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Seismic Assessment and Retrofit Prioritisation of Auckland Council's Property Portfolio

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ABSTRACT

Territorial authorities in New Zealand are responding to regulatory and market forces in the wake of the 2011 Christchurch earthquake to assess and retrofit buildings determined to be particularly vulnerable to earthquakes. Pending legislation may shorten the permissible timeframes on such seismic improvement programmes, but Auckland Council's Property Department is already engaging in a proactive effort to assess its portfolio of approximately 3500 buildings, prioritise these assets for retrofit, and forecast construction costs for improvements. Within the programme structure, the following varied and often competing factors must be accommodated:

- The council's legal, fiscal, and ethical obligations to the people of Auckland per building regulations, health and safety protocols, and economic growth and urban development planning strategies;
- The council's functional priorities for service delivery;
- Varied and numerous stakeholders across the largest territorial region in New Zealand in both population and landmass;
- Heritage preservation and community and cultural values; and
- Auckland's prominent economic role in New Zealand's economy which requires Auckland's continued economic production post-disaster.

Identifying those buildings most at risk to an earthquake in such a large and varied portfolio has warranted a rapid field assessment programme supplemented by strategically chosen detailed assessments. Furthermore, Auckland Council will benefit greatly in time and resources by choosing retrofit solutions, techniques, and technologies applicable to a large number of buildings with similar configurations and materials. From a research perspective, the number and variety of buildings within the council's property portfolio will provide valuable data for risk modellers on building typologies in Auckland, which are expected to be fairly representative of the New Zealand building stock as a whole.

1. INTRODUCTION

While the apparent seismic hazards in Auckland are relatively low, especially in Central Auckland where a plurality of population and unreinforced masonry (URM) buildings reside, the vulnerability of Auckland's built infrastructure is high. As of 2012, Auckland's economy accounts for an estimated 37% of New Zealand's GDP, and the region's economic growth has outpaced New Zealand's national economic growth 7 of the past 11 years (Monitor Auckland 2012). The estimated population of 1.5 million people within the Auckland territorial authority area accounts for about one third of the nation's population (Statistics NZ 2012). Hence, a major natural disaster in Auckland would be detrimental to much of New Zealand.

Auckland Council has established a seismic retrofit prioritisation programme, which is being administered by the Auckland Council Property Department (ACPD), to investigate the seismic vulnerability of all of the buildings in the council's property portfolio. As the council owns approximately 3500 building properties within the ACPD portfolio, a significant amount of work needs to be carried out to establish the prioritisation framework for the building stock, beginning with a programme to assess the buildings. Auckland Council's interest from a property portfolio and management perspective, as distinct from its regulatory function, will be to assess its building assets in detail in accordance with existing policies and guidelines as well as state-of-the-art engineering and property management practices. The council's associated seismic risk exposure will then be analysed in regard to compliance issues, effects of upgrades per building standards and practices, and the functional implications of the portfolio. ACPD is working together with the University of Auckland to ensure that engineers are using state-of-the-art field inspection practises.

This project can be divided into three primary phases:

Stage 1 – Baseline analysis of building stock

- This stage will involve the collection of inspection data and analysis through preliminary assessments of the most at risk buildings (emphasising URM and non-ductile concrete) followed by the submission of an investment proposal for detailed engineering evaluations for buildings which are assessed as earthquake prone. An estimated 165 URM buildings exist in the ACPD portfolio based on construction type distributions estimated for Auckland (Cousins 2005). Preliminary recommendations from this work are intended to be made in time for inclusion in the 2013-2014 fiscal budget.
- Work to establish the current earthquake proneness of Auckland Council buildings will include:
    - categorising all buildings owned by the council in terms of construction type, number of levels, age, functional priority, etc.;
    - identifying all Auckland Council owned buildings that have earthquake performance assessment scores (%NBS, representing "new building standard") of less than 33% and 67% of current building code requirements for demand;
    - working alongside engineering inspectors to undertake earthquake vulnerability assessments for council buildings; and
    - developing a programme structure for determining which buildings need advanced analysis.

Stage 2 – Detailed analysis of critical assets and sizing preliminary retrofit costs

- This stage will include detailed assessments often referred to colloquially as "detailed engineering evaluations" (DEEs), which more closely consider the critical structural weaknesses and expected resilience of individual buildings, and quantity surveying for an order of costs. Buildings with low preliminary assessment scores and deemed critical to the council's service functions or posing unusually high danger to life and property will be selected for advanced analysis, most likely to be performed by outside consultants. Suggested retrofits for these buildings as well as generic solutions determined for portions of ACPD's portfolio (e.g., parapet tie-backs for URM buildings) will be reviewed for quantities and costs by a surveyor (also, most likely a third-party consultant). The structure for retrofit prioritisation will be finalised (pending the inclusion of new information) at this stage. Recommendations from this work are intended to be made in time for inclusion in the 2014-2015 fiscal budget.

Stage 3 – Requesting quotes for specific retrofit work

- This stage will primarily involve the submission of requests for proposal/quote (RFP/Q) to contractors for retrofit work, with an emphasis on packaging groups of buildings in order to reduce unit costs.

3. RELATED POLICIES AND OTHER BACKGROUND

Regulations, policies, plans, and guidelines relevant to this work are as follows:

- Auckland Council's *Earthquake-Prone, Dangerous, and Insanitary Buildings Policy (2011-2016)*;
- *Building Act* (NZ Parliament 2004);
- Canterbury Earthquakes Royal Commission Final Report, Volumes 1-7 (Cooper et al. 2012);
- NZSEE's *The Assessment and Improvement of Performance of Buildings in Earthquakes* (2006);
- *Health and Safety in Employment Act* (NZ Parliament 1992);
- *Auckland Plan* (Auckland Council 2012a); and
- *Auckland Council Property Strategy* (2012b).

Auckland Council released its *Earthquake-Prone, Dangerous & Insanitary Buildings Policy* (*2011 to 2016)* in response to the Building Act (New Zealand Parliament 2004) requirements that territorial authorities adopt such policies (Section 131) to identify if buildings are considered earthquake-prone (Section 122), dangerous, or otherwise unsuitable for human occupation. Under this policy, a process has been outlined for identifying earthquake-prone buildings and, where applicable, working with building owners to establish a scope and timetable for any building improvements. Auckland Council regulatory policy mandates that most normal buildings deemed by Building Control to be earthquake-prone be retrofitted within 20 years, and additional allowances are provided for buildings with heritage value.

Separate from the local policy, the Canterbury Earthquakes Royal Commission (CERC, Cooper et al. 2012) of Inquiry reported on the causes of building failure as a result of the 2010-2011 Christchurch earthquakes as well as the legal and best-practice requirements for buildings in New Zealand Central Business Districts (CBDs). Auckland's CBD is one of these districts. The inquiry began in May 2011 and recommendations from the Royal Commission are likely to be implemented into building regulations by the Ministry of Business, Innovation, and Employment (MBIE) and into a new version of the Building Act as soon as 2014. A consultation document from MBIE (2012) detailing such proposed regulations recommended that consideration be given to accelerating average seismic assessment timeframes across the country such that all "earthquake-prone" buildings be inspected within 5 years and seismically retrofitted within 20 years from the passing of the next Building Act.

Regulations in response to these recommendations may force all territorial authorities in New Zealand to accelerate the rate of seismic building inspections and retrofits in their jurisdictions. Regardless of what legislation ultimately formulates, it is ACPD's stance that the need (in terms of public perception, market demands, and possibly legal liability) to accelerate its proposed inspection programme warranted obtaining additional temporary staff.

Student engineers and other researcher contractors from the University of Auckland are assisting with initial inspections of council-owned buildings in order to provide a basis of knowledge by which hired consultants' efforts could be more efficiently directed. All affiliates follow inspection guidelines to procure data, records, and photographs to aid the council in prioritising its buildings for seismic retrofitting. The inspectors have been utilising a programme based on the Initial Evaluation Procedure (IEP) per NZSEE (2006), but they have also been applying more advanced metrics in order to improve both the accuracy and the bandwidth of building assessment scores so as to facilitate efficient retrofit prioritisation.

Seismic assessments are performed in three generic stages as prescribed in the NZSEE assessment guidelines (2006) – Preliminary, Initial Evaluation Procedure (IEP), and Detailed Engineering Evaluation (DEE, which can be performed using a variety of methods). The Initial Evaluation Procedure (IEP) is a provisional screening procedure that provides an approximate assessment of seismic risk. In comparison, a detailed engineering evaluation (DEE) typically provides more detail and involves calculations and/or computer models specific to the building being assessed. A "preliminary" assessment for purposes of this programme is effectively the IEP sans an assessment of critical structural weakness (CSWs, which are generally geometric irregularities) such that the procedure can be applied knowing only the building height, structural system, age of construction, and importance level (NZS 1170.0:2002). All assessment types entail a scoring system of percent new building standard (%NBS) which indicates the expected capacity of the building as a percentage of the ultimate limit state (ULS) demands prescribed by current standards (NZS 1170.5:2006). The phrase "new building standard" is indicative of the intent of the scoring system - a building that is assessed as having a resistance exceeding 100%NBS is expected to withstand the current ULS "design basis earthquake" (DBE) demands, whereas a building assessed at 33% is expected to withstand only one-third of the DBE. An earthquake-prone building is defined in Regulation 7 (Cartwright 2005) of the Building Act, and is functionally identified as one having a %NBS score less than or equal to 33% (NZSEE 2006). Note that the earthquake defined by the design code (NZS 1170.5:2004) as the DBE for any particular building is influenced by a number of factors, including the location, site conditions, and functional purpose of the building being considered. Note also that the correlation between %NBS scores determined for existing, older buildings and those determined for newly designed buildings can be skewed by, amongst other factors, differences in characteristic strengths presumed and factors of safety utilised (Au et al. 2013).

A building with a %NBS score of less than 33 is deemed "earthquake prone" and is potentially subject to regulatory measures per the 2004 Building Act and current Auckland Council policy (2011), warranting further assessment and possibly structural retrofits. A building with a %NBS score less than 67% is deemed "earthquake risk" and is potentially subject to the provisions of the 1992 Health and Safety in Employment Act. Council has responsibilities under the Act (1992) to take all practicable steps to reduce risk in all workplaces (through structural enhancement and/or safety training) for which it is the employer, the entity in control of the workplace, or the principal (in regard to contractors and subcontractors). Furthermore, Council is required to notify employees in buildings if the building is seismically assessed as being "earthquake-risk" (hence, the <67%NBS threshold). These items are summarised in Table 1. Note that calculated risk levels are not proportional to the %NBS scoring range, as a building determined to have a score of 33%NBS is assumed to have a collapse or partial collapse risk that is approximately ten to twenty times higher than a building rated at 100%NBS (NZSEE 2006).

Table 1. Associated values and implications of seismic assessment %NBS scores (NZSEE 2006)

%NBS	Risk Category	Seismic Grade	Approx. Relative Risk (NZSEE 2006)	Potentially Affected by Building Act (2004) and Council Policy (2011)	Potentially Affected by Health & Safety in Employment Act (1992)	Non-compliant with current loading standard (2006)
%NBS < 20.00	EQ prone	E	> 25 times	X	X	X
20.00 ≤ %NBS ≤ 33.33		D	10-25 times	X	X	X
33.33 < %NBS ≤ 66.67	EQ risk	C	5-10 times		X	X
66.67 < %NBS ≤ 80.00	Low risk	B	2-5 times			X
80.00 < %NBS ≤ 100.00		A	1-2 times			X
%NBS > 100.00	Presumed to comply with current loading standard	A+	< 1 time			

4. PRECEDENT FOR SEISMIC RISK MANAGEMENT OF LARGE PORTFOLIOS IN NEW ZEALAND

This programme as outlined is consistent with what other major public asset owners in New Zealand have utilised in regard to its prioritisation and assessment policies.

