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# ENGINEERING ASSESSMENT PROCESSES FOR WELLINGTON BUILDINGS FOLLOWING THE NOVEMBER 2016 KAIKŌURA EARTHQUAKES

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## ABSTRACT

The 14 November 2016 Kaikōura earthquake resulted in long duration shaking in excess of the code demand for many buildings with fundamental periods between 1 and 2 seconds in Wellington, particularly in those parts of the city where shaking has been amplified due to basin effects and deeper deposits, notably in the port area or Thorndon basin.

This paper outlines the initial response of engineers and the engineering assessment processes undertaken in Wellington in the weeks following the Kaikōura Earthquake, along with the technical support provided to Wellington City Council through the establishment of the Critical Buildings Team and the Wellington Engineering Leadership Group. An overview is provided of the Targeted Assessment Programme subsequently undertaken by Wellington City Council to look more closely at the buildings most likely to be affected. Background is provided to the key elements of the Targeted Damage Evaluation Guidelines that were developed in support of this programme, including the relationship with the Detailed Engineering (Damage) Evaluation process used following the Canterbury Earthquake Sequence.


## INTRODUCTION

The 14 November 2016 $M_w$ 7.8 Kaikōura earthquake resulted in long duration shaking in excess of the code demand for many buildings with fundamental periods between 1 and 2 seconds, particularly in those parts of the city where shaking has been amplified due to basin effects and deeper deposits, notably in the port area or Thorndon basin [1].

Damage has therefore been concentrated in 6 to 15 storey concrete moment frames with precast flooring systems. The highest concentration of damaged buildings has been in locations where basin effects and/or soft soils have amplified the demands in the 1 to 2 second period range. The duration of the earthquake has also meant that these structures were likely subjected to multiple cycles of inelastic action.

The earthquake, however, exhibited low spectral demands in the short period range throughout Wellington which meant that most short stiff buildings experienced well below code-level shaking demands during the earthquake. As a result, unreinforced masonry and other low strength but stiff buildings were untested and suffered little or no damage. This includes numerous existing earthquake-prone buildings previously identified throughout the city.

This paper summarises the engineering assessment processes undertaken in Wellington in the initial weeks following the Kaikōura Earthquake, and the targeted damage evaluation process subsequently developed to address the affected buildings. Background is provided to the key elements of the Targeted Damage Evaluation Guidelines, prepared by NZSEE and SESOC members for Wellington City Council. This includes the relationship with the Detailed Engineering (Damage) Evaluation process used following the Canterbury Earthquake Sequence, and the process of identifying affected buildings. An accompanying paper in this Bulletin issue outlines in more detail the criteria for identifying the critical damage states across the affected buildings [2].

## INITIAL RESPONSE OF ENGINEERS

There was an early exchange of texts and calls between key practitioners in Wellington in the early hours of 14 November as they viewed buildings around the city for which they had responsibilities or prior knowledge.

Early reports indicated damage of a similar nature to that from the 2013 Cook Strait earthquakes – for example pounding between older medium-rise buildings and failure of glass panes, with no notable failure of URM elements. There were also no reports of damage to motorway structures and city bridges. Advice of the failure of floor units in the six storey Statistics House was however received prior to daybreak, confirming the likelihood that some buildings had experienced significant shaking.

A small group of engineers, including the first author and NZSEE President, volunteered to assist at the Wellington Regional Emergency Management Office (WREMO) soon after 7am to assist Wellington City Council building control officers. Council's initial focus was on undertaking inspections of the streets where damage in relation to facades had been reported and with high pedestrian counts. This information would inform decisions on whether a building-by-building placarding operation was warranted in affected parts of the City, and whether a Civil Defence declaration would be needed to enable this process.

At that point early in the response it was considered that the best use of available engineers would be to undertake a sweep of buildings with similar characteristics to Statistics House (ie. precast floors, medium-rise, and located on softer soils). The small set of buildings chosen for this quick sweep were primarily car parking structures – firstly, as more elements of

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the primary lateral load resisting structure could be readily viewed and, secondly, as these buildings as a set had performed poorly in the 2013 earthquakes. Two other multi-storey office buildings, one close to the waterfront and the other up on The Terrace, were also able to be accessed by team members that morning. Collectively, these were essentially used as 'initial indicator buildings', as an adjunct to the Rapid Impact Assessment undertaken by the emergency services and Council officials.

From the approximately ten buildings that were rapidly viewed in this way by six engineers working in pairs, no clear pattern of more significant or serious structural damage emerged.

The decision was made later that first day by Civil Defence Emergency Management and other Council officials not to declare a state of emergency. One of the implications of this decision was that a placarding operation would not be undertaken. The regional and city Controllers were however actively managing a major response operation, and continued to liaise closely with key engineers.

It was also known that most available engineers in Wellington were undertaking Rapid Building Assessments for owners and key tenants from the initial hours after the earthquake. This was able to occur swiftly, as many owners and tenants had well-established relationships with engineering consultancies due to both the work following the 2013 Cook Strait earthquakes and the seismic assessment work that has been undertaken in Wellington over the past decade.

This appreciable engineering response was informed by important input from the GeoNet team and QuakeCoRE. Early spectral information indicated that buildings near the waterfront with a period between 1.2 and 1.8 seconds had experienced close to or in excess of ultimate limit state design loading. Further sharing of information on general anonymised observations from inspections, aftershock risk, and geotechnical impacts was achieved through weekly Physical Clearinghouse meetings organised by NZSEE. Non-confidential information was shared on a Virtual Clearinghouse (http://www.eqclearinghouse.org/2016-11-13-Kaikōura/) set up as a collaboration between EERI, NZSEE, GNS Science, and QuakeCoRE.

The Rapid Building Assessments undertaken in the first few days were identifying obvious structural damage as well as significant non-structural damage. These inspections typically included lifting of ceiling tiles in suspended grids and looking at locations where damage had occurred in 2013. However, with the benefit of subsequent knowledge, this process did not enable or provide a full appreciation of the damage to key aspects such as precast concrete floor systems and precast concrete cladding panel connections.

## THE WELLINGTON CITY COUNCIL CRITICAL BUILDINGS TEAM

On Thursday 17 November, recommendations were made to the regional and Wellington City Civil Defence Controllers to establish a Critical Buildings Team to assist the City with intelligence around building damage and wider impacts. This proposal was broadly modelled on the Critical Buildings Unit set up by Christchurch City Council following the 22 February 2011 earthquake, albeit in quite a different context. The objective was to ensure that Wellington City Council had access to additional engineering resources, and in particular to engineers with operational experience from the Canterbury earthquakes.

On Friday 18 November, the following scope and taskings were established by the Critical Buildings Team (CBT):

1. Assist WCC with decision-making in relation to buildings that are or could be in imminent danger of collapse or loss of façade elements
2. Assist WCC to actively identify other buildings that may have sustained significant structural damage
3. Provide an active linkage between WCC and building owners' engineers
4. Provide support to owners' engineers where complex decisions around building risk are required

The CBT was led by the first author, and comprised senior engineers from consultancies already contracted by the Council (Rob Jury and David Wood from Beca, and Carl Ashby from Opus International Consultants), plus others with experience from Christchurch City Council and the Canterbury Earthquake Recovery Authority (John Hare from Holmes Consulting, Paul Campbell and Noel Evans from Opus International Consultants, and John Snook and Ian Smith).

As a consequence of a state of emergency not being declared, neither the Controllers nor the City's building control officers were receiving information about building damage from owners or their engineers due to usual confidentiality constraints. Conscious of the need to get some form of active information exchange going, the CBT initiated a process of 'collaboration in confidence'. Representatives from key practices were asked on Friday 18 November to share with the CBT the addresses and names of those buildings that their practices had undertaken some form of assessment of following the earthquake. No information about either the owner or even the condition or status of the building was sought – the initial objective was simply to know whether or not the building had had engineering 'eyes' over it. One of the concerns of Council at this point in the response was the possibility that an unoccupied building with an overseas owner on a major street may not have had any engineering oversight, and therefore represented an unknown public safety risk. This was part of addressing the second of the above taskings - understanding the unknowns – and was a large focus of the work of the CBT, which extended over a four week period.

