2021-2024 QuakeCoRE Research Programme Contract Detail

Title of proposed coordinated project:
Interdisciplinary Programme 1: Achieving Functional Recovery with Repairable Multi-storey Buildings

Project Leader: Ken Elwood

Project Co-Leader(s): Geoff Rodgers and Alice Chang-Richards

Project code: [This field will be completed by the QuakeCoRE Support Team – Please leave blank]

Project Investigators

Project Leader Name (Organisation)	Quake CoRE PI/AI	Quake CoRE Industry Affiliate	New for 2021 - 2024	Diversity			
				Female Engineer	Māori	Pasifika	New / Emerging
Ken Elwood (UA)	☒	☐	☐	☐	☐	☐	☐
Investigator Name (Organisation)							
Geoff Rodgers (UC)	☒	☐	☐	☐	☐	☐	☐
Alice Chang-Richards (UA)	☒	☐	☐	☒	☐	☐	☐
Rajesh Dhakal (UC)	☒	☐	☐	☐	☐	☐	☐
Tim Sullivan (UC)	☒	☐	☐	☐	☐	☐	☐
Giuseppe Lopocaro (UC)	☒	☐	☐	☐	☐	☐	☒
Max Stephens (UA)	☒	☐	☐	☐	☐	☐	☒
Rick Henry (UA)	☒	☐	☐	☐	☐	☐	☐
Charlotte Toma (UA)	☒	☐	☐	☒	☐	☐	☒
Lucas Hogan (UA)	☒	☐	☐	☐	☐	☐	☒
Olga Filippova (UA)	☒	☐	☐	☐	☐	☐	☐
Meagan Boston (WU)	☒	☐	☒	☒	☐	☐	☒
Fei Ying (AUT)	☐	☐	☒	☒	☐	☐	☒
Julia Becker (MU)	☒	☐	☐	☐	☐	☐	☐
Nick Horspool (GNS)	☒	☐	☐	☐	☐	☐	☐
Rob Cardwell (ME)	☐	☐	☒	☐	☐	☐	☒
Charlotte Brown (ResOrg)	☒	☐	☐	☒	☐	☐	☐
Didier Pettinga (Holmes)	☐	☒	☐	☐	☐	☐	☐
Helen Ferner (NZSEE)	☐	☒	☐	☒	☐	☐	☐
Reza Jafarzadeh (AC)	☐	☒	☒	☐	☐	☐	☐
Greg MacRae (UC)	☒	☐	☐	☐	☐	☐	☐

Project Proposal

1. Project Abstract :

Inter-Disciplinary Programme 1 will promote functional recovery and develop solutions to maintain and restore building function following a large earthquake. Factors such as economic, societal, and sustainability drivers for more resilient buildings will be investigated and linked to low-damage design concepts and risk-targeted design for functionality. Research will also investigate technical requirements to restore function and associated expectations and timeframes for repair in a post-earthquake environment. This programme will investigate drivers for uptake of increased post-earthquake functionality and the wide-ranging motivation for, and consequences of, improved functional recovery. Specific technical, economic, and societal challenges to develop evidence-based guidance on functional recovery will be identified. Overall, this programme will support and promote increased societal resilience through greater uptake of low-damage building designs and guidance on the repair of buildings that suffer damage during a large earthquake.

2. Detailed outline of project:

Project Outline

Research Context:

Recent earthquakes in New Zealand have clearly demonstrated the success of past research in earthquake engineering to develop modern seismic design codes which protect lives. These events have equally demonstrated the impact of the lack of consideration for how the functionality of buildings, businesses and communities will recover after an earthquake (Marquis et al 2017, Chang et al 2014). Growing out of these experiences, cities are increasingly focused on how they will return to function after a strong earthquake (e.g. WCC 2017). Such a return to function requires buildings to be designed with explicit consideration of not only safety, but also repair and recovery time (EERI 2019). Internationally, policy makers have also been advocating for better performing buildings (e.g. Federal Register 2016; AIJ 2019), but there is a lack of technical understanding, methods, and tools for implementation.

Functional recovery is herein defined “as a post-earthquake state in which the capacity is sufficiently maintained or restored to support pre-earthquake functionality” (EERI 2019). This definition points to three critical components of functional recovery: continuous maintenance of functionality; restoration of functionality; and identification of time to restoration. This interdisciplinary programme will provide the underlying science to support the development of the world’s first functional recovery-based seismic design standard, including guidance on effective means to communicating with end users, building owners, and tenants.

Focusing on the functional recovery of multi-storey buildings, this interdisciplinary programme includes four key objective: (1) define the drivers for change toward building design based on functional recovery, (2) identify design methods which provide a high confidence of maintaining functionality; (3) identify the level of damage which is acceptable to repair and the expected performance of repaired buildings; and (4) identify achievable and acceptable timeframes for restoration of function considering external constraints and stakeholder requirements.

Key Objective(s):

The Interdisciplinary Programme is comprised of four key objectives:

1) Drivers for change

2) Maintaining functionality

3) Repaired buildings

4) Timeframes for restoration of function

Research Methodology:

1) Drivers for Change: Considering the significant fundamental shift suggested from a purely life-safety focus to considering design for functional recovery, there is a need to define and substantiate the drivers for change. Such evidence base will be needed by policy makers in order to justify building regulations and guidelines. The drivers will be explored from three perspectives: economy, sustainability, and societal expectations.

1a – *Economic Drivers for Change* (Cardwell, Filippova): A disaster, earthquake or otherwise, results in a drop in economic activity, followed by a recovery period. A move toward functional recovery in building design is expected to lead to a smaller drop in economic activity and a faster recovery period. This project seeks to quantify these changes in economic activity and hence the overall economic benefits of targeting building designs based on functional recovery objectives.

1b – Sustainability Drivers for Change (Toma, Chang-Richards): As New Zealand moves toward a zero-carbon economy, the construction sector must adapt. This time of change provides an opportunity to assess the impact of current seismic design standards on the environment in light of a major earthquake. This project will seek to define how functional recovery design targets can lead to fewer building demolitions, less construction waste following earthquakes and during reconstruction, and longer life cycle of buildings. [Aligned funding – BRANZ-funded PhD student, Rosa Gonzalez, on *Building the Carbon Case for Resilient Design*]

1c – Societal expectations (Brown, Becker): Building codes serve the people who use, own, and operate buildings, hence, any fundamental changes in performance objectives need to be linked to societal expectations of building performance. This project, closely linked the EQC-funded Resilient Buildings Project, will seek to assess the expectations of building performance across a range of earthquake intensities. This project will also be linked with project 4b which explores the expectations of time frames for return to function for different building owners and tenants. [Aligned funding – EQC-funded Resilient Buildings Project led by NZSEE. This funding will support lead Brown and Postdoc (Shannon Abeling).]

2) Maintaining Functionality: The optimal outcome would enable near-immediate occupancy of buildings after a damaging earthquake, facilitating community resilience and rapid recovery. Such performance objectives might initially be applied to high importance-level structures or those with long-term institutional tenants with additional motivation for building resilience, before becoming more widespread. While specific drivers and social/economic factors which influence adoption of low-damage designs will be investigated within projects 1a-c, there is also a need for robust technical guidance to ensure that low-damage structural designs achieve their intended performance goals. This objective will test, analyse, and optimise Low-Damage Design Guidance and extend the methodology to a Risk-Targeted Design process.

2a – Low-Damage Design (Rodgers, Henry): This objective will examine, test, and modify existing low-damage design guidance to assess whether this guidance provides the intended objectives to maintain functionality, enable rapid re-occupancy and support more resilient building design. Research will focus upon assessment of maintaining functionality, seek to improve and optimise guidance, as well as identify cases where designs might meet the definitions, but not the intent of the guidelines. [Aligned funding: This project will leverage significant existing funding for the MBIE-funded Low-Damage Design Guidelines.]

2b – Risk-Targeted Design for Functionality (Stephens, Horspool, Hulsey): Risk-targeted design has recently been proposed to select design levels to ensure buildings do not exceed an acceptable annual fatality risk (Horspool et al 2021). Such concepts can be extended to be framed in terms of risk of losing functionality. With a focus on identifying non-structural components most likely to cause significant impact on

functionality, this project will seek to define a framework for assessing the probability of losing functionality.

2c – Seismic Performance of Non-structural Elements (Dhakal, Sullivan): Maintenance of functionality is often governed by the seismic performance of non-structural elements (NSE) and their interaction with the structural system. Identification of performance of existing NSE is critical to understanding the expected functionality of current designs, while development of new low-damage NSE will be critical to providing functionality for strong earthquakes. [Aligned funding: Quake Centre Building Innovation Partnership programme includes substantial funding to investigate the seismic performance of non-structural elements. This programme will be integrated with IP1 through this project.]

2d – Ensuring Resilience (MacRae, Rodgers): This project aims to define how low-damage construction will increase the "degree of confidence" (i.e. reduce the epistemic uncertainty) in our measures of loss, while also accounting for aleatory uncertainty. The project aligns with the ongoing ROBUST collaboration between QuakeCoRE and ILEE. The project will include workshops with practitioners to seek to overcome barriers to low-damage technology implementation. [CSC aligned funding for Zheng Luo, visitor to UC in 2022.]

3) Repaired Buildings: It is not economical or realistic to design all buildings to maintain functionality in the whole range of earthquake intensities possible in NZ urban regions; however, buildings can be designed to facilitate repair and return to function. This objective seeks to understand societal views of repaired buildings (e.g. loss of trust or value) and identify engineering criteria for when a building is repairable.

3a – Building user views of repaired buildings (Becker, Filippova): One rationale provided for demolition of lightly-damaged buildings after recent earthquakes has been the perception that tenants will not want to live or work in a repaired building (Marquis et al 2018). This project seeks to better understand the perceptions of building users and owners of repaired buildings, what drives these perceptions, and what can be done to build confidence in the performance of buildings repaired after strong earthquakes. This project is closely tied to project 1c and 4b, including a shared PhD student between project 3a and 4b.

3b – *Component limits for repairability* (Elwood, Hogan, Lopocaro): Current design standards provide material strain (or curvature) limits to ensure structural components will be able to perform as intended at the ultimate limit state. Such limits may or may not ensure repairability of the structural components. With an initial focus on reinforced concrete components, this project will seek to define material strain limits which provide a high probability of repairability and identify component detailing changes which will enhance the repairability of conventional construction in New Zealand. A particular emphasis is placed on relatively simple means of repair which enable earlier return to function. [Aligned funding – FEMA-funded project on Guidelines for Repair of Concrete Buildings led by Elwood and UA Doctoral Scholarship Student, Ryo Kuwabara.]

4) Timeframes for restoration of function: Post-earthquake recovery models can be used as decision support tools for both pre- and post-event building restoration planning. However, due to the complexities around data availability and requirements and interplays between socio-economic factors, there have been few opportunities to quantify the timeframes for restoring buildings to functional recovery. This objective seeks to understand those complexities that influence the timeframe of functional recovery.

4a – Relating functionality timeframes to building occupancies (Boston, Chang-Richards): Different functionality timeframes will lead to different decisions on building occupancy, and associated effects of those decisions. This project seeks to use fragility curves of buildings to evaluate the criticality of both structural and non-structural building systems for achieving functional recovery; and then formulate a stochastic model by establishing relationships between functionality timeframes and building occupancies over time.

4b – *Expectations of restoration timeframes* (Filippova, Ying): The lack of tools and data to aid in repair-demolish decision-making offers plausible explanation regarding the key impediments to successful building restoration decisions (Ying et al., 2016). This project seeks to establish an expectation continuum

of building owners/users around the restoration timeframes and how these expectations can be better managed and factored in when identifying acceptable functional recovery timeframes. This project is closely tied to project 1c and 3a, including a shared PhD student between project 3a and 4b.

4c – Timeframes for repair in post-earthquake environment (Chang-Richards, Cardwell): External constraints such as engineering and construction capability and stakeholder requirements are widely associated with the ability for attaining achievable and acceptable timeframes for buildings to restore functions (Chang-Richards et al., 2017). This project seeks to develop data-driven repair time models by using multivariate logistic regression to quantify the parameters that drive the step changes in functional recovery timeframes for multi-storey buildings

Relationship to our Vision Mātauranga Strategy: The project team has considered areas where there is a clearly identified Mātauranga Māori aspect to the research. However, the project leaders wish to request further discussion with QuakeCoRE Associate Director - Māori, Professor Anthony Hoete to further improve the identification of areas where greater consideration of Mātauranga Māori may be of relevance and mutual benefit.

