2017 QuakeCoRE Annual Meeting

4-6 September, 2017 – Wairakei Resort, Taupo, New Zealand

Poster List

Abeling, S., Vallis, S., Gálvez, F., Dizhur, D., & Ingham, J., 24
Seismic Vulnerability Assessment of New Zealand Church Inventory

The 2010/11 Canterbury earthquakes demonstrated that churches, particularly unreinforced masonry (URM), are highly vulnerable to earthquakes and resulted in the loss of local architectural heritage. In an attempt to prevent further destruction of church architecture in New Zealand due to earthquakes, a pilot study was undertaken to identify the seismic vulnerability of properties owned by the Anglican Diocese of Waikato and Taranaki. A screening framework that identified vulnerability factors of churches was created based on international literature and churches damage observations following the 2010/2011 Canterbury earthquakes. The screening framework was applied to an inventory of buildings containing 70 churches, including 7 brick URM and 2 stone URM churches. Detailed general, architectural, and structural information was gathered for each of the buildings in the inventory. Church typologies were identified based on material and geometric characteristics. Churches in the inventory were assigned a vulnerability rating that will be used by the stakeholders to prioritise seismic strengthening interventions.

Andrew, J., Tucker, C., & Whittaker, C., 63
Tsunami Loading Characteristics on Utility Poles

Electrical networks allow societies to communicate, function and thrive, as well as facilitating post-disaster aid. Large-scale natural disasters such as tsunamis have the potential to destroy utility poles, vital components of the electricity network, delaying disaster relief and recovery. Due to the significance that New Zealand puts on its electrical networks following a natural disaster it is important to investigate the vulnerability of the network (starting with components such as utility poles), to establish potential damage states in post-disaster scenarios. This research will consider historical data for past tsunami events to form a basis of our experimental modelling and establish the fragility of utility poles under tsunami inundation. The laboratory testing will model two typical concrete utility pole designs as well as one wooden utility pole design against expected tsunami heights for New Zealand. The raw data from this laboratory testing will be processed into a structural model to output damage states, and hence fragility curves, for each of the utility pole designs subjected to tsunami loading. The primary objective is to establish fragility curves for common utility poles found in New Zealand due to tsunami loading. Secondary objectives include exploring the effects of transformers on the utility poles and debris in the tsunami bore. The poster will highlight the objectives and scope of the research and the methodology undertaken to achieve these objectives, as well as preliminary data from testing.

Aslam, K., & Taborda, R., 1

3D Earthquake Ground Motion Simulations for the Christchurch Area Including the Effects of the Surface Topography

We present initial results from a set of three-dimensional (3D) deterministic earthquake ground motion simulations for the northern Canterbury plains, Christchurch and the Banks Peninsula region, which explicitly incorporate the effects of the surface topography. The simulations are done using Hercules, an octree-based finite-element parallel software for solving 3D seismic wave propagation problems in heterogeneous media under kinematic faulting. We describe the efforts undertaken to couple Hercules with the South Island Velocity Model (SIVM), which included changes to the SIVM code in order to allow for single repetitive queries and thus achieve a seamless final-element meshing process within the end-to-end approach adopted in Hercules. We present our selection of the region of interest, which corresponds to an area of about 120 km x 120 km, with the 3D model reaching a depth of about 60 km. Initial simulation parameters are set for relatively high minimum shear wave velocity and a low maximum frequency, which we are progressively scaling up as computing resources permit. While the effects of topography are typically more important at higher frequencies and low seismic velocities, even at this initial stage of our efforts it is possible to observe the importance of the topography in the response at some key locations within our model. To highlight these effects we compare the results of the 3D topographic model with respect to those of a flat (squashed) 3D model. We draw relevant conclusions for the study of topographic effects during earthquakes for this region, and describe our plans for future work.

Bae, S., Lagrava, D., McGann, C., Chandramohan, R., Motha, J., & Bradley, B., 77

QuakeCoRE SW Workshops and Training

The QuakeCoRE Software team was established with a recognition of importance of developing computational capability for the QuakeCoRE research community. Subsequently, it has successfully delivered a number of software projects. Another role which needs to be highlighted, is the provision of workshops and training to grow computing capability of the QuakeCoRE research community, in order to enable computational capabilities to be fully utilized. This poster summarizes the past and current training offerings, such as Software Carpentry, OpenSees, Paraview and Git workshops, to invite ideas for development of future training programmes.

Bae, S., Lagrava, D., Zhu, M., Bradley, B., McGann, C., Robinson, D., & Ni, Y., 76

Visualisation for Scientific Discovery and Communication: Kaikoura Earthquake as a Case Study

The 2016 M7.8 Kaikoura earthquake was one of the largest earthquakes in New Zealand history and attracted attention not only from the research community, but also from the whole nation. QuakeCoRE researchers have obtained the ground motion simulation data of the event, and developed a visualisation workflow that constructs a 3D animation from the simulation data. This visualisation was augmented by the seismic response model of Wellington buildings and recovery progress of road networks. The 3D animation proved to be an effective way to improve understanding of the simulation data. Additionally, it improved the communication of the research output with the general public. This poster will illustrate the software packages and techniques used for the production of the Kaikoura earthquake visualisation.

Bahrebar, M., & Lim, J., 37
Nonlinear Seismic Behaviour of Perforated Steel Plate Shear Walls with Curved Corrugated Infill Plates

Recently, there has been renewed interest towards the use of different shape of corrugated infill plates in steel plate shear wall (SPSW) systems. Studies on steel plate shear walls with corrugated plates offer some clear advantages compared to flat infill plates including increase the energy absorption capacity, ductility performances, and improved buckling stability. Up to now, far too little attention has been paid to investigation on hysteretic behaviour of perforated steel shear wall with curved corrugated plate and very little is known about performances of such efficient lateral force-resisting systems. On this basis, this study set out to investigate the cyclic performance of SPSWs with horizontal curve corrugations and perforated infill plates. Numerous finite element models with various geometrical properties are developed and analysed under cyclic loading. Square perforations are implemented at the centre of the curved infill plates with areas equal to 5, 15, and 30 percent of the web-plate out-of-plane projected area. The findings of this study are indicative of effectiveness of the infill-plate thickness, angle of corrugation, and perforation size on the cyclic behaviour of corrugated- and perforated-web steel shear wall systems. These findings also enhance our understanding of the proper design and optimal selection of the infill plate geometrical and corrugation parameters as well.

