QuakeCoRE
NZ Centre for Earthquake Resilience
Te Hiranga Rū

Flagship 1 Coordinated Project 2019-2020

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Project Contributors

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2018-2020 TEC Contract for delivery by QuakeCoRE Flagship 1 Programme

Flagship 1:

This flagship will provide a paradigm shift in strong ground motion prediction in New Zealand and internationally through the use of high-fidelity physics-based prediction methods, which merge state-of-the-art knowledge in strong motion seismology and geotechnical earthquake engineering. The impact of this flagship will result from the reduction in the design level seismic hazard in many regions through an increased prediction precision, identification of regions with an increased seismic hazard resulting from systematic basin and topographic ground motion phenomena; quantification of ground motion intensity affecting spatially distributed infrastructure networks. The key thrust areas are:

1. Development and refinement of ground motion simulation methods that enable the generation of acceleration time series for the seismic response analysis of infrastructure.
2. Development of 'velocity models' of the earth's crust in new regions of New Zealand, or improvements in existing regions.

3. Develop, validate, and apply models for nonlinear near surface site and topographic response for use in conjunction with ground motion simulation methods.
4. Utilize ground motion simulations to forecast the severity of ground shaking over spatially-distributed regions in future major New Zealand earthquakes.
5. Examination of modelling uncertainties in ground motion simulation methods and utilization for probabilistic seismic hazard analysis.
6. Explore the role of simulated ground motions for use in seismic response analysis of engineering infrastructure, including comparisons with as recorded ground motions and development of procedures for simulated ground motions in infrastructure seismic design guidelines.

Thrust Areas	Key tasks/Deliverables	Start	Finish
FP1.1 Simulation methods	1. Integrate existing codes used in New Zealand into NeSI computational resources	1/01/2016	31/12/2016
	2. Validate simulations using historical New Zealand earthquakes	1/01/2016	31/12/2020
FP1.2 Velocity model development	1. Develop enhanced 3D velocity models in two regions of New Zealand	1/01/2016	31/12/2018
	2. Utilize full waveform tomography for high-resolution velocity modelling	1/01/2018	31/12/2020
FP1.3 Nonlinear site and topographic response	1. Directly integrate site response and topography into ground motion simulations vs. the use of Vs30. Examine the effects in Canterbury and Wellington	1/01/2016	31/12/2019
	2. Perform detailed analysis on when site-specific account for nonlinear and topographic effects is justified vs. simplified approaches	1/01/2018	31/12/2020
FP1.4 Application for major New Zealand scenarios	1. Perform ground motion simulation case studies for cross-flagship research and outreach and compare with empirical predictions	1/01/2016	31/12/2018
	2. Develop a 'Ground motion simulation atlas' illustrating seismic intensity over a region for 50 earthquake ruptures which are greatest risk to New Zealand	1/01/2017	31/12/2019
FP1.5 Uncertainties and PSHA	1. Develop advanced ground motion simulations with treatment of modelling uncertainties	1/01/2017	31/12/2020
	2. Perform 'Cybershake' simulations performed for T>1s in New Zealand. Compare with hazard from codes and GMPEs	1/01/2017	31/12/2020
FP1.6 Use of simulations in earthquake engineering analyses	1. Develop a co-created industry working document on the use of ground motion simulations in engineering design	1/01/2016	31/12/2018
	2. Compare and assess simulated vs. recorded ground motions with archetype engineering structures used to determine bias in simulation methods for feedback to developers	1/01/2017	31/12/2020

FP1 Coordinated Project Plan – 2019-20

<u>Research Activities:</u>

Activity 1a: Validation of simulations for NZ-wide historical events

This project aims to first quantify the predictive capability of simulation-based ground motion prediction as compared to conventional empirical prediction models. For each event, simulated and observed ground motions are compared quantitatively, and therefore across all observations and events, the salient trends in bias and precision of the prediction can be ascertained. The second part of this objective will utilize the large number of prediction-observation pairs to draw inferences as to the physical causes of bias and imprecision, based upon which advances to the simulation methodology and input parameters/models will be made and subjected to further validation.

Activity 1b: Ground motion simulation with multi-segment rupture

Recent NZ events such as the 2010 Darfield, 2011 Christchurch, and 2016 Kaikoura, NZ earthquakes have demonstrated significant complexity in the form of multi-segment ruptures. Such rupture complexity causes additional challenges in physics-based ground motion simulation, with prior pseudo-dynamic rupture generators being primarily developed for single fault plane applications. This project will undertake ground motion simulation of these three events (which have been previously simulated considering simplified rupture geometries) in order to examine the potential prediction advances that can be made through additional rupture complexity.