WHAKAAROTAU: The projects which involve understanding societal perceptions of performance will include Māori perspectives on resilience. The concept of resilience and long-term performance of the built environment includes the concept of Kaitiakitanga and long-term guardianship to create a built environment which does not become a liability for future generations. When seeking Māori input on expectations of performance, the research programme will be required to comply with the Te Mana Raraunga Charter, acknowledging that data is potential taonga for Māori in relation to its utility and contribution to the collective research project. Māori will be consulted throughout the research and research outcomes will be disseminated to Māori to recognise their contribution to the project and to maintain Māori rangatiratanga/sovereignty over their data that has contributed to the research.

WHAKARAKEI: Across all projects dealing with economic, societal, or technical challenges, efforts will be made to incorporate Māori perspectives across the decision-making process to enable the built environment to be more resilient to natural hazards. Many of the design decisions that have led to a poor level of building resilience stems from a lack of long-term thinking. A new approach that considers long-term resilience and guardianship of the built environment for future generations may resonate with a Māori world view.

WHAKATIPUORA: Efforts will be made to recruit Māori postgraduate students who can contribute to the research programme. At all stages of the research, efforts will be made to include a Māori perspective through Summer scholars, research assistants, as well as with postgraduate students and faculty members.

Expected Impacts:

QuakeCoRE is uniquely positioned to positively influence the direction of building codes in New Zealand and internationally in the next 3-5 years. Building codes and standards related to seismic design last saw fundamental changes over 40 years ago (late 1970s) with the introduction of ductile design methodologies. With the 10-year and 5-year anniversaries of the Canterbury and Kaikoura earthquakes, respectively, there is a growing sense that such methodologies are no longer serving the needs of society and there exists a once in a generation opportunity to challenge and improve our fundamental approach to seismic design of buildings. The New Zealand building regulator, MBIE BSP, has recently initiated a multi-year effort to identify possible future changes to the codes and standards. This Interdisciplinary programme will provide fundamental science and an evidence base in support of these changes.

References:

AIJ. Towards a proposal of resilience and Business Continuity Performance (BCP) level for evaluating the performance of building functionality preservation and recovery after natural disasters. Architectural

Institute of Japan, Special survey committee on resilience and BCP. 2019 AIJ Annual Meeting. Kanazawa, Japan, (2019).

Chang S, Taylor J, Elwood K et al. Urban Disaster Recovery in Christchurch: The Central Business District Cordon and Other Critical Decisions. Earthquake Spectra 30, 513-532, (2014).

EERI. Functional Recovery: A conceptual framework, (2019). https://www.eeri.org/images/archived/wp-content/uploads/EERI-Functional-Recovery-Conceptual-Framework-White-Paper-201907.pdf (accessed June 2021).

Federal Register. "Executive Order 13717 of February 2, 2016: Establishing a Federal Earthquake Risk Management Standard." V.84, n.24, February 5. (2016).

Marquis F, Kim JJ, Elwood KJ et al. Understanding post-earthquake decisions on multi-storey concrete buildings in Christchurch, New Zealand. Bulletin of Earthquake Engineering 15, 731-758, (2017).

Wellington City Council. Wellington Resilience Strategy. 116 pp (2017). https://wellington.govt.nz/-/media/wellington-city/about-wellington/resilient-wellington/files/strategy/reslience-strategyj001767-100-web.pdf?la=en&hash=69C495782BAC7751C6627CBF6E8759AF0E144EF0

Chang-Richards Y., Wilkinson S., Seville E., & Brunsdon D. An organizational capability framework for earthquake recovery. Earthquake Spectra, 33(4), 1257-1278. (2017).

Ying F., Wilkinson S., Corner J. Challenges to seismic rehabilitation decision process in New Zealand: A focus of decision environment. International Journal of Strategic Property Management, 20(3), 305-315. (2016).

3. Project Budget

Budget template attached

4. Budget Justification:

Roles:

Name	Role (e.g. Project Leader, Project Investigator, Student, Translation partner)	Responsibilities
Ken Elwood	Project co-lead	Lead of objective 1 and 3, co-lead of project 3b
Geoff Rodgers	Project co-lead	Lead of objective 2, lead of project 2a
Alice Chang-Richards	Project co-lead	Lead of objective 4, lead of project 4c
Robert Cardwell	Investigator	Lead of project 1a, co-lead 4c
Olga Filippova	Investigator	Lead of project 4b, co-lead of 1a and 3a
Charlotte Toma	Investigator	Lead of project 1b
Rosa Gonzalez	Student	Student project 1b
Charlotte Brown	Investigator	Lead of project 1c
Julia Becker	Investigator	Co-lead project 1c, Lead project 3a
Shannon Abeling	Postdoc	Researcher in project 1c
Rick Henry	Investigator	Co-lead project 2a
Max Stephens	Investigator	Lead of project 2b
Nick Horspool	Investigator	Co-lead project 2b
Anne Hulsey	Postdoc	Researcher in project 2b
Rajesh Dhakal	Investigator	Lead of project 2c
Tim Sullivan	Investigator	Co-lead project 2c
Kieran Haymes	Student	Student project 2c
Greg MacRae	Investigator	Lead project 2d
Lucas Hogan	Investigator	Lead project 3b
Giuseppe Lopocaro	Investigator	Co-lead project 3b
Ryo Kuwabara	Student	Student project 3b
Meagan Boston	Investigator	Lead project 4a
Beth Mayer	Student	Student project 4a
Fei Ying	Investigator	Co-lead project 4b
Helen Ferner	Industry Partner	Partner for objective 1
Didier Pettinga	Industry Partner	Partner for objective 2 and 3
Reza Jafarzadeh	Industry Partner	Partner for objective 4

Resources:

As shown below, project costs include RA support, workshops, Annual Meeting Travel, and other project travel for collaboration as described below:

- RA will organise monthly zoom calls, take minutes, maintain Wiki page, organise workshops, etc.
- One IP1 in-person workshop per year is planned to be held around Auckland to minimise travel.
- Annual Meeting travel of $1000 per active collaborator of IP1 is included.
- Small travel budget is distributed between participants of IP1 to facilitate collaboration and travel for project related activities (e.g. interviews)

		01 JUL 2021 - 30 JUN 2022	01 JUL 2022 - 30 JUN 2023	01 JUL 2023 - 30 JUN 2024	01 JUL 20234 - 31 DEC 2024		
RA support		$ 3,000	$ 6,000	$ 6,000	$ 6,000	$ 21,000	
Workshops		$ 5,000	$ 10,000	$ 5,000	$ 5,000	$ 25,000	
AM Travel		$ 19,000	$ 23,000	$ 23,000	$ 23,000	$ 88,000	
other travel		$ 7,000	$ 8,000	$ 8,000	$ 8,000	$ 31,000	
Students		$ 44,000	$ 228,000	$ 228,000	$ 210,000	$ 710,000	
TOTAL		$ 78,000	$ 275,000	$ 270,000	$ 252,000		
Programme Total			$ 875,000				

5. Outline of aligned funding:

Description of aligned activities:

Project 1b: Student partially funded by BRANZ scholarship, *Building the Carbon Case for Resilient Design.*

Project 1c: Postdoc and Project Lead funded by EQC on Resilient Buildings Project (led by NZSEE). Also aligned with MBIE Seismic Risk Work Programme being initiated in 2021.

Project 2a: Leverages MBIE-funded Low-Damage Design Guidelines. No direct funding.

Project 2b: Postdoc Anne Hulsey has applied for EQC Biennial Grant to support her time. Co-lead Horspool supported by GNS SSIF.

Project 2c: Quake Centre Building Innovation Partnership programme includes substantial funding to investigate the seismic performance of non-structural elements. This aligned funding will support students associated with this Project.

Project 2d: Chinese Scholarship Council providing support for Luo Zheng to travel to UC for 2022.

Project 3b: FEMA-funded project on Guidelines for Repair of Concrete Buildings led by Elwood and UA Doctoral Scholarship Student, Ryo Kuwabara.

Personnel (salaries and student scholarships):

Name	Funding source	FTE	Cost (including overhead and salary related costs)
Rosa Gonzalez	BRANZ		$50000
Charlotte Brown	EQC		$50000
Shannon Abeling	EQC	1.0	$182,000
Anne Hulsey	EQC/WCC	0.5	$100,000
Muhammad Rashid	Quake Centre BIP		$96,000
Ryo Kuwabara	UoA		$96,000
	Total:		$574,000

Total aligned funding: $574000

6. Project Deliverables:

Research Programme Deliverables		
Deliverables / Milestones		**Due Date**
Objective 1 - Document summarising drivers for change in the seismic design of buildings and consideration of functional recovery		Dec 2024
Objective 2 - Document summarising design factors and methods for creating building systems that maintain functionality through moderate to large earthquakes		Dec 2024
Objective 3 – A document summarising means to address social and technical barriers to repair of earthquake-damaged buildings		Dec 2024
Objective 4 - A document summarising the complexities influencing functional recovery timeframes and quantification of those parameters that drive the step changes in functional recovery timeframes for multi-storey buildings		Dec 2024
Publication and Data		**Due Date**
Publications	**1.** 2022 Peer Reviewed Journal Publications: At least 3 peer reviewed journal publications	31/12/2022
	2. 2023 Peer Reviewed Journal Publications: At least 3 peer reviewed journal publications	31/12/2023
	3. 2024 Peer Reviewed Journal Publications: At least 3 peer reviewed journal publications	31/12/2024
Data	1. Share all appropriate 2022 data on DesignSafe, DIVE or equivalent platform	31/12/2022
	2. Share all appropriate 2023 data on DesignSafe, DIVE or equivalent platform	31/12/2023
	3. Share all appropriate 2024 data on DesignSafe, DIVE or equivalent platform	31/12/2024

7. Communication and Engagement

Communication of findings and engagement with stakeholders and end-users will be done at regular intervals throughout the project. Workshops will be held with the research community and industry by aligning the workshops with key events such as the QuakeCoRE Annual Meeting, NZSEE, and SESOC conferences. Monthly videoconferences will be held to ensure that stakeholders and end-users are engaged to help guide direction and co-create research ideas, as well as ensuring that the different objectives within IP1 have regular interaction and cross-pollination to avoid the different objectives operating in silos. We also anticipate one QuakeCoRE seminar per year as part of the monthly seminar series to the broader QuakeCoRE community.

While the different objectives are led by full-time researchers, they align with other initiatives led by industry and stakeholders. For example, objective 1c is strongly aligned with the EQC-funded and NZSEE-led Resilient Buildings Project which ensures that there is representation from practicing engineers and the industry body in the research. The programme leaders also have strong industry connections and will leverage these connections to ensure industry-relevance of the research from inception to final delivery.

8. Risks

The success of the project relies on the quality contribution of research students. Given the Covid impact and ongoing uncertainty of immigration policy for overseas students, there is a risk where students that are key to the delivery have not been identified. To mitigate this risk of low student participation, we are drawing on strong existing relationships and utilising networks among domestic engineering Part IV students and Masters students to identify the potential candidates. In addition we are approaching the University leadership teams to put forward a round of applications to Immigration New Zealand for overseas PhD students who have "a role that is essential for the completion or continuation of a science programme under a government funded or partially government-funded contract, including research and development exchanges and partnerships." We anticipate that Immigration New Zealand will see the benefits from granting entry for overseas students who will make a contribution to the project.

The second risk is withdrawal or absence of a key team member. The QuakeCoRE wider research team has worked together on a number of projects and have successively and proactively responded to disruptions when they arose. The institutions involved in this project have research teams and expertise that are also ready to provide additional project support, if necessary.

9. Ethics or Regulatory Approvals:

Does this project require ethics and/or regulatory approval(s)?

☒ Yes ☐ No

We will obtain ethics approval for both the interview and survey components of the research for sub-objectives of 1a, 1c, 2d, 3a, 4b and 4c.

This application is consistent with the QuakeCoRE collaboration agreement and has been read by both the applicant and employing organisation and it is acknowledged that if this proposal receives QuakeCoRE funding, the terms and conditions set out in the agreement must be adhered to. I confirm that all of the people named in this proposal are aware of their involvement in this project and are committed to supporting a successful project outcome.

SIGNATURE: 

Date: 27 June 2021

International Review

International Advisor Review

As programme (Co) Leaders, please liaise with an international colleague who can act as an advisor to provide a review of this proposed programme. The aim of the international review, as indicated by the questions below, is to ensure that the programme meets the expectations of research excellence for the relevant research area. It is expected that prior to completing the form below there may be iterative discussion and adjustment between the programme (Co) Leaders and the International Advisor.

For each of the criteria listed below, please indicate how well you feel the project meets this area.

1. **Research Excellence**
   As a centre of research excellence, we are committed to undertaking world class research. Our funders place an emphasis on measuring research excellence by peer reviewed publications.
   Please consider these criteria in your evaluation:
   - Quality of proposed research
   - Track Record & ability to deliver proposed research
     - **Excellent**

2. **Human Capacity Development**
   QuakeCoRE is committed to developing human capacity in our community.
   Please consider these criteria in your evaluation:
   - Involvement of postgraduate students and emerging researchers (both Postdoctoral fellows and researchers that are less than 7 years from conferment of their PhD)
   - Development & support for members of under-represented groups in particularly women in engineering, researchers that identify as Māori or Pasifika.
     - **Excellent**

3. **Fit with QuakeCoRE Mission**
   QuakeCoRE is funded by TEC to deliver on our mission of placing Aotearoa New Zealand at the worldwide forefront of earthquake disaster resilience by utilising Aotearoa New Zealand as a natural earthquake laboratory, producing new knowledge on the seismic response of the built environment, developing models to understand vulnerabilities within this environment, and designing innovative technologies and decision-support tools enabling rapid recovery of Aotearoa New Zealand communities.
   Please consider these criteria in your evaluation:
   - Alignment of the proposed research with the QuakeCoRE Mission
   - Value and additionality of proposed research relative to its cost. Opportunities, relevance and translation to practice including direct involvement of end-users and stakeholders.
     - **Excellent**

Briefly outline below how the research in this project proposal corresponds with international research priorities

This proposal is similar to research discussions in the US and Europe with regard to incorporating functional recovery into building codes in order to integrate long term resilience into building standards. In the US two recent major publications by the National Institute of Building Standards (one in collaboration with FEMA) address the research needs and the steps necessary to both undertake the research and translate that into implementable codes and programs. In Europe, Italy is leading on resilience programs for their electrical grid and they are beginning to integrate seismic improvement programs with energy conservation programs as part of a broader outreach.

Please comment briefly on the quality of the research and provide a brief critique of the project proposal

The QuakeCoRE programme outlined here is one of the first to focus on the human factors in decision-making and incorporate that into the issues that impact adoption. This is an excellent example of a holistic research to implementation approach. Looking at the drivers for change is critical to implementation and adoption of new building standards, and understanding owners and users perceptions of building repair is critical to the acceptance of repaired buildings. In this section, I would note that it will be important to include the views and processes used by the insurance sector, as these will have sinificant influece on owner decisions. Further, the Mātauranga Māori aspects of the research clearly are critical to understanding and adoption of the research outcomes.

On the technical side, the integration of the performace of structural and nonstructural systems is critical, and I would suggest that if possible, the nonstructural should include some critical contents in certain building types. Hospitals and labratories, for example, are as dependant on the functioning of contents as they are on the building systems.

Minor comments to improve the clarity of the proposal:
In the Abstract, make clear that the functional recovery is focused on new construction, while the research on repairability applies to all buildings.
In the Research Context, it would help to define what is meant by the restoration of function to pre-earthquake conditions. Is this full functionality or is some percentage acceptable? How is this different from sufficient maintenance to maintain pre-event functionality?
In the Research Methodology, Sections 2a and 2c are clearly related, but there is no discussion of any testing or analysis of the interactions between structural and nonstructural systems. In 3b on the Structural Component Limits for repairability, there is no mention of similar work on nonstructural components? Is that part of the research, or are there specific components that should be part of the research? With regard to timeframes for repair, a new paper on this subject has just been published in Earthquake Spectra, and will be included for the researchers review.

Based on your review of the project, would you recommend that QuakeCoRE fund this proposal as written?

☒ **Yes** ☐ **No**

International Reviewer Details

Name: Mary Comerio

Organisation: University of California Berkeley

Email Address: mcomerio@berkeley.edu

Industry / Stakeholder Review

Industry / Stakeholder Review

As programme (Co) Leaders, please liaise with an industry/stakeholder colleague who can act as an advisor to provide a review of this proposed programme. The aim of the industry review, as indicated by the questions below, it to ensure that the programme meets the expectations of end-user engagement. It is expected that prior to completing the form below there may be iterative discussion and adjustment between the programme (Co) Leaders and industry reviewer.

For each of the criteria listed below, please indicate how well you feel the project meets this area.

4. **Research Excellence**
   As a centre of research excellence, we are committed to undertaking world class research. Our funders place an emphasis on measuring research excellence by peer reviewed publications.
   Please consider these criteria in your evaluation:
   - Quality of proposed research
   - Track Record & ability to deliver proposed research

   SELECT FROM:
   - Excellent
   - Well Above Average
   - Average
   - Below Average
   - Well Below Average

   Excellent

5. **Human Capacity Development**
   QuakeCoRE is committed to developing human capacity in our community.
   Please consider these criteria in your evaluation:
   - Involvement of postgraduate students and emerging researchers (both Postdoctoral fellows and researchers that are less than 7 years from conferment of their PhD)
   - Development & support for members of under-represented groups in particularly women in engineering, researchers that identify as Māori or Pasifika.

   SELECT FROM:
   - Excellent
   - Well Above Average
   - Average
   - Below Average
   - Well Below Average

   Excellent

6. **Fit with QuakeCoRE Mission**
   QuakeCoRE is funded by TEC to deliver on our mission of placing Aotearoa New Zealand at the worldwide forefront of earthquake disaster resilience by utilising Aotearoa New Zealand as a natural earthquake laboratory, producing new knowledge on the seismic response of the built environment, developing models to understand vulnerabilities within this environment, and designing innovative technologies and decision-support tools enabling rapid recovery of Aotearoa New Zealand communities.
   Please consider these criteria in your evaluation:
   - Alignment of the proposed research with the QuakeCoRE Mission

- Value and additionality of proposed research relative to its cost. Opportunities, relevance and translation to practice including direct involvement of end-users and stakeholders.

  SELECT FROM:

  - Excellent
  - Well Above Average
  - Average
  - Below Average
  - Well Below Average

  Excellent

Briefly outline below how the research in this project proposal will support the benefit to industry and communities in Aotearoa New Zealand.

This research project proposal represents an aggregate of understanding and insight into what the next steps are for Aotearoa New Zealand to be better prepared and more responsive to earthquakes that affect its communities. Drawing on recent research and in-the-field local experience, the need for decision-making that focuses on the human factors has become apparent, and this proposal represents a clear recognition of this need. The proposed multi-discipline approach outlined in this proposal will not only help the industry to understand the drivers for adopting improvements in responding to seismic related challenges, but will also provide the industry and communities with the tools and communication understanding, to make better informed decisions through design, assessment and planning for earthquake events.

Please comment briefly on the quality of the research and provide a brief critique of the project proposal

Considering the proposed components to the research, and the track-record of the lead contributors, this proposal can provide a high-quality contribution to Aotearoa New Zealand earthquake preparedness. As it draws from a strong body of local experience, with continued and engaged international contributions, this research represents an excellent opportunity to make a defining impact both here and overseas.

In reviewing the proposal, I would suggest the following adjustments be considered to ensure that the projects develop in a way that generates the best opportunities for uptake.

- As part of (2) – Maintaining Functionality, consider including an output that provides a heirarchy of LDD targets that provide a scale from optimal to “less than optimal but better than code minimums”. This would be along the lines of the steps currently proposed in the LDD guidelines but more specific to maintaining functionality. This feels like a good underlying link from 1a/1b/1c to (2) (noted that it is a bit in the wording of 2b).
- Where industry engagement through workshops is proposed, I would recommend that multiple opportunities are provided. For example (2d) would be better posed if there is an opportunity for initial feedback on proposed measures, time to go away and think about it/trial/update/improve, and then come back as a group to get buy-in and understanding on the use and limitations.
- I would emphasize that in planning the components to the proposal, keep sight of what are the current industry directions. For example in looking at repairability, the significant body of work and understanding of has come from reinforced concrete structural element research following recent earthquakes and the existing building-stock in Christchurch and Wellington, this doesn’t necessarily align with the industry move to structural steel that has become a major part of significant new building development in the past 10 years. With regards to (3b) it would be very beneficial to include structural steel systems in the proposed research and methodology development.

Based on your review of the project, would you recommend that QuakeCoRE fund this proposal as written?

☒	**Yes**	☐	**No**

Industry Reviewer Details

Name: Didier Pettinga

Organisation: Holmes Consulting LP

Email Address: didier.pettinga@holmesconsulting.co.nz