several years with expected financial losses in excess of $1 billion
- low probability of severity experienced in 2011 Christchurch event

Difficult to economically justify even a short closure of a city for public safety reasons.

What should building owners and tenants do until DEE’s can be completed?
Interim Use Evaluation (IUE)

Proposed to be carried out for private clients (owners / tenants)

Essentially the same as a level 2 rapid assessment except;
  • requires specific observation of the primary structural systems in order to observe critical damage.

If the structural engineer cannot identify primary systems (vertical and lateral), then they cannot assess suitability for re-occupation.

Could be extended to specifically address re-occupancy of URM buildings where;
  • substantial securing works cannot be observed, and;
  • seismicity is such that stronger shaking is considered likely
Form of Seismicity

‘Active’ faults generate regular earthquakes with relatively predictable aftershock sequences

‘Intra-plate’ earthquakes may trigger other nearby faults with different characteristics
- Because energy released is small, shaking intensity drops off quickly with distance
- Small aftershock a short distance away can generate significantly greater shaking there than triggering event

Should we consider approach to reoccupation of buildings based on the form of the local seismicity?
- Damage focused in major fault zones
- Vulnerability focused in regions of moderate seismicity
Vulnerabilities and Disproportionate Damage

Observation in Christchurch that local vulnerabilities rather than global capacity were typically the cause of collapse
  • URM parapets and floor to wall connections
  • Concrete elements lacking ductility

Difficult to identify vulnerabilities without access to drawings - need to be addressed prior to an earthquake

ATC 52-4 concept of ‘disproportionate damage’
  • May have had application following 2010 Darfield event
  • Of little relevance following 2011 Christchurch event as level of shaking would have exceeded all thresholds
  • Requires sufficient instrumentation to assess local ground shaking
Alternative Long-Term Approach

Develop building database
  • Expected performance (%NBS)
  • Database with key data
  • A4 Summary sheet

A4 sheets could be distributed to TA’s building assessment teams, or downloaded for use for private clients

Compliments proposed building safety rating system
Summary

Post-EQ rapid building safety evaluations should continue to be based on assessing the significance of damage sustained

- Level 1 rapid assessment only considered suitable for assessing overall scale of disaster

- Level 2 rapid assessment considered suitable for assessing extent of public cordons required

A continuum of assessment processes is required to transition through the response and recovery phases.
Interim Use Evaluation (IUE) proposed for re-occupation
  • Similar to level 2 rapid assessment but requires structural systems to be understood and observed
  • An adaptation of the IUE to URM buildings may be possible to consider local seismicity

Guidelines have been developed for the scope and requirements of a detailed engineering evaluation
  • Include method for consideration of local vulnerabilities

Concepts for further discussion and development
  • Forms of seismicity
  • Local vulnerabilities and disproportionate damage
  • Development of a building database