Activity 2a: Development of basin models in NZ sedimentary basins using 1st order methods

Earthquakes in New Zealand and internationally have demonstrated the influence of sedimentary basins on site amplification, particularly the influence of basin edge effects. The aim of this project is to develop and implement a methodology to provide 'rapid' geophysical characterisation of New Zealand sedimentary basins using the horizontal-to-vertical spectral ratio method (HV method).

Activity 2a: Full waveform tomography for velocity model improvement

Previous research has indicated that tomographically-improved crustal models provide a significantly improved ground motion prediction of independent validation events. We seek to examine this question explicitly for the 2010-2011 Canterbury earthquake sequence by first undertaking full waveform tomography using over 400 small-to-moderate magnitude earthquakes in the South Island that have GeoNet moment tensor solutions (Ristau 2013), and then secondly comparing the residuals between predictions for the 10 major events in the Canterbury earthquake sequence (CES).

Activity 3a: Explicit site response analysis in simulations of the Kaikōura earthquake

Conventional ground motion simulations (performed at a regional scale of 100's of km) often simplify near-surface site effects though the use of simplified Vs30-based amplification factors. This project will extend the Canterbury-based work in this area to strong motion stations in the 2016 Kaikōura earthquake region (North Eastern South Island, and Wellington regions).

Activity 3b: Topographic modelling for Alpine fault and Kaikōura earthquakes

This project will further advance pilot research into the consideration of topographic effects in ground motion simulations of the Canterbury earthquakes. This project will be extended to examine several historical earthquakes associated with the 2016 Kaikōura sequence and also undertake a simulation of the Alpine fault with topography to compare with prior results based on flat-earth models.

Activity 4a: Simulation of Wellington Fault earthquakes

This project will perform simulations of the Wellington fault which will provide data to aligned work looking at the impacts of a Wellington Fault earthquake.

Activity 4b: Simulation of Hikurangi subduction zone earthquakes

This project will extend work on validation simulations of NZ subduction zone earthquakes (the 2009 Dusky Sound earthquake) and perform simulations of potential future Hikurangi Subduction Zone earthquakes. Particular attention will be given to the earthquake rupture generation based on international analogies.

Activity 4c: Simulation of moderate magnitude earthquakes in the Auckland region

The recent earthquakes in Canterbury demonstrate the potential hazard that low strain-rate regions pose to New Zealand's large population centres. Given their relative quiescence, it follows that such regions typically have sparse monitoring and few recorded events. However, when proximity to urban centres, and the risk factor this introduces, is considered, some low-strain rate regions such as the the Kerepehi Fault warrant a closer look. The goal is to replicate ground motions for some historic events that have occurred in the rift and to undertake scenario earthquake ruptures which might be anticipated from the Kerepehi fault.

Activity 5a: Analysis and propagation of modelling uncertainties in ground motion simulation

This project will examine inherent simulation modelling uncertainties, quantify them, and propagate their effect on ground motion prediction. This project will seek to reconcile existing literature as to the uncertainties in the various parameters and models that are inputs to ground motion simulations.

Activity 5b: Simulation-based seismic hazard analysis for New Zealand at 200m resolution

This objective will utilize the ground motion simulation approach that will be advanced through projects 1a and 5a in order to assess the future hazard of earthquake-induced ground motions in New Zealand - providing an illustration of the potential for worldwide implementation. This study will exhaustively consider uncertainties, and quantify the error associated with only modelling uncertainties in rupture hypocentre and slip distribution considered in prior research by Cybershake. Secondly, in order to improve computational efficiency, probabilistic seismic hazard analysis will be performed first using empirical models, and only the major ruptures which dominate 99% of the hazard will be simulated. Advanced visualisation and database methods will be used to enable access to the results from simulation-based probabilistic seismic hazard analysis by both technical and lay-audiences.

Activity 6a: Application of code-compatible simulation vs recorded ground motions for structural and geotechnical systems

QuakeCoRE researchers have developed a guidance document on ground motion simulation validation, which includes the effects of simulations (vs. observed) ground motion for use in seismic response analyses of structural systems. This project will expand on this work to include geotechnical and soil-foundation-structure-interaction problems. Seismic site response, the performance of geotechnical embankments, and structures on flexible foundations will be considered.

Activity 6b: Guidance on selection of simulated ground motions as an alternative method for use in NZ

QuakeCoRE researchers have developed a guidance document for ground motion simulation validation. As a follow-on, this project aims to develop guidance on the selection of simulated ground motions for use in seismic response analyses in New Zealand. In parallel, this project will develop guidance, and examples, on the selection of simulated ground motions for use in NZ.

For further details please contact the Flagship Leader