QuakeCoRE
NZ Centre for Earthquake Resilience
Te Hiranga Rū

Flagship 4 Coordinated Project 2019-2020

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Project Contributors

Project Leader Name (Organisation)	QuakeCoRE PI/AI	QuakeCoRE Industry Affiliate	Others – Aligned Researchers, Stakeholders, Students etc
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2018-2020 TEC Contract for delivery by QuakeCoRE Flagship 4 Programme

Flagship 4:
This flagship will seek a new design paradigm whereby reparability and damage-control is explicitly considered in the design process. This requires the development of new low-damage systems, quantification of the reparability (cost and time) of conventional systems, and design process methodologies for implementation. This flagship will also result in important changes to implementation standards; which provide the mainstream technology transfer mechanism given that all future designs must satisfy these standards. Significant economic benefits are also expected through both reductions in future earthquake losses and increased international competitiveness of New Zealand engineering consultants and marketing of new seismic protective devices. The key thrust areas are:

1. Development of new technologies for buildings (structural and non-structural) to control damage in future events and enable rapid recovery.
2. Development of procedures to reliably assess and communicate the performance of new and conventional systems, including consideration of residual capacity of earthquake-damaged infrastructure and cost-effective repair techniques.
3. Integration of reparability performance objectives into implementation standards and alignment with insurance policies optimised for rapid recovery.

Thrust Areas	Key tasks/Deliverables	Start	Finish
FP4.1 New technologies for buildings	1. Develop low damage systems for buildings (with focus on whole-of-building performance) including guidance for their design and construction.	1/01/2016	31/12/2020
	2. Development of a risk-targeted design methodology for new systems.	1/01/2018	31/12/2020
FP4.2 Performance objectives and reparability of systems	1. Develop methodology for assessing residual capacity of building structures (generalised and material specific)	1/01/2016	31/12/2016
	2. Use of large-scale test results for validation of models to assess performance (including residual capacity and repair techniques)	1/01/2018	31/12/2020
	3. Develop improved means of considering reparability within the performance assessment of new and conventional buildings systems	1/01/2018	31/12/2020
	4. Develop alternative repair strategies for existing structures considering advanced performance measures	1/01/2018	31/12/2020
FP4.3 Implementation	1. Identify means (economic, regulatory, etc) to implementation of low-damage systems	1/01/2016	31/12/2020
	2. Propose alternative methods to assess performance (economic or other relevant reparability performance objectives) of traditional building solutions with that of low-damage systems	1/01/2017	31/12/2020

FP4 Coordinated Project Plan – 2019-20

Research Activities:

Activity 1: Risk targeted seismic design

This work will build on the research into the simplified SAC-FEMA approach that identified means of improving its accuracy.

- Establish a suitable framework for risk-targeted seismic design. The means by which inelastic spectra could assist with risk-targeted design will be assessed, with the objective of evaluating whether an inelastic spectrum approach would be more suitable than scaling of elastic spectra for a practice-oriented risk-targeted design framework. The performance of the approach will be evaluated by comparing the predicted rates of exceeding key limit states with those obtained via a more traditional PBEE evaluation currently used in practice. This first task will focus on examining SDOF systems but efforts will be made to ensure that the framework will be easily transferrable to MDOF systems.
- Once a suitable framework has been identified, identify the best means of accounting for different sources of uncertainty in the risk-targeted design process. This step will include trialling the use of the SAC-FEMA approach developed in 2018 as well as more rigorous methods that include monte-carlo sampling. This task will include consideration and evaluation of both single- and multi-storey building systems.
- Validate the proposed approach for a range of structural typologies and developing examples that can serve as guidance for the industry.

Activity 2: Improving the reparability of structural steel systems

The research to be undertaken within the coordinated project will include continued preparation and then execution of the experimental research. A PhD student will be using the research results to support the development of low-damage friction devices for reparable structural steel systems. This topic, and the ROBUST project in general, is expected to greatly facilitate the uptake of low-damage structural steel systems in practice and will prompt further state-of-the-art research into reparable steel structural systems.

Activity 3: Analytical assessment of residual capacity of reinforced concrete systems, including repaired systems and retrofit systems.

This project will supplement this work with additional research into concrete walls at the University of Auckland, focusing on the following aspects:

- Testing of alternative wall designs, considering a range of solutions from conventional reinforced concrete walls and low-damage modifications / systems. For each test wall detailed information will be collected on damage states to develop fragility curves and repair limits.
- Repair and retesting of walls subjected to certain earthquake demands. Assessment of residual capacity and performance of repair strategies for different levels of damage.
- Improvement of tools to estimate damage states and repair limits, including simplified (desktop) estimates and detailed models that can aid design of such systems.

At the University of Canterbury, the work will focus on developing means of accounting for duration effects on the reparability of RC structures. The following tasks are planned for 2019-2020:

- A cyclic pushover analysis will be developed that enables the consideration of both the peak deformations and the cyclic degradation experienced under an earthquake ground motion, to estimate its residual capacity.
- The ability of various structural modelling techniques to capture the anticipated deterioration in structural strength and stiffness under cyclic loading will be examined.
- The number and amplitude of cycles to be used to conduct this cyclic pushover analysis will be determined by simulating the response of a wide range of structures under both short and long duration ground motions, and observing the number of deformation cycles experienced by various structural components.
- This study will also inform the development of long duration loading protocols for component testing and qualification, to complement the short duration loading protocols that are prevalent in current practice.
- The bidirectional deformation demands induced on a structure under an earthquake will also be assessed.

Activity 4: Improving reparability of timber structures

The seismic performance of timber structures is greatly dependent on the characteristics of the connections between timber members and between timber and steel members. To this extent, the traditional approach for connecting heavy timber members has been to use dowels but this presents a number of challenges. The specific tasks will be to:

- Undertake experimental testing of self-drilling dowelled connections to permit quantification of strength, stiffness, ductility and overstrength properties, including the factors that affect these characteristics.
- Develop analytical means of quantifying the seismic performance of timber structures with such connections, comparing design equations for the connections from Eurocode 5 and from dowel manufacturers with the experimental results and proposing refinements where necessary.

A parallel thrust of this research area will be to examine the fragility/reparability of timber-framed houses. Subsequently, the research will consider what steps could be taken to reduce the likelihood of damage in future earthquakes.

Activity 5: Response modelling and implementation guidance for including new energy dissipation mechanisms into multi-level structures.

There are a range of innovative new energy dissipation methods available to modify seismic structural response. A key focus of this flagship is to both facilitate wider field usage of this technology, but to also provide guidance so that field implementation is done effectively.

Key objectives:

- Investigate rocking wall structures that exhibit non-linear elastic response, where added damping forces and associated phasing effects have an even bigger influence on total foundation loads.
- displacement-dependent and both linear and non-linear velocity dependent response characteristics will be used to capture a wide range of existing devices available within New Zealand and internationally.
- The multi-level simulations will build upon the case study building developed as part of the loss-modelling tranche part of the co-ordinated project.
- Develop tools in OpenSEES which will made available to ensure that the resulting models are available to other researchers or practitioners.
- Provide simplified guidance for initial design and retrofit of existing structures will be included, so that more detailed time-history is not required. In cases where a simplified design approach will be implemented, the guidelines can be used to include an appropriate energy dissipation and/or bracing configuration.

Activity 6: Development and testing of a practice-oriented means of defining both horizontal and vertical acceleration and displacement spectra at various floor levels in structural systems.

The topic of floor response spectra has received increased attention in recent years as it is recognized that current code methods are of limited accuracy. The following will be undertaken:

- Examining the results obtained from the study into horizontal floor spectra, a new practice-oriented approach will be formulated for use in New Zealand. This approach will receive input from the industry to ensure that the approach is suitably simple and to assist in eventual uptake by the consulting engineering community.
- The applicability and performance of the new procedure for the estimation of vertical floor response spectra will be assessed and refinements and modifications to the approach will be made as necessary.
- Means of developing inelastic floor response spectra will also be investigated, with the objective of identifying a new set of simplified rules that permit elastic floor response spectra to be transformed into inelastic floor response spectra for a range of different non-structural (or secondary structural) systems possessing different hysteretic properties.

Activity 7: Investigating the seismic performance of non-structural elements with and without innovative detailing solutions.

The 2019-2020 project proposes to continue supporting research on seismic performance of glazing systems, with a focus testing different types of glazing systems.

The research area will also support investigations into the seismic performance and low-damage design of sprinkler piping systems. An experimental shake-table testing of sprinkler systems is planned.

Finally, the ROBUST building project is planning a 3-storey shake-table test of a low-damage steel building possessing non-structural elements. This co-funded research will generate data related to the seismic performance of non-structural elements that can be used to inform on the dynamic characteristics of non-structural elements as well as the complex interaction that can occur between them.

Activity 8: Development of a value proposition for next-generation construction technologies in New Zealand.

To achieve widespread implementation of low-damage systems, the economic benefits of such systems must be demonstrated. This is expected to require a long term outlook and an assessment of life-cycle costs. As such, this part of the project will build on previous the research findings, undertaking the following tasks:

- Analytical studies to permit comparison of the seismic performance, in terms of expected annual losses due to repair, of different low-damage structural systems and design strategies. In particular, the objective is to consider the potential benefits of low-damage concrete systems and further examination of the likely performance of low-damage steel systems, integrating the latest knowledge about the fragility and repair costs of non-structural elements.
- Identification of the relevance and value of building performance/damage to different stakeholders such as the public, local iwi, local government, central government and insurers.

For further details please contact the Flagship Leader