
Wellington City Council Targeted Assessment Programme

following the
Kaikoura Earthquake of 14 November 2016

Summary Report

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Summary of the Technical Report on the Wellington City Council Targeted Assessment Programme Following the 14 November 2016 Kaikoura Earthquake

This overview report summarises the key findings, observations and recommendations from the Technical Report prepared by Kestrel Group for Wellington City Council.

Overview and Context

The 14 November 2016 Kaikoura Earthquake produced long duration shaking that was close to New Zealand Building Code seismic design levels for certain types of multi-storey buildings in Wellington, particularly in those parts of the city on deeper deposits near the Central Business District waterfront. Damage was concentrated in moment-resisting concrete frame buildings between 6 and 15 storeys in height.

In early December 2016, the Wellington City Council (WCC) received a letter from the Ministry of Business, Innovation and Employment (MBIE) highlighting the early observations from their investigation into the performance of Statistics House, which had experienced the loss of support for some precast flooring units in the lower levels. This letter emphasised the need for systematic and careful engineering inspections to be undertaken for buildings that were of a similar profile to those of the Statistics House, and others of similar form that were known to have sustained significant non-structural damage. The information in the letter from MBIE, in conjunction with the availability of emergency powers to request structural inspections resulting from the amendment to the Civil Defence Emergency Management Act following the Kaikoura Earthquake, formed the basis of Wellington City Council's Targeted Assessment Programme.

The focus of this programme was to address public safety issues by confirming the structural integrity of multi-storey buildings that had experienced significant shaking in the Kaikoura Earthquake. The wider objective was to provide confidence to building owners, occupants and the community that appropriate engineering investigations of buildings most affected by this earthquake were being carried out, and where found necessary, appropriate repairs and remediation were being carried out.

Building Selection

A list of buildings in the central city area that contained characteristics of a similar nature to Statistics House was compiled by Wellington City Council, and formal letters issued to owners in the week commencing 19 December 2016. The list didn't include four buildings that were already known to be significantly damaged and/ or under demolition, including Statistics House which was the subject of the MBIE-led investigation.

Eighty building owners were initially notified of the need to commission a targeted damage evaluation. This number reduced following clarification of property addresses, and the subsequent exclusion of four more buildings that were found to have damage requiring more comprehensive engineering evaluations. As these buildings were being closely scrutinised by engineers and Council and appropriate actions were being taken, they did not present public safety concerns. Other buildings that did not meet any of the required criteria and had clearly sustained no structural damage, were also subsequently removed from the list.

This led to a total of 64 buildings being subject to targeted damage evaluations, in addition to the 8 significantly damaged buildings being excluded from this process.

The Targeted Damage Evaluation Process

The key technical component of the Targeted Assessment Programme was the *Targeted Damage Evaluation Guidelines* that were prepared on behalf of the New Zealand Society for Earthquake Engineering (NZSEE) and the New Zealand Structural Engineering Society (SESOC) by a group of experienced engineers closely involved in the initial response to the earthquake event. These guidelines outlined the process for undertaking and reporting on intrusive investigations of the buildings.

A Targeted Damage Evaluation is primarily a qualitative assessment in 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. The process did not require a quantitative assessment or rating of the current capacity of the building. However the ability to access and draw upon recent Detailed Seismic Assessments carried out for many of these buildings provided a valuable reference point for those undertaking targeted damage evaluations.

The overall objective of the Targeted Damage Evaluation process was to identify the presence of any critical damage states that could affect either local or global stability, and hence require restriction of the occupancy of part or all of a building and associated repairs.

Key Findings

A range of damage levels were identified within the 64 buildings that were the focus of the Targeted Assessment Programme. The observed damage ranged from isolated and local damage through to damage that is more distributed throughout some buildings, and with varying degrees of severity.

In overview, nine buildings were identified that had distributed floor and/or frame damage in various locations, in addition to the eight significantly damaged buildings. A further 19 had relatively localised floor or frame damage, and another seven only had isolated floor damage. No identified structural damage was reported in 31 buildings (43%), but most of these had non-structural damage to ceiling systems and plasterboard linings. Some damage was found in precast concrete cladding panels and stairs.

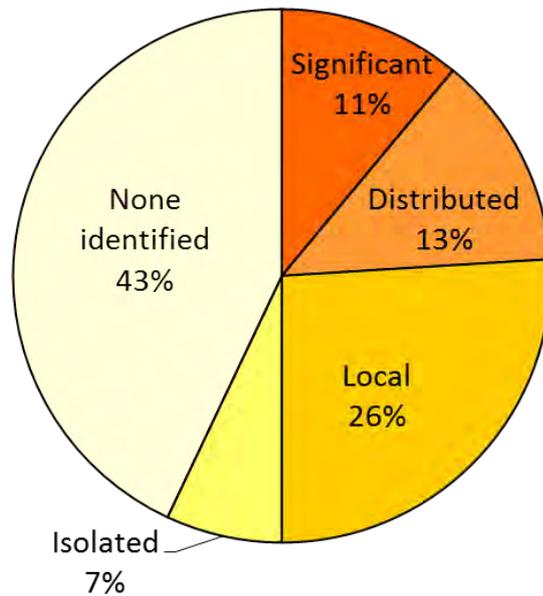
For precast floors, damage ranged from pre-existing shrinkage cracks and other cracks that hadn't been noticeably worsened by the earthquake through to full-depth cracking. Most of the earthquake damage was observed in ductile frame buildings with hollowcore flooring that were constructed during the 1980s. Limited damage was reported in buildings with double tee flooring units and ribbed floors, noting that these systems were present in less than one third of the buildings investigated.

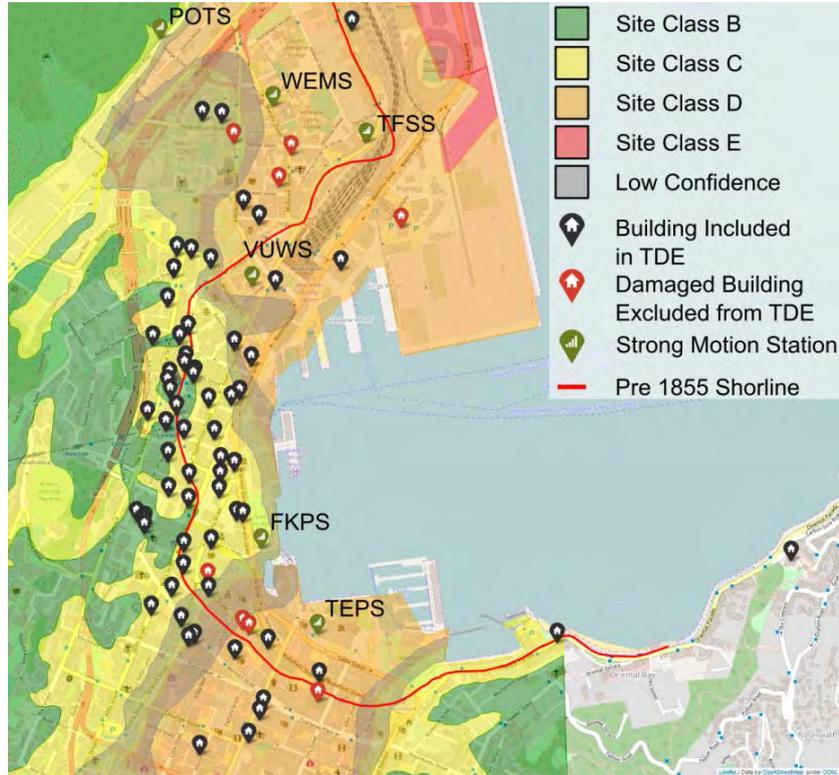
Most of the damage recorded within the primary structure was concentrated in beams of moment-resisting frames. Beam elongation was identified in at least eight buildings, predominantly affecting those with unrestrained corner columns that were moving away from the building. In most cases the extent of residual elongation and the associated floor corner cracking were minor, and none exhibited the degree of beam elongation described in the Statistics House report.

The damage is summarised in the table on the following page. The locations of the buildings, the classes of their foundation soils, and the indicative depths to bedrock are shown in the figures on the subsequent page.

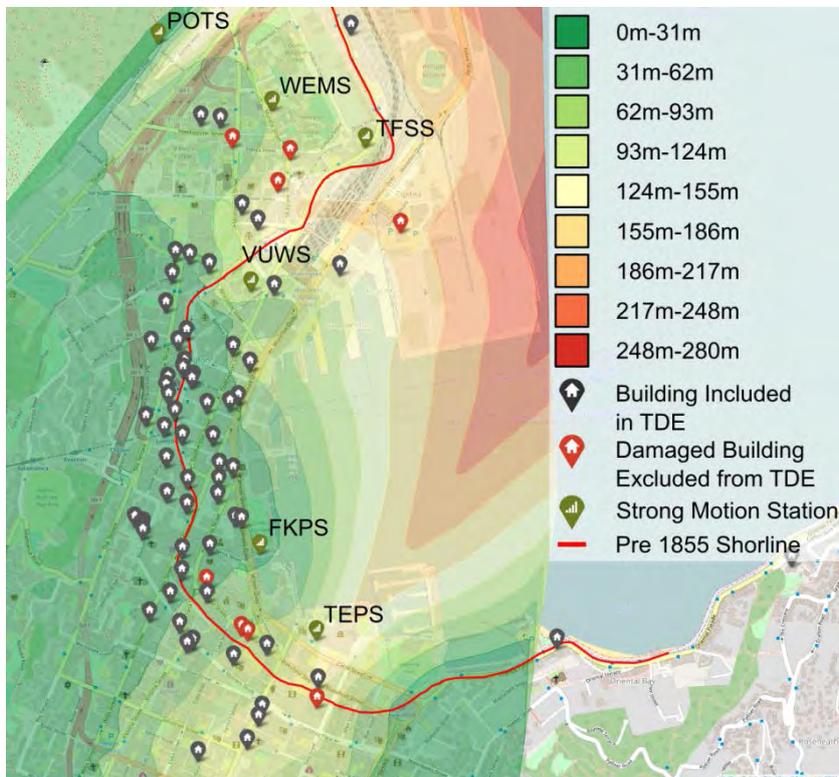
Summary of Damage

		Structural Damage Category	Number	Percentage	Comments
		Significantly damaged	8	11%	Buildings already demolished or excluded from the requirement for a Targeted Damage Evaluation (eg. Statistics House)
Targeted Damage Evaluation Buildings	Structural damage distributed across the building		9	13%	Buildings with distributed damage in frames and floors
					Distributed damage in frames or floors
	Local structural damage		19	26%	Local damage in both frames and floors
	Isolated floor unit damage		5	7%	Some not thought to be earthquake-related
	No identified structural damage		31	43%	Non-structural damage was noted in most of these buildings
Total Buildings		72			





(a) Site class



(b) Depth to bedrock

Map of (a) site class and (b) depth to bedrock with location of buildings

Key Observations

Key observations are summarised below under theme headings, and elaborated upon further in the main report.

Damage and Remediation

Where damage was reported, recommendations for further investigation and remedial work generally provided clear directions for owners and agents to follow. Further research is however urgently needed to understand the progression of damage to precast concrete floor systems. For example, relatively few voids within the hollowcore units reported on were inspected. Priority should also be given to quantifying the capacity of units cracked beyond the extent of supplemental supports that were provided in past retrofits.

There is also an urgent need for standard retrofit and repair details to provide for the gravity support of hollowcore and double tee units with transverse or web cracks respectively from this earthquake, both generally and at the corners of buildings.

Geological and Geotechnical Influences

The unique geological setting of Wellington means that the ground conditions change rapidly over the city, even within the boundaries of the CBD, both in terms of the depth to rock and the deposits that make up the soil profile above rock. With these varied ground conditions, and given the basin effects in this area, a significant variation in shaking intensity throughout the city is expected.

The results indicated a trend to an increased level of damage on softer sites with a greater depth to bedrock. There is no apparent relationship with the damage and whether or not the building was located on reclaimed land. This is most likely because the materials used for the reclamation often make up only a small portion of the overall soil profile thickness at each location, and the reclamation materials may be stiffer than the underlying natural deposits.

There were no indications of foundation failure or undue deformation of foundations that may have led to the observed superstructure damage.

Seismic Assessment

Previous research along with the Canterbury, Cook Strait and now the Kaikoura earthquakes has established the vulnerabilities within precast concrete floor systems when subject to deformations during strong ground shaking. This has re-iterated the need for more careful assessment of precast floor systems designed and constructed using earlier standards.

A precautionary approach should therefore be taken to the seismic rating of existing ductile multi-storey buildings with precast concrete floors that have not been designed to current code requirements. It is understood that further guidance on this is being prepared for incorporation into the revised national seismic assessment guidelines for existing buildings, in accordance with Recommendation 2 from the Statistics House investigation report. It is essential that this guidance covers all precast concrete floor systems (ie. hollowcore, double tee, rib and timber infill and flat slab systems), and that an interim version of this guidance be produced as soon as practicable.

Post-earthquake Assessment Processes and Building Instrumentation

The Targeted Damage Evaluation reports have identified that the Level 2 Rapid Building Assessments were not necessarily identifying all of the structural damage present in some buildings. This programme has subsequently demonstrated the value of invasive investigations that were targeted at hotspots, which in turn were informed by an engineering understanding of the building and how it was expected to perform.

The extent of the varied seismic demands on buildings throughout the Wellington CBD was not initially well understood due to the sparse distribution of strong motion instruments across the city. More widespread instrumentation across the CBD, both on the ground and in buildings, would enable a better understanding of the seismic demands on buildings and the likely building response. With this knowledge, the initial rapid building assessment processes could be more strategic and targeted, taking into account the particular characteristics of the event. This is especially important for long duration shaking with damage likely to be more distributed throughout larger CBD buildings.

There is also support for establishing a wider set of *pre-earthquake indicator buildings* – buildings representing the range of structural types, heights, and ages in the city, along with land features that can be quickly viewed in the hours following a significant earthquake and used to develop an early appreciation of the nature and extent of impacts. Having these buildings and land features instrumented is a key part of this, noting that this will involve instrumenting some older structures. Access to building drawings is also essential for these indicator buildings immediately after an event.

If the information from expanded instrumentation of buildings and land features is to be utilised to its full potential, there is a need to be able to quickly convene a pre-established specialist operational panel to form a view and advise on early stage actions, utilising other event information from GeoNet and other instrumentation sources.

Conclusions and Recommended Actions

The Targeted Assessment Programme undertaken by Wellington City Council has provided a basis for systematically evaluating the set of multi-storey buildings considered to have been most affected by the Kaikoura earthquake. The process of undertaking these evaluations has highlighted many instances of damage to structural elements that were unlikely to have been identified without the systematic and intrusive investigations required under this programme.

This programme has identified a number of buildings with various levels of structural damage to precast concrete floors, panels and primary elements. It has addressed the first recommendation of the Statistics House investigation report in relation to the Wellington CBD – namely that buildings of a similar design to Statistics House be investigated as soon as possible. There is a high level of confidence that buildings within this programme have received careful engineering consideration, and that cases of significant damage have been identified. It is however understood that there are some multi-storey buildings with precast floors in the Wellington CBD not included in this programme that do have structural damage, and owners and engineers should be pro-active about undertaking more detailed inspections using the targeted damage evaluation guidelines prepared by NZSEE and SESOC.