This information was sought with the assurance of confidentiality from the CBT and Council, and willingly provided. The GIS team operating out of WREMO commenced entering, verifying and plotting this information. Approaches were made to other consultancies, and extended at the Technical Clearinghouse meeting held on 23 November. By the end of November it was established that approximately 1,100 buildings in the inner city area had been inspected by thirty engineering consultancies.

This information provided considerable comfort to WREMO, WCC, the emergency services and central government that there was a high level of engineering oversight of the city's building stock, and that the likelihood of there being unrecognised significantly damaged buildings in the city was low. However, due to the confidentiality constraints involved, there was no information as to the level of detail of the engineering inspection, nor the outcome or occupancy status. This meant that it was challenging to develop a comprehensive overview of the damage experienced across the city.

Collaboration continued in the form of the Engineering Leadership Group, an informally constituted group of technical leaders from a number of engineering practices. This essentially volunteer group convened on a weekly basis during December to exchange observations and insights, and acted as a 'top table' at Technical Clearinghouse meetings, sharing their observations with other practitioners.

## WELLINGTON CITY COUNCIL TARGETED ASSESSMENT PROGRAMME

### Basis of Programme

While it was generally understood that most engineers were undertaking Level 2 Rapid Building Assessments in accordance with the MBIE Guidelines [3], WCC were not receiving this information as they had no basis to request this from building owners.

In early December, WCC received a letter from MBIE highlighting the early observations from their investigation into Statistics House. This letter emphasised the need for systematic and careful engineering inspections to be undertaken for buildings of a similar profile to those of Statistics House, and others of similar form that were known to have sustained significant non-structural damage.

Amendments were made to the Civil Defence Emergency Management Act on 29 November 2017 by Parliament sitting under urgency, These provided powers to require owners to undertake building assessments and provide information to council when under a transition period, either when a state of emergency had expired or, as in the case of Wellington, when no emergency had been declared [4].

The Mayor gave notice of a Transition Period on 14 December 2016, following the appointment of Wellington City Council's Chief Resilience Officer, Mike Mendonca, as the City's Recovery Manager. Two subsequent extensions of the 28 day transition period were sought, through until 8 March.

The CDEM legislation imposes significant constraints on the management of the information from building assessments obtained under the emergency powers. A Controller or a Recovery Manager may only use or disclose the building assessment obtained under the emergency powers only for the purposes of the CDEM Act. For example, this means that the information cannot be put on a Land Information Memorandum or used for purposes under other legislation (e.g. the Building Act 2004) without the owner's consent. The outcome of the Controller or Recovery Manager considering the assessment and taking action may however be publicly available - for example, the building may be placarded, evacuated or demolished if the building was found to pose a risk to injury or safety or persons or property as a result of the assessment undertaken.

The emergency powers enabled Wellington City Council to establish a Targeted Assessment Programme to address public safety issues and to provide confidence that appropriate engineering investigations of buildings most affected by this earthquake were being carried out, and that where found necessary, appropriate repairs and remediation were being implemented.

A list of 72 buildings in the central city area that contained characteristics of a similar nature to the Statistics Building (refer *Affected Building Profile* below) was compiled by Wellington City Council, and formal letters issued to owners in the week commencing 19 December. The imminent Christmas holiday period added urgency to this notification, given the short time frames of the transition period.

### Preparation of the Targeted Damage Evaluation Guidelines

The key technical component of the Targeted Assessment Programme was provided by the document *Engineering Guidelines for Targeted Damage Evaluation following the November 2016 Kaikōura Earthquake* [5]. This document was prepared by a group of experienced engineers and researchers closely involved in the response to this event, drawing upon guidance previously developed by the Ministry of Business, Innovation and Employment following the Canterbury Earthquake Sequence and past research at the University of Canterbury and University of Auckland. Input was also provided from regular meetings of the Engineering Leadership Group.

This overall assessment framework provided the following:

1. Profiles of buildings and damage according to the characteristics of the Kaikōura earthquake and observed shaking and damage patterns.
2. A regime of targeted investigations that must be included for Targeted Damage Evaluations.
3. The requirements for the reporting of the Targeted Damage Evaluations.

The Targeted Damage Evaluation process is illustrated in general terms in Figure 1 from the Guidelines, reproduced below:

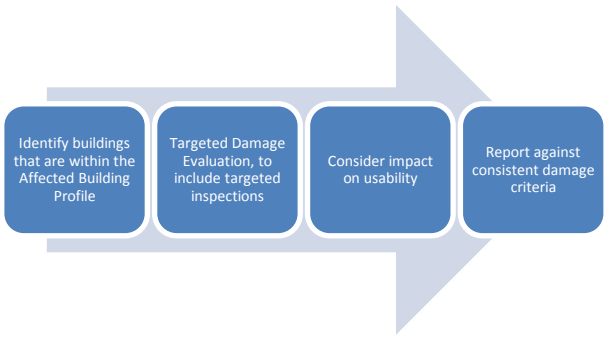


***Figure 1: Targeted Damage Evaluation Framework [5].***

The objective of the Targeted Damage Evaluation process was to identify the presence of any local or global *Critical Damage States* that may not have been apparent from the Rapid Building Assessments and may affect continued occupancy. The basis for the definition of Critical Damage States is outlined further in the accompanying paper [2].

A Targeted Damage Evaluation is primarily a qualitative assessment under which engineers must be satisfied that they can understand the primary load-resisting systems of a building (both gravity and seismic), and can view all critical elements in the load paths. A quantitative assessment of the current capacity of the building is not required under this process. However the ability to access and draw upon recent Detailed Seismic Assessments provided a valuable reference point for those undertaking Targeted Damage Evaluations.

One of the requirements of the TDE Guidelines is to obtain and review available drawings and information about the building in order to identify 'hotspots' where damage is most likely to have occurred. This identification of hotspots was also in the context of what had been learned from the early stage reviews of 'proto-typical' damage from this event that contributed to the definition of the Affected Building Profile. While the profile was based on certain forms of characteristic damage, engineers needed to be alert to other forms of atypical damage, seeing that this group of buildings had been subject to a number of cycles of code (ultimate limit state) level ground shaking.

In order to identify the presence and extent of damage to floors, primary structure and precast panel connections, intrusive inspections were required to be undertaken, using the hotspots as a starting point. The approach to be taken was one of ***progressive inquiry*** – one that involves consideration of both the configuration of the building as designed and the

levels of damage observed from a review of the drawings and an initial investigation. Where only limited or no structural damage is encountered, then no further intrusive investigation is required. However where damage of a certain nature and extent is found, then a second and more comprehensive level of further investigation is to be undertaken.

Where there was no damage to either the primary load-resisting systems or secondary structure and non-structural elements that would impair its continued function or lead to a public safety risk, the building may be considered suitable for continued use, bearing in mind the increased risk of aftershocks. Where uncertainty remains, or damage affecting the primary load paths is observed, then a Detailed Damage Evaluation (DDE) should be undertaken. Further details of the damage assessment process recommended in the TDE guidelines are provided in [1].

**Affected Building Profile**

The Guidelines established the profile of buildings requiring Targeted Damage Evaluation (the Affected Building Profile) as comprising the following combination of structural form, size and siting:

- Building characteristics:
  - Principal lateral load resistance through concrete moment frames, coupled with precast flooring systems (noting that the most vulnerable to loss of support for precast units are those where there are multiple frame bays in parallel with a single span of flooring); and
  - A natural period range of 1-2 seconds (typically 8-15 storeys, but note that this occurs in some flexible frames as low as 6 storeys); or
  - Sites where the shaking in the period range has been amplified. This amplification may be due to basin effects and/or soft soils.
- Building damage:
  - Significant loss of contents and/or non-structural damage (partitions, ceiling tiles etc); or
  - Signs of frame ‘stretch’, for example in carpet tiles; or
  - Signs of significant inter-storey drift; or
  - Signs of cracking to precast floor units when visible, particularly transverse to the direction of the span of the unit.

**Evolution of Data Summary Spreadsheet**

Owners of identified buildings were required to provide to Wellington City Council an engineering report and a data summary spreadsheet. The data summary spreadsheet was modelled after that developed by SESOC for the Detailed Engineering Evaluations (DEE, now being renamed as Detailed Damage Evaluations, DDE) after the Canterbury Earthquakes [6], but with changes to reflect the specific nature of the Kaikōura Earthquake. Additional data collected included a detailed description of floor diaphragm system, damage to non-structural elements, any closure of building after earthquake, and detailed information on damage to enable assessment of the critical damage states [2]. Damage data collected included the nature and extent of cracking of hollowcore units or ribs, seating movement, beam elongation, damage to frame elements, cracking of diaphragm and fracture of mesh.