The Department of Corrections (Corrections) owns over 870 buildings and commissioned an engineering consultant to assess the buildings using the initial evaluation procedure. As the results became available, Corrections formed a seismic risk committee to make executive decisions on seismic risk-related policy. The risk-framework developed was largely quantitative in nature and took into account seismic risks of the buildings (IEP), health and safety issues related to seismic hazards that may not normally be captured by the IEP, and functional utilisation of the buildings (based on hours of use). These three categories were assigned weighted scores (30%, 50%, and 20% respectively) in order to compute an overall risk value. The risk value spectrum was divided into four action categories for the buildings to be assigned response plans within 12, 24, or 36 months or to consider the building for future disposal (Lindstrom and Sharpe 2013).

The Ministry of Education (MoE) owns and manages approximately 16,000 buildings, excluding ancillary structures such as boiler houses. The MoE has formed an Engineering Strategy Group (ESG) to provide technical leadership on structural assessments and strengthening of school buildings. That group has advised that the MoE's buildings be prioritised based on risk to the safety of occupants during an earthquake, which can be linked to structural configuration - unreinforced masonry, buildings of two or more storeys with heavy (e.g., reinforced concrete) construction, and, lastly, single storey buildings with large open areas. The ESG has also been working on guidelines for the seismic evaluation of timber framed buildings to correlate with the evidence of the relatively good performance of timber framed buildings seen in the Canterbury earthquakes and the results of field tests they have performed, though their high level of concern with timber framed buildings is likely related to the prominence of such buildings within their portfolio as compared to ACPD's.

Based on data from the MoE property management information system, at least 80% of the buildings in MoE's portfolio are constructed largely of timber (Sheppard and Brunsdon 2013, Armstrong 2013).

Wellington City Council (WCC) owns 683 buildings. Their building regulators also use the IEP (as do Auckland Council's regulators). WCC's policy is to perform a DEE for every building within their portfolio that could subject them to action under the Health and Safety in Employment Act (1992), and they count 128 buildings in this group. WCC are in the process of performing a DEE for all 128 of these high-priority buildings regardless of the IEP score, given Wellington's high seismic hazard relative to Auckland's (Brown 2013).

5. SEISMIC VULNERABILITY OF ACPD'S PORTFOLIO BY STRUCTURE TYPE

In determining which buildings to inspect with priority, two building types have been documented by the CERC as being particularly vulnerable to earthquakes:

- Unreinforced masonry (URM) buildings typically constructed between 1880 and 1935, being a building type that was responsible for 39 fatalities in Christchurch at 20 different sites; and
- Non-ductile reinforced concrete (RC) buildings built anytime from the early 1900s to as recent as 1995 (including notably those let for construction in years 1982-1995 with 3+ storeys per DBH 2012), being a building type that was responsible for 133 fatalities in Christchurch due to the collapses of the Canterbury Television (CTV) Building and Pyne Gould Corporation (PGC) Building, the latter of which was constructed in the 1980s.

6. INSPECTION PRIORITIES IN ACCORDANCE WITH FUNCTIONS AND VULNERABILITIES

In order to accommodate various stakeholders as well as address issues pertaining to building value outside the scope of seismic vulnerability, the ACPD Strategic Planning & Partnerships Team hosted a forum on assigning values for seismic retrofit prioritisation in November 2012. This forum assisted with the development of a strategic plan to manage the risk of the building property portfolio, with an emphasis on the consequence-related component of risk. The four proposed categories of values, including public life safety risk, civil defence needs, council services, and community value, were generally agreeable.

Unfortunately, the only data currently available for all of the approximate 3500 buildings in ACPD's records (*SAP* database platform) are location and functional type. Hence, while many of the notions discussed may be applied for retrofit prioritisation, inspection prioritisation per council-assessed value has been determined based solely on location and functional type with emphasis on the "service" portfolios – buildings that are used to provide services directly to the community. Those service portfolios and the types of buildings they house are as follows:

- Corporate Accommodation;
- Local Board Accommodation;
- Libraries;
- Community Development, Arts, and Culture (CDAC) including:
    - Community halls,
    - Community centres, and
    - Arts/Museum/Cultural Centres;

- Parks, Sports and Recreation (PSR) including:
    - Swimming Complexes/Aquatic Centres,
    - Recreation/Leisure Centres, and
    - Stadiums/Grandstands/Arenas.

7. PRELIMINARY SEISMIC ASSESSMENT AND COST MODELLING

Currently, 511 seismic assessments have been performed, including 349 preliminary assessments, 158 IEPs, and 4 DEEs. Preliminary assessments were performed as IEPs without regard to critical structural weaknesses or compensating factors. Critical building characteristics needed for a risk assessment of the portfolio are summarised in Table 2. Floor areas were taken from representative buildings within each portfolio-risk group, and if not available from the service provider, were generally calculated as the footprint area measured from Auckland Council GIS multiplied by the number of storeys visible above grade. Note that the Parks, Sports, and Recreation (PSR) portfolio was subdivided for the costing estimates that follow because of the large disparity in building floor areas between its two subgroups. Extrapolated data intended to represent the entirety of each service portfolio was determined by taking the percentages of seismic risk groups for the buildings assessed within each service portfolio and applying them proportionally to those buildings that have not yet been assessed by any method.

Table 2. Summary of critical building attribute assumptions

Service Portfolio -->	Portfolio-Wide	Corporate	Local Board	Libraries	CDAC	PSR – Rec & Aquatic	PSR – Other
Typical floor area of EQ-prone bldg. in portfolio (m^2)	500	900	1000	570	500	5100	250
Typical floor area of EQ-risk bldg. in portfolio (m^2)	500	3000	3000	720	700	4000	250
Importance Levels	1-4	2-4	2-3	2-3	2-3	2-3	2-3

Assumptions for cost estimates were based on proprietary knowledge provided to the technical lead by local engineering consultants. Detailed engineering evaluations (DEEs) are assumed to cost $15,000 per building. While this cost may be low for large, complex buildings in the ACPD portfolio, it should represent a conservative value for the average building in the portfolio assuming that, ultimately, buildings of all sizes and complexities are addressed and that buildings can be grouped into packaged projects so as to keep the unit cost of evaluation per building low. Seismic retrofit costs were assumed to be \$500/m^2 on average in order to upgrade buildings to 33%NBS and \$600/m^2 on average in order to upgrade buildings to 67%NBS. The technical lead wishes to emphasise the expectation of a very high variance in construction costs, and recommends that Auckland Council control such variances as much as possible by packaging buildings of similar structural configurations and geographic locations together in the requests for proposal to engineers, architects, and contractors.

8. CONCLUDING NOTIONS

Based on the metrics and assumptions previously described, risk profiles and forecasted evaluation and retrofit costs set to alternative %NBS targets have been produced and are currently being considered by council executives. The seismic risk assessments will be considered within the broader context of the strategic property portfolio review and will factor into the determination of whether rehabilitation, disposal, or change-of-use should be considered for individual buildings. Council policies on health and safety, heritage preservation, life cycle costs, and level of service will largely influence such strategic decisions as well. Buildings that are ultimately deemed to warrant seismic retrofitting after these varied implications have been considered will be grouped by structural configuration and functional classification and marketed to consultants and contractors in such groupings in order to facilitate efficient implementation of exemplar retrofits across multiple buildings concurrently.

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