In most cases where **isolated** or **local** damage was identified in floor units, remedial work has already been undertaken. For buildings with **distributed** or **significant** damage to floor systems and/or primary structural systems, more careful evaluation of the cause of the damage and appropriate remedial and retrofit measures is required. While the nature of the damage noted to primary frame elements is generally unlikely to require urgent repairs, the extent of the reduction of the capacity will require further detailed engineering consideration in some cases.

The data from the Targeted Assessment Programme should be used to enable a wider understanding of the vulnerabilities and potential community impacts from future earthquakes, and to inform the development of appropriate mitigation strategies.

While the focus of the Targeted Assessment Programme was on buildings most affected in this earthquake – ductile multi-storey buildings with precast floor systems – and there was only limited damage to other older forms of construction, it is essential that efforts be maintained to identify and address other forms of building structures vulnerable to earthquake shaking. Unstrengthened unreinforced masonry buildings remain highly susceptible to damage in closer earthquakes, and medium and high-rise buildings from the 1950s to 1970s era of non-ductile concrete construction need careful assessment given the numbers of occupants involved.

Specific recommendations for priority actions that follow on from the results of this programme and the issues discussed above are presented in the following table.

Table of Recommendations

Recommendation 1:	<i>Owners and managers of buildings in Wellington City with damage identified in targeted damage evaluation reports should follow through on the further investigations and repairs proposed in those reports, with appropriate further engineering input.</i>
Recommendation 2:	<i>Experimental testing of damaged precast units is urgently needed. This should include more systematic access and viewing of hollowcore voids in order to understand the trajectory of transverse cracks.</i>
Recommendation 3:	<i>A set of industry-agreed and experimentally verified standard details and corresponding performance objectives should be prepared for retrofitting precast concrete floor systems in ductile moment-resisting frame buildings. This is required urgently to assist work both on buildings with damage from this earthquake and undamaged buildings with precast floors.</i>
Recommendation 4:	<i>Ground conditions across Wellington City and the region should be better defined through enhanced site characterisation for the purposes of both seismic assessment and design, and to enable better estimation of seismic demands on buildings after an event. Local input should also be provided to the national efforts to improve understanding of the influence of basin-edge effects in the Wellington region, as recommended in the Statistics House report.</i>
Recommendation 5:	<i>Interim guidance for practitioners on rating existing precast concrete floor systems in ductile multi-storey buildings is needed with some urgency (as per Recommendation 2 of the MBIE Statistics House report). It is recommended that a precautionary approach be taken for assessing such buildings not designed to current code requirements.</i>
Recommendation 6:	<i>The learnings from this programme should inform an update of the arrangements for post-earthquake rapid assessments of multi-storey buildings, including criteria for when invasive investigations are required.</i>
Recommendation 7:	<i>Wellington City Council and GeoNet should support expanded instrumentation across the Wellington CBD, both on the ground and in buildings, to rapidly provide information on the shaking demands and likely impacts after an event. Instrumentation needs to be coupled with a better understanding of the structural characteristics of the building inventory and rapid access to building drawings.</i>
Recommendation 8:	<i>Wellington City Council, in conjunction with the Wellington Region Emergency Management Office and the Ministry of Business, Innovation and Employment, should establish a specialist operational panel to utilise event information from GeoNet and other instrumentation sources and to provide strategic oversight to rapid building assessment processes.</i>
Recommendation 9:	<i>Wellington City Council should provide other researchers access to the building and damage information from this programme (suitably anonymised) when the current analysis phase is complete, within the current constraints of the Civil Defence Emergency Management Act as amended in November 2016.</i>

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