**Outcomes of Programme**

At the time of writing, the detailed analysis of the data from the Targeted Damage Evaluation reports by QuakeCoRE researchers on behalf of the Council was underway.

Key observations of the process outcomes from the Targeted Assessment Programme include the following:

- The process of undertaking the Targeted Damage Evaluations has highlighted many instances of damage to structural elements (across the range of significance) that were unlikely to have been identified without the systematic and intrusive investigations required under this programme. This therefore points to the need to customise post-earthquake assessment processes to the earthquake and its specific impacts.
- The Targeted Damage Evaluation inspections also highlighted the need for a robust building inspection methodology which is both practical given the distribution of precast floor damage in buildings and refined enough to provide high enough confidence of not missing a location of critical damage.
- The role of, and operational protocols for, instrumentation in buildings needs urgent consideration and development in order to inform this customisation process in a timely way.
- The evolution of the Targeted Damage Evaluation process from the Detailed Damage Evaluation process used following the February 2011 Christchurch Earthquake was done in active consultation with the engineering community through the Technical Clearinghouse process. This collaboration is considered an essential tool without which a timely and common level of understanding of technical needs and requirements could not have been achieved.
- There is a fine balance between the timeliness of this form of guidance to meet practitioner needs and accuracy or completeness of content. The development of the criteria for the Affected Building Profile and Critical Damage States was both interactive and evolutionary. It is therefore a matter of judgement of where to draw the line and issue guidance for use by practitioners.

The report on the MBIE investigation into the performance of Statistics House on the Wellington waterfront [7] was released in March 2017. This report further informs the understanding of the response of modern multi-storey buildings with precast floors to long duration (and amplified) strong ground shaking. Recommendations are provided for the development of technical guidance in relation to buildings with precast floor systems and frames that may be subject to beam elongation, and improved understanding of the amplification of earthquake ground shaking due to basin-edge effects and the impacts of long duration shaking.

The key findings of the Wellington City Council Targeted Assessment Programme were subsequently presented in the report prepared by Kestrel Group and QuakeCoRE [8].

## CONCLUDING OBSERVATIONS

The response by the engineering and scientific community following the Kaikōura earthquake both in the epicentral region and in Wellington was once again significant, and was publicly commended by the Minister of Building and Construction, the Hon. Dr Nick Smith. The collaboration between practitioners and emergency operations centre personnel in Wellington was a particular feature of this response, operating in a complex environment with many sensitivities associated with information exchange.

The enhancement of building assessment processes following major earthquakes in New Zealand continues, with this event

providing a number of learnings for the case where a state of emergency is not declared. The Targeted Damage Evaluation process was created as a new component in the suite of operational assessment tools. This process was a refinement of the Detailed Damage Evaluation developed following the February 2011 earthquake, and was able to be put in place within five weeks of the Kaikōura earthquake. Further review and refinement of the Targeted Damage Evaluation guidelines will follow the completion of the Wellington Targeted Assessment Programme.

The Wellington Targeted Assessment Programme is providing a unique set of data and observations that will inform the critical need to understand how precast concrete floors in ductile structures respond to long duration shaking. While the availability of the information from this programme at the individual building level is constrained by the Civil Defence Emergency Management legislation, the aggregated results of the analysis by QuakeCoRE members, underway at the time of writing, is being fed into the working group being established by MBIE, NZSEE, SESOC and the New Zealand Concrete Society to address issues relating to existing precast concrete floor systems.

## ACKNOWLEDGEMENTS

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|---|---|
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| Hamish McKenzie | Holmes Consulting |
| Stuart Palmer | Tonkin & Taylor |
| Ray Patton | Clendon Burns and Park |
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| Laura Stockton | IPENZ |
| Adam Thornton | Dunning Thornton Consultants |
| John Hare | Holmes Consulting Group |
| Ken Elwood | University of Auckland and QuakeCoRE |
| Dave Brunsdon | Kestrel Group |

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