Baki, A., Cubrinovski, M., & Stringer, M., 16
Effects of Partial Saturation on Liquefaction Triggering

Effects of partial saturation on the liquefaction resistance of silty sands is poorly defined although there is a clear evidence that soils at shallow depths below the ground water table are often partially saturated where their voids contain air bubbles or gas. After 2010-2011 earthquakes in Canterbury region of New Zealand, detailed field investigations have been conducted in Christchurch which indicated that the deposits within a zone of about 0.50 m to 1.50 m depth below the water table, and in some cases over larger depths, were partially saturated. These soil deposits typically contain layers of fines-containing sandy soils of low plasticity. Although simplified liquefaction evaluation methods reasonably predicted the severity and extent of liquefaction in Christchurch, a number of issues and unsatisfactory performances had also been identified. For example, the simplified methods for liquefaction assessment predicted moderate-to-severe liquefaction over large areas of Christchurch where no liquefaction manifestation was observed. These high levels of conservatism in the assessment have been identified as a major concern in the application of simplified liquefaction evaluation methods. Thus, in this research, triaxial testing has been conducted in two types of typical Christchurch soils at different levels of saturation, Sr (including a fully saturated soils) to investigate and quantify the effects of partial saturation on liquefaction resistance of sandy soils. Test results are presented here for discussion.

Bastin, S., Cubrinovski, M., Van Ballegooy, S., & Russell, J., 17
Characterization and Interpretation of Lateral Spreading Observations from the 2010-2011 Christchurch Earthquakes

Liquefaction-induced lateral spreading from earthquakes poses a significant hazard to the built environment, as observed during the 2010 to 2011 Canterbury Earthquake Sequence (CES). It is critical for geotechnical engineers to be able to estimate lateral spread displacements for design purposes. Displacement estimates derived from published empirical and semi-empirical models have been shown to vary by a factor of <0.5 to >2 from those measured in parts of Christchurch following the CES. Post-CES studies have indicated that the distribution and extent of lateral spreading in Christchurch was strongly influenced by geomorphic and topographic features. These features are not appropriately accounted

for in the predictive models and may account for some of the discrepancies between predicted and observed displacements. In addition, the published models contain different assumptions regarding the mechanism driving lateral spreading (i.e. co- and post-seismic contributions) which may also result in some of the inconsistencies between predicted and observed displacements.

In this study, the influence of topographic and geomorphic variability on the maximum inland extent of lateral spreading is examined for a study area in eastern Christchurch. Geotechnical characterization of the subsurface soil conditions across geomorphic areas indicates the extent of lateral spreading is strongly influenced by the thickness of potentially liquefiable sediment proximal to the river, which is shown to vary between geomorphic areas. The study area is also sub-divided into topography and free-face-related ground surface displacements to examine potential topographic effects. Future work will include the evaluation of the temporal evolution of lateral spread displacements from analysis of ground motion records to separate earthquake loading into pre-liquefaction triggering and post-liquefaction triggering phases. These results will be supplemented with observational records from local residents to establish co- and post- seismic contributions. Newmark-type analysis will additionally be undertaken to compare displacements modelled using the results from the ground-motion record analysis with that recorded. It is anticipated that combining the observational data with detailed geotechnical characterization will enable the lateral spreading mechanism best supported by the CES to be determined and the effects of topographic and geomorphic variability to be examined. In addition, comparison of the observed lateral spread displacements with that predicted by conventional analyses will enable the applicability of the current methods recommended to geotechnical engineers to be evaluated.

Becker, J., Carter, L., Brower, A., McBride, S., Beaven, S., Schoenfeld, M., Saunders, W., 25

Improving the Input of Earthquake Science and Engineering Information into Decision-Making: Results of a Workshop

An outcome of the QuakeCoRE Flagship 3 research initiative suggested that earthquake scientists and engineers would benefit from a better understanding of how science and engineering can inform decision-making (e.g. policy). To address this issue, a three-hour workshop on earthquake science-to-practice was held on 26 April 2017. The key objectives of the workshop were to: Investigate the barriers and opportunities for effective input of earthquake science and engineering into decision making (with a focus on policy).Provide a discussion around activities that need to take place to assist scientists, engineers and researchers to inform decision-making effectively. Approximately 40 people attended the workshop from varying sectors. The sectors represented included earthquake scientists, structural engineers, engineering geologists, social science researchers, emergency managers, policy personnel at local and central government levels, consultants, insurance sector representatives, and economists. The workshop provided a forum for participants to learn about the complexities of the science-policy environment, an opportunity to discuss barriers and opportunities for input, and an ability to make suggestions for future activities. We documented the workshop discussions and analysed the results in a social science research context. Our poster outlines some of the key points that arose during the workshop, and contemplates the benefits that such a forum can have for increasing co-operation between different sectors.

Bellagamba, X., Bradley, B., Wotherspoon, L., & Hughes, M., 64
Fragility Functions for Buried Pipelines in Liquefiable Soils Based on New Zealand Data

This poster presents parametric fragility functions for buried pressured water pipelines located in liquefaction-prone areas based on data collected following the 22 February, 13 June and 23 December 2011 events in the Canterbury earthquake sequence. The fragility of buried pipelines is expressed as a failure rate (number of reported pipe failures per kilometre) and utilizes the peak ground velocity as ground motion intensity measure. Considered model parameters are based on pipe characteristics (construction material and diameter) as well as local soil condition characterized by its susceptibility to liquefy under seismic loading expressed by the cyclic resistance ratio. To minimize the model error, multiple functional forms are tested and validated through a K-Fold cross-validation process. The model takes into account the within-model uncertainty represented as the apparent fitting error. In addition, the between-model uncertainty is explicitly considered in the proposed model based on unknown parameters, such that for each unknown parameter, the between-model uncertainty increases. The adopted framework enables a wide application of these fragility functions to analyse the seismic performance of buried pipeline networks, irrespective of the available information on the studied system. The proposed fragility functions are tested via Monte-Carlo simulations with the ground motion intensities recorded following the aforementioned earthquakes to compare predicted and observed damage to the Christchurch water network.

Best, T., Stephens, M., Elwood, K., & Horspool, N., 73
Smart Seismic Cities: Informing Pre-Earthquake Planning and Post-Event Response with Near Real-Time Impact Tools (NRITs)

The effectiveness of disaster planning and post-disaster response efforts is heavily reliant on the rapid availability of situational information, such as high-level estimations of extents of damage, loss of critical infrastructure functionality, and loss of life. The ability to quickly garner this information allows for the immediate accessibility of not only a pulse on the situation but a more detailed picture of the aftermath, thereby promoting a more organized, efficient, and confident response in the early hours following a disaster. This project seeks to develop a framework of near real-time impact tools (NRITs), particularly consisting of a network of instrumented buildings and other monitoring sources feeding information to structural analysis software tethered to a city-wide inventory of structures in Wellington. The output of these tools will provide rapidly-accessible situational information, aiding in decision-making and resource allocation.

Blick, G., de Raadt, A., Johns, B., & Reese, I., 74
Earthquake Impact on Geodetic and Topographic Infrastructure in New Zealand

The dynamic nature of New Zealand, with substantial active deformation from its position across a major plate boundary, provides substantial challenges in maintaining national geodetic and topographic infrastructure and products. Steady state motion is well observed and can be modelled with good accuracy, but earthquake events can cause major disruptions that can have severe effects. For example, the 2010/11 Canterbury and 2016 Kaikoura earthquakes resulted in permanent ground displacement well beyond the accuracy needs of many users and had an immediate impact on data collection, processing, and longer term data durability. We discuss the implications for national datasets including the cadastral network, elevation, and imagery.

Blount, S., Henry, R., Ryan, K., Lu, Y., Li, Z., & Elwood, K., 38
Experimental Evaluation of Various Low Damage Solutions for Concrete Shear Walls

As a consequence of recent earthquakes in New Zealand, many concrete buildings have been demolished due to severe damage to structural concrete components. Designing concrete elements that sustain less damage in seismic events would enhance overall reparability and ability to recover with significantly reduced financial impact. In concrete subsystems (frames and walls) damage is usually localized to the plastic hinge region. A number of innovative solutions have been explored that reduce the extent of damage in the plastic hinge region and decrease residual drift. Solutions include debonding of longitudinal reinforcement, substituting engineered cementitious composites (ECC) and shape memory alloy (SMA) bars in the plastic hinge region, post-tensioning the system, and substituting rubber isolators in the plastic hinge region. Debonding of the longitudinal reinforcement prevents strain localization and allows the reinforcement to be more fully utilized before failure. ECC is a mortar like material that contain polyvinyl alcohol fibre. The addition of these fibres incites a tensile strain hardening response out to large strains and increases the compressive strength by binding the matrix together. SMA bars are superelastic, which promotes recentering. Unbonded post-tensioning will produce a restoring force recentering a structure. Rubber isolators can sustain high flexural deformation without excessive damage. To date, these innovative techniques have been explored primarily in concrete columns, while much less attention has been focused on low damage walls. In this project, four concrete half-scale walls with different low damage solutions are currently being tested at the University of Auckland, New Zealand. Low damage alternatives were selected based on literature review and discussion with industry professionals. The first wall has debonded reinforcement encased in steel tubing extended into the foundation, which is intended to trigger a crack at the wall base and distribute the reinforcement strain across the debonded length. In the second and third wall, ECC is substituted for conventional concrete in the plastic hinge region, which will increase the tensile capacity of the wall and delay deterioration in the hinge region. Higher axial load will be applied to the third wall relative to the second to observe the impact fibres have on confinement. In the fourth wall, steel fibre-reinforced concrete is substituted for conventional concrete throughout the wall, which should allow for increased tensile strain hardening and confinement, but is expected to be lesser when compared to ECC. This paper will describe the test program and present preliminary test results for some of the walls.

Boersen, K., 82
East Coast LAB (Life at the Boundary)

Just off the East Coast of New Zealand's North Island lies the Hikurangi plate boundary. Living on this boundary where the earth is constantly changing means communities can be affected by a number of natural hazards such as earthquake and tsunami. These hazards pose a significant risk to the regions the project covers – Gisborne, Hawke's Bay, Manawatu/Wanganui and Wellington. East Coast LAB (Life at the Boundary) is a collaborative project which brings together scientists, emergency managers, experts and stakeholders from across the East Coast to make it easy and exciting to learn more about the natural hazards. It aims to improve the resilience of communities on the East Coast of the North Island of New Zealand to natural hazards associated with the plate boundary and living on the coast. It seeks to:1) Research: Foster well connected and coordinated research within the natural 'LAB' to increase our understanding of the plate boundary and associated natural hazards. eg. earthquakes, tsunami, volcanic eruptions, and coastal erosion etc.2) Education and engagement: Encourage communities to become engaged and participate in science so that they understand the risks associated with living at the boundary.3) Risk

reduction: Ensure communities are aware of the hazards that affect them, know how to prepare and respond to hazard events, and in the event of a natural hazard continue to thrive. The project was officially launch in September 2016 and activities are underway.

Bradley, B., Motha, J., Polak, V., Thompson, E., Wald, D., Maurer, B., & van Ballegooy, S., 78
Coupling Ground Motion Simulation with Regional Modelling for Rapid Impact Assessment

This poster presents regional impact models for liquefaction, landslides, and macro impact (via the USGS PAGER: Prompt Assessment of Global Earthquakes for Response) that have been implemented in New Zealand as part of the QuakeCoRE computational workflow. All three impact models can be executed in an automated fashion and are based on input variables that are available throughout New Zealand. The input variables include ground shaking via peak ground velocity, water table depth, precipitation, distance to rivers/coast, topographic slope, 30m-averaged shear wave velocity, among others. When coupled with near-real-time (NRT) ground motion modelling these tools provide NRT impact assessment, as well as a means to assess at a high-level the susceptibility of a location or region to these earthquake-induced geotechnical and geologic hazards. We present NZ-wide susceptibility maps, as well as estimated impacts for several recent earthquake ruptures and potential future earthquake scenarios.

Brown, N., Johnston, D., Rovins, J., Orchiston, C., & Feldmann-Jensen, S., 52
Building Disaster Resilience within the Hotel Sector

The dynamic nature of resilience precludes trying to become resilient. Resilience is an on-going process and requires constant learning, flexibility, adaptation, and evaluation to continue to build resilience to disaster at any point in time. Building disaster resilience within the hotel sector must first start with an understanding of components that can be used to measure resilience. This research develops a framework that explores economic, social, human, physical, natural, and cultural capital as individual groups of predictors, all providing separate entry points to develop disaster resilience for a hotel. This framework's aim is flexibility in how organisations in the hotel industry can begin to improve their disaster resilience, recognising that steps forward in many different directions provide increased disaster resilience. Additionally, multiple entry points for building resilience provides greater flexibility on the part of hotel leadership to enter into resilience building. A spectrum of disaster resilience predictors allows for a multi-faceted look at a dynamic issue.

Cardwell, R., Wilkinson, S., Smith, N., & Brown, C., 53
Defining the Value of Built Infrastructure

The built environment is highly connected and provides significant value to our communities. Yet, the traditional mechanisms to value the worth of built typically consider those assets in isolation: neither considering the community they serve nor the wider built environment they connect with. The project aims to provide a nomenclature and system mapping of the services and values of the built environment in communities. The framework will be derived through expert elicitation and will be presented in a user-friendly online platform. The framework will help decision-makers to better value the built environment, more clearly define losses that occur to communities upon damage or destruction of built assets, and enable more robust and objective conversations concerning investments and policies relating to resilience of the built environment.

Ceferino, L., Markhvida, M., Cremen, G., Heresi, P., Husley, A., Balbi, M., Deierlein, G., 54

Probabilistic Framework for Quantifying Resilience Performance Objectives

Resilience agencies such as San Francisco Bay Area Planning and Urban Research Association (SPUR) and Oregon Seismic Safety Policy Advisory Commission have published "expected" and "desired" recovery targets of key city and state infrastructure after an earthquake scenario. Previous regional loss analysis frameworks, such as HAZUS, built initial robust methodologies for assessing expected values of earthquake consequences. However, these methodologies do not consider interdependence in the recovery of infrastructure systems and recovery of relevant building infrastructure, while quantifying the time required to reach a given functionality or a performance objective. This poster provides a summary of an end-to-end analysis framework for current formulation of community resilience performance objectives that incorporates elements of regional risk and recovery analyses, such as uncertainty and correlation in ground motion used in damage estimation of heterogeneous urban infrastructure, interdependence in functionality of systems, and tracking of interdependent functionality recovery of the urban system through time. The proposed methodology aims to link and integrate the advances in earthquake engineering and resilience analysis in order to assess key resilience performance objectives using robust probabilistic analysis.

Chandramohan, R., Baker, J., & Deierlein, G., 39

Incorporating Ground Motion Duration in Structural Performance Assessment and Design Guidelines

Modern structural performance assessment guidelines (e.g. FEMA P695, FEMA P-58) and building design standards (e.g. ASCE 7-16, NZS1170.5) do not explicitly consider the duration of earthquake ground motion, although the effect of ground motion duration on structural collapse risk has been established by recent studies. These recent studies have shown, for example, that long duration ground motions from large magnitude subduction earthquakes can increase the mean annual frequency of collapse of a structure by about 140%, relative to ground motions from shallow crustal earthquakes with shorter durations. This study explores different methods of varying complexity by which this effect of ground motion duration can be incorporated into modern structural performance assessment and design guidelines. The effect of duration can be captured in a multiple stripe analysis, as required by the FEMA P-58 time-based assessment methodology, by explicitly selecting ground motions to match target distributions of ground motion duration, in addition to target response spectra. This multiple stripe analysis approach is compared to an alternative method that accounts for the effect of duration in a manner similar to the FEMA P695 methodology, by adjusting the median collapse capacity estimated using an incremental dynamic analysis, based on the duration and response spectral shape of the ground motions anticipated at the site. Finally, a modification to the ASCE 7-16 procedure is proposed, to account for the effect of duration on structural collapse risk, and thereby, maintain a consistent risk of collapse for structures designed at different geographic locations. This modification is applicable to the NZS1170.5 design procedure as well.

Chang-Richards, A., Brown, C., & Smith, N., 55

A System Dynamics Model of Post-Earthquake Reconstruction Pathways

The time for restoring the damaged built environment after a major disaster is a critical issue in the study of the economic impact of disasters. To assist policy makers and recovery agencies with planning and sequencing reconstruction efforts from large disaster events, in this study we provide a methodology for estimate of reconstruction time path and its associated economic impacts at a regional scale. Based on Christchurch earthquake

reconstruction experience, we use system dynamic modelling to investigate how a given building stock of a similar type (i.e. governed by similar decision rules) changes over the reconstruction period from the damage state to a full recovery state. Through simulation, it was found that the critical dynamics underlying the reconstruction time trajectory included the dynamics of engineering and construction sector re-adjusting after building regulatory changes, resource allocation of construction and insurance industries, and the interactions of different stakeholders as a result of the decisions they make. The behaviour of the system seems to be exponential growth with a series of oscillations due to the significant time delay of releasing reconstruction pipelines. Therefore a better construction information reporting system is needed to improve the reconstruction planning and expedite the reconstruction process. The research reported in this research is the starting point in a very complex challenge to build a theory of post-earthquake reconstruction. The model provides a structure to analyse the economic impact of decisions in regard to resilient built systems and the alternative strategies for disaster recovery.

Chen, F., Wang, Z., Dhakal, R., Khakurel, S., & Yeow, T., 40
Development of Cladding Loss Contribution Functions for use in Loss Optimization Seismic Design

Loss Optimization Seismic Design (LOSD) is a practice-orientated framework to aid in designing more resilient buildings by rapidly estimating seismic losses associated with repair costs, downtime, and injuries using storey-level loss functions. However, data on typical types, densities, damage fragility, and repair cost of various building components are needed to develop these storey-level loss functions. This project focuses on estimating the contribution of cladding to storey-level loss functions. Building site surveys were conducted to obtain information on typical density of claddings used per m2 of floor area. In addition, it was observed that the three most common cladding types in residential buildings are brick veneer, Hardie Planks, and monolithic cladding. In contrast, glazing, lightweight metal panels, and precast concrete panels are more commonly used in commercial buildings. Fragility functions for these six types of cladding have been sourced from literature. The next stage of the project, which is currently underway, is to survey contractors on the common type and cost of work required to repair the damage types identified from fragility functions. This will then be combined with the density and fragility functions via Monte Carlo simulations to develop cladding contribution functions; i.e. the fraction of floor loss contributed by damage to claddings.

Crawford, M., Johnston, D., Saunders, W., Hudson-Doyle, E., & Leonard, G., 56
Risk Modelling as a Tool to Support Natural Hazard Risk Management in New Zealand Local Government

Demand for natural hazard risk modelling has significantly increased over the last few decades as we seek to use risk modelling to assess the consequences for hazard scenarios we have little historical information about. By giving an estimate of loss, risk models provide policy makers and decision makers with a starting point for the risk communication process and decisions for natural hazard management. However, while local government can see the value in risk modelling, some fundamental challenges limit its use related to: uncertainty over council natural hazards management, limited use of 'knowledge brokers' and 'gate keepers', and immaturity of risk modelling and its data. This poster provides some recommendations to circumvent these barriers and enable risk modelling in local government: legislate greater mandate for natural hazard risk management; adopt effective and meaningful participatory approaches; enable the movement of knowledge through the development of 'knowledge broker' and 'gate keeper' roles; and enable greater capacity and capability building for collecting, managing and using natural hazard risk data.

Crawford-Flett, K., Wilson, M., & Shamseldin, A., 65
Characterisation of New Zealand Stopbank (Flood Protection) Infrastructure

Stopbank networks are a critical distributed infrastructure network, providing the primary means of flood protection for people and properties in many New Zealand communities. Damage to this network may have significant economic and social impacts; therefore, a clear understanding of the attributes of this system is needed to be able to assess the expected performance and impacts. In New Zealand, stopbank networks are currently maintained and managed at a regional level. Characteristics of the physical stopbank assets vary widely, as do standards for design and maintenance. Stakeholders presently lack a comprehensive national perspective on asset characteristics and relative levels of: (1) hazard exposure along networks, and (2) protection afforded by stopbank structures. The aim of this project to develop a database of the New Zealand stopbank networks, with a specific focus on earth stopbank structures. In conjunction with Regional Councils, this project will characterise distributed stopbank networks using a range of hydrologic and geotechnical attributes to allow for the national assessment of performance across a number of hazards. The provision of a national inventory will inform future decisions around centralised asset and risk management for flood protection networks throughout New Zealand.

Davies, A., 66
Assessment of Post-Disaster Distributed Infrastructure Level-of-Service Expectations by Stakeholders and Isolated Settlement Communities

Hazards to distributed infrastructure networks are indirect hazards to isolated settlements, and communities may be affected even if a settlement is not directly impacted. To reduce community risk, this project aims to assess post-disaster level-of-service expectations by infrastructure providers and communities, and how to effectively communicate level-of-service expectations between infrastructure providers and communities. Impact scenarios and recovery management strategies will be co-created by infrastructure stakeholders and community members to integrate knowledge, and lessons learned from previous events will also be used. From the national and regional economy perspective, the "Kaikōura" earthquake impacts were severe due to the damage to distributed infrastructure, and particularly transportation networks. This poster will also summarise direct and indirect impacts of the "Kaikōura" earthquake on South Island transport infrastructure, and the subsequent management through the emergency response and early recovery phases, including 100 days of post-earthquake level-of-service mapping for roads, commercial flights, ferries, rail, and shipping.

de la Torre, C., & Bradley, B., 3
Modeling Nonlinear Site Effects in Physics-Based Ground Motion Simulation

This study examines the performance of nonlinear total-stress wave-propagation site response analysis for modelling site effects in physics-based ground motion simulations of the 2010-2011 Canterbury, New Zealand earthquake sequence. This approach allows for explicit modelling of 3-dimensional ground motion phenomena at the regional scale, as well as detailed site effects and soil nonlinearity at the local scale. The approach is compared to a more commonly used empirical VS30 (30 m time-averaged shear wave velocity)-based method for computing site amplification. The detailed site response analysis is performed at 16 strong motion stations in Christchurch that recorded the earthquakes to compare simulations with observed ground motions. Differences in performance between these two site response methodologies are quantified and discussed for simulations of 10 large magnitude events (i.e., MW ≥ 4.8) for which soil nonlinearity may have influenced the

response. Improvements in simulations are observed using the proposed wave-propagation site response for certain strong motion stations at which site effects are significant.

Dempsey, D., 4
Using Physics-Based Models to Forecast Future Earthquakes at the Groningen Gas Field, The Netherlands

Earthquakes induced by natural gas extraction from the Groningen reservoir, the Netherlands, put local communities at risk. Responsible operation of a reservoir whose gas reserves are of strategic importance to the country requires understanding of the link between extraction and earthquakes. We synthesize observations and a model for Groningen seismicity to produce forecasts for felt seismicity (M>2.5) in the period February 2017 to 2024. Our model accounts for poroelastic earthquake triggering and rupture on the 325 largest reservoir faults, using an ensemble approach to model unknown heterogeneity and replicate earthquake statistics. We calculate probability distributions for key model parameters using a Bayesian method that incorporates the earthquake observations with a nonhomogeneous Poisson process. Our analysis indicates that the Groningen reservoir was not critically stressed prior to the start of production. Epistemic and aleatoric uncertainty are incorporated into forecasts for three different future extraction scenarios. The largest expected earthquake was similar for all scenarios, with a 5% likelihood of exceeding M 4.0.

Egbelakin, T., Yakubu, E., Ingham, J., & Glavovic, B., 26
Improving Earthquake Resilience in Provincial Towns – A Town-Centre Regeneration Approach

There is a growing acceptance that property redevelopment and sustainable town- centre regeneration is a responsive strategy to the regulatory demands of seismic strengthening in NZ. This project uses a precinct approach to examine financial, regulatory and property market arrangements that can best be practically applied to strengthening the building stock in several provincial towns in New Zealand. Project objectives are to; (i) investigate the critical success factors that may influence the implementation of regenerating a resilient and sustainable town centre; and (ii) developed a multi-criterion framework to sift through existing earthquake-prone buildings (EPBs) within a district or region's portfolio to identify and rank EPBs with high residual value for possible seismic strengthening and adaptive reuse, using a mixed-methods approach, comprising a focus group workshop and analysing buildings data in Whanganui, the project offers a focus on a specific locality at risk and therefore offers scope to pool resources, economies of scale, and the co-funding of associated infrastructure improvements (e.g. street upgrades and parking). The research findings will create a pathway way for redeveloping and improving the earthquake resilience of older character buildings in Whanganui and other provincial towns in New Zealand. As a result, this project outcome will provide recommendations for policy guidance to local authorities and key stakeholders involved in risk mitigation planning on how to better address earthquake resilience by locating vulnerable EPBs, and decisions about them within their local suburban contexts.

Fauzi, U., 5
Site-Specific Probabilistic Seismic Hazard Maps of New Zealand for 475 Years and 2,475 Return Period

A probabilistic seismic hazard analysis with a site spacing of 1 km in latitude and longitude for an area between 166°E to 179°E and 34° and 48° (more than 67,000 locations) were carried out for understanding the hazard condition in New Zealand accurately. It is important to note, however, that the New Zealand seismic hazard map in NZS 1170.5:2004 is generalised because it has been developed to cover all New Zealand and based on

earthquake data set until the year 2000, i.e. not including the latest 2010-2011 Christchurch Earthquake Sequence and 2016 Kaikoura Earthquake. The Authors understand that site-specific studies typically provide spectral accelerations different to those shown on the national map (Z values in NZS 1170.5:2004); and sometimes even lower. This poster shows the peak ground acceleration (PGA) contour at Site Class C (Vs = 500 m/s). The PGA contours represent for 10% probability of exceedance (PE) in 50 years (475 years earthquake) and 2% PE in 50 years (2,475 years earthquake). The Authors used the active faults and area seismic sources incorporated in the 2010 New Zealand National Seismic Hazard Model (NZNSHM) developed by a team of the earthquake engineers, geologists, seismologists, and engineering seismologist. The Authors also used time-dependent model for Canterbury based on Oomori Law and New Zealand site-specific Ground Motion Prediction Equation (GMPE) by Bradley and McVerry et al. Logic tree method was also applied to account for epistemic uncertainty including maximum magnitude and two attenuation functions. The seismic source model was uploaded into SHA software (OpenQuake 2.1.0) to calculate the site-specific earthquake ground motion hazard for 67,000 sites.

Fikri, R., Dizhur, D., Walsh, K., & Ingham, J., 27

Seismic Performance of Reinforced Concrete Frame with Masonry Infill Buildings in The 2010/2011 Canterbury, New Zealand Earthquakes

As a result of the 2010/2011 Canterbury, New Zealand earthquakes, Reinforced Concrete Frame with Masonry Infill (RCFMI) buildings experienced a level of damage that was different to that observed for other construction systems. An extensive survey was conducted by the Christchurch City Council (CCC) and the Canterbury Earthquake Recovery Authority (CERA) following the earthquakes to document damaged buildings in the affected area. The collected data were then merged into the Canterbury Earthquake Building Assessment (CEBA) database, and the database was utilised to assess the damage sustained by RCFMI buildings. In order to provide a reliable estimation of the seismic vulnerability for RCFMI buildings in the region, empirical fragility curves were generated using the Lognormal Cumulative Distribution method by utilising the post-earthquake dataset provided in the CEBA database, with the expected median and standard deviation values derived using the Maximum Likelihood Estimation method. Results showed that the majority of low-rise to mid-rise RCFMI buildings performed satisfactorily during the Canterbury earthquakes, with several high-rise RCFMI buildings sustaining moderate to heavy damage.

Foster, K., Bradley, B., Wotherspoon, L., & McGann, C., 6

A Vs30 Map for New Zealand Based on Surficial Geology, Topography and Direct Measurements

We present the status of our regional Vs30 (time-averaged 30-metre depth shear wave velocity) map developed for New Zealand, based on methods employed in California by Thompson et al. (2014). Vs30 is among the most widely used parameters for site characterisation in routine earthquake engineering problems. The map is developed using regional correlations of Vs30 with geology and topographic slope, then refined in the vicinity of available Vs30 field measurements using Regression Kriging. The geology- and topography-based model predictions are derived and interpreted in a Bayesian framework, which has the advantage of incorporating assumptions about measurement uncertainty for the various sources of Vs30 data. The final result is a continuous map providing Vs30 estimates and uncertainty components for all of New Zealand. As a predominantly data-driven resource, the map will remain a work in progress and can be updated with new data as it becomes available. The benefits of this modelling methodology include (i) using Kriging to honour Vs30 measurements near data locations; (ii) applying reasonable inferences based on geologic and topographic data for areas where direct Vs30 measurements are

unavailable; (iii) a rational approach to measurement uncertainty; (iv) parsimoniously quantifying the uncertainty across regions with both rich and sparse field data density; (v) establishing a robust framework for routine map updates when additional field data is collected.

Galvez, F., Ingham, J., & Dizhur, D., 29
Using the Macroelement Method to Seismically Assess Complex URM Buildings

Existing URM buildings often follow traditional construction techniques, with poor connections between walls and diaphragms which results in poor performance when subjected to seismic actions. In these cases the assumption of a common equivalent static procedure is not applicable because it is not possible to assure "box like" behaviour of the structure. In such conditions the ultimate strength of the structure relies on the behaviour of the macro-elements that compose the mechanisms of the whole structure. These macro-elements are single or a combination of structural elements of the structure which are bonded one to each other. The Canterbury earthquake is taken as a reference to estimate the most commonly occurring collapse mechanisms in order to define the macro-elements. When the macro-elements and their connections are defined, the next step is to impose equilibrium conditions and find the collapse mechanism most likely to be formed via the collapse coefficient. The classification into macro-elements and collapse mechanisms of a church allows the definition of methods to assess damage and to quickly acquire useful information for handling emergencies. Once the damage is assessed, the vulnerability of the church is defined. In addition to this estimation, which would serve as an example for professionals around New Zealand, other numerical models are assembled to simulate the same building and serve as a reference to calibrate the method for a final adaptation from the European standards. The level of considered earthquake shaking is consistent with New Zealand loading standards and described in terms of the peak ground acceleration (PGA).

Gauland, M., Bradley, B., & Moghaddasi, M., 79
OpenSLAT Software for Estimating Seismic Risks

OpenSLAT is a set of software components based around the PEER framework, and released under an open-source license. It allows researchers and practicing engineers to assess structural and non-structural losses related to seismic activity. Users can create projects as C++ or Python programs, or as commands in its own language; a web-based interface is under development. OpenSLAT will incorporate the work of other QuakeCoRE and QuakeCentre work, to provide fragility and consequence functions that are specifically applicable to New Zealand structures.

Hashemi, A., Zarnani, P., & Quenneville, P., 41
Seismic Resilient Structures using Rocking Walls Coupled with Innovative Resilient Slip Friction Joints (RSFJs)

There is an increasing public pressure to have damage avoidance structural systems in order to minimize the destruction after severe earthquakes with no post-event maintenance. This study presents a hybrid steel-timber damage avoidance Lateral Load Resisting System (LLRS) using rocking timber walls coupled with innovative Resilient Slip Friction Joints (RSFJs) and boundary steel columns. RSFJs are used as ductile links between the adjacent walls or between the walls and the columns. These joints are capable to provide a self-centring behaviour (the main deficiency of conventional friction joints) in addition to a high rate of energy dissipation all in one compact device. The advantages of the proposed concept are the out of plane deformation compatibility, minimum bending stresses in the wall panels and the fact that the self-centring behaviour is provided without relying on the gravity loads. In addition to large scale experimental test results, a numerical model containing the proposed

concept is developed and subjected to time-history simulations. The results confirm that this system can be used in the new generation of resilient LLRSs for different types of structures as the presented technology is in fact material independent.

Hatami, M., MacRae, G., Rodgers, G., & Clifton, C., 42
The Performance of Friction Connections with Large Grip Length Bolts

Detailed finite element (FE) models have been developed to obtain accurate and efficient methods for modelling asymmetric friction connections (AFC). The models developed consider: contact interaction between different surfaces, bolt interaction with plates during sliding, bolt load variability, and dynamic friction coefficient. In particular, effects of different bolt size and length were investigated. It was shown that the model captured the pertinent aspects of the behaviour of connections over the likely range of bolt grip length to bolt diameter ratio and represented findings from experimental tests well. The FE tool developed can be used for prediction of the performance of large friction connections.

Hatton, T., Lawler, S., & Seville, E., 57
Interdisciplinary Options for Improving the Seismic Resilience of New Zealand

Decisions on investments to improve the seismic resilience of New Zealand are often driven by people or groups with specific interest or expertise in a particular field. While these proposals are valuable, researchers and practitioners have started to call for decision-making processes that take into account ideas from diverse disciplines (Cutter, 2016; Peek, Sutley, & van de Lindt, 2017). The current project aims to compile a 'menu' of seismic resilience options that crosses disciplinary and interest group boundaries, thereby demonstrating a variety of investment choices available across a broad spectrum of expertise areas. This menu is intended to encourage users to consider a broader range of resilience investment options than they might otherwise. With an eye on applicability to New Zealand, the menu will consider theoretical concepts on how resilience can be created, as well as practical solutions that have been applied here and abroad. Resilience initiatives will be categorised by type of resilience they engender and the dimension of resilience they address, using the classification system developed by Bruneau et al (2003). This system may likely be revised as the project progresses. Categorisation will also include the focus unit for the initiative, i.e., community, organisational, and physical systems. Initiatives will ultimately also be grouped into themes or families of types of initiatives, covering the built, social, economic, natural, and cultural environments. We will conduct a short survey, consisting of two open-ended questions, of QuakeCoRE researchers, as well as a cross-section of academic staff from New Zealand universities. This survey will ask participants to identify alternative ways they believe may improve seismic resilience. Survey results will be classified and contrasted with the key themes represented in the literature to consider whether they are aligned and to ensure that our 'menu' includes as wide as possible range of options. The outcomes of this project will include a report, a database of resilience initiatives, and a journal article. We are also exploring an interactive visual website display that practitioners may use to seek solutions to resilience problems.

Hazaveh, N., Rad, A., Rodgers, G., Chase, G., Pampanin, S., & Ma, Q., 43
Shake Table Testing of Low Damage Steel Buildings with 2-4 Direction Displacement Dependent (D3) Damper

To improve seismic structural performance, supplemental damping devices can be incorporated to absorb seismic response energy. The viscous fluid damper is a well-known solution. However, while they reduce displacement demand, they can increase overall base shear demand in nonlinear structures as they provide resistive forces in all four quadrants of force-displacement response. In contrast, 2-4 Direction and Displacement Dependent (D3)

viscous dampers offer the opportunity to reduce both displacement and base-shear demand by providing damping only in quadrants 2 and 4.The research experimentally examines the seismic performance of a 1/2 scale, two storey steel frame building fitted with the 2-4 D3 and typical viscous damper. Shake table testing assesses the base shear, maximum drift and residual deformation under 25% to 100% scales of 6 different earthquakes (Northridge, Kobe, Christchurch (CCCC), Christchurch (CHHC), Tabas and Bam ground motion). Using 2-4 D3 devices for both linear and nonlinear deformation, the displacement demand, column axial forces and base shear do not increase. The overall results show that reduction in both displacement and base-shear demand for linear and nonlinear response is only available with the (passive) 2–4 D3 device.

Hogan, L., Scott, A., Nataraj, S., Dizhur, D., & Ingham, J., 30
Seismic Performance of Corroded New Zealand Buildings

Assessing the seismic capacity of existing reinforced concrete (RC) buildings is a complex task, and this challenge is compounded when the structure has deteriorated due to corrosion of the reinforcement. Currently there is a lack of industry guidance on the residual seismic capacity of corroded RC members or the effect of corroded members on the overall seismic response of the building. This project is a pilot study to determine the predominant corrosion mechanism in older New Zealand RC buildings in order to determine the feasibility of performing seismic retrofit work on a corroded RC building or if the due to the corrosion mechanism, the retrofit works would be subject to corrosion as well. Such understanding is crucial for building owners in order to make the decision to seismically strengthen a building that has corrosion damage. Additionally, the project has investigated previous research to determine the residual capacity of corroded RC buildings using information that can be readily obtained during site investigation. This information will be used to help develop design tools to allow engineers to account for the strength and deformation reduction of a concrete member that has been subjected to corrosion.

Hopkins, J., & Thompson, L., 31
Safe As? The Impact of the Building (Earthquake-Prone Buildings) Amendment Act 2016 on New Zealand's Existing Building Stock

This legislation came into effect on 1 July 2017 and aims to strike a balance between public safety and the cost of improving New Zealand's building stock. Local Authorities are required to identify earthquake-prone buildings within certain timelines using methodology set by MBIE. Buildings which are less than 34% of new building standard will be recorded as an Earthquake Prone Building on a national publicly accessible register. The building owner will be required to display notices on their building and remediate within certain time-frames. Our project aims to examine the impact and outcomes of this legislation.

Huang, J., Bae, S., Polak, V., Bradley, B., Razafindrakoto, H., Thopmson, E., Motha, J., 80
Real-Time Ground Motion Simulation Workflow

QuakeCoRE's implementation of the ground motion simulation workflow based on Graves and Pitarka (2010, 2015) is composed of many steps where manual inputs were frequently required. This made it difficult to run the simulation under time pressure, especially when near real time (NRT) simulation is desirable in the immediate aftermath of a significant earthquake to inform scientific reconnaissance and civil defense response. The 14 November 2016 Mw7.8 Kaikoura earthquake prompted the need for streamlining of the computational workflow, and we have successfully delivered a workflow that can compute the entire simulation pipeline in an efficient semi-automated manner. Now we can produce the simulation result with 3~4 hours of computational time and only a few minutes added for

manual interaction. This poster will present the overview of the current workflow and its capability as well as future development plan, touching our plan for complete automation and reduction of computational time using the new NZ National eScience Infrastructure (NeSI) compute resources.

Jeong, S., Wotherspoon, L., & Ma, Q., 72
Recent Research Activities of QuakeCoRE Technology Platform 2

QuakeCoRE Technology Platform 2 (TP2), which focuses on the further development of field testing and monitoring capabilities, has been involved in numerous field research activities since its inception. This poster presents a summary of research activities, either directly led by or supported by QuakeCoRE TP2. Key objectives of this platform include: the development of standardised field testing and processing guidelines, the development of advanced field testing capabilities to support research, the development of guidelines for rapid deployment of field monitoring equipment, the development of advanced field monitoring capabilities to support research, and the development of data processing and archiving workflow. Recent geophysical site characterisation activities supported by QuakeCoRE TP2 cover the following regions: 1) Auckland, 2) Tauranga, 3) Wellington/Centreport, 4) Nelson/Tasman, 5) Blenheim/Wairau plains, and 6) North Canterbury. QuakeCoRE TP2 also has been supporting the development of field testing capabilities, including the direct-push crosshole testing, and the low cost accelerometers for structural field testing. Recent structural and geotech-nical field monitoring activities supported by QuakeCoRE TP2 include: 1) an experimental study of the topographic amplification at Mt. Pleasant, Christchurch, 2) the temporary monitoring of bridges in North Canterbury after the 2016 Mw7.8 Kaikoura earthquake, 3) a study of seismic responses of instrumented buildings in Wellington during the 2016 Kaikoura Earthquake, and 3) the temporary monitoring of wine storage tanks in the Marlborough region after the 2016 Kaikoura earthquake.

Johnson, E., Yu, T., Brewick, P., & Christenson, R., 44
Modeling of a Full-Scale Experimental Base-Isolated Building

Modelling the behaviour of base-isolated buildings is essential for evaluating their performance (in both design earthquakes and extreme earthquakes that are of increasing concern), identifying damage mechanisms, developing retrofit strategies, and studying the effects of design changes. E-Defense, part of Japan's National Research Institute for Earth Science and Disaster Resilience (NIED), constructed (2012-13) and tested (March and August 2013) a base-isolated building. The isolation layer was composed of rubber bearings, rubber sliders, steel U-shaped metallic yielding dampers and, in some test, oil dampers (with solenoids to set the valves in real time to one of several settings). The superstructure is a four-story reinforce-concrete structure with an asymmetric plan, with a corner stairway with a strong shear core and a cut-out in the top floor, and is designed according to standard Japanese design code. Tests in August 2013, in which the lead author participated, included both lower-level stochastic band-limited white noise excitation in multiple directions, as well as scaled versions of historical and synthetic earthquake records. Using design drawings and dynamic response data from the August 2013 tests, this paper discusses dynamic models that have been developed to reproduce the motion of this structure: linear models of the superstructure and nonlinear models of the isolation layer. The nonlinear isolator components -- specifically, the rubber sliders and metallic yielding dampers -- are modelled with a Bouc-Wen hysteresis, using the time-dependent vertical load on the sliders to properly model the friction behaviour in the sliders. The responses of the model are compared to those measured in the August 2013 tests to evaluate the suitability of the models for further studies (which are to evaluate possible controllable damping strategies that may be tested at a future date).

Johnston, D., Ardagh, M., Deely, J., MacDonald, C., Lambie, E., Doyle, E., Lindell, M., Characterizing Human Behaviour in Earthquakes: The 2010-2016 Sequence in New Zealand 32

The goal of reducing earthquake casualties in future events gives importance to understanding how people behave during and immediately after the shaking, and how their behaviour can expose them to risk of death or injury. The 2010-2016 earthquake sequences in New Zealand provided a unique opportunity to better understand this human behaviour. Most previous studies have relied on an analysis of medical records and/or reflective interviews and questionnaire studies. In Canterbury we were able to combine a range of methods to explore earthquake shaking behaviours and the causes of injuries. In New Zealand, the Accident Compensation Corporation (a national health payment scheme run by the government) allowed researchers to access injury data from over 17 000 people from eight earthquakes from 2010 to 2016. We were able to classify the injury context as direct (immediate shaking of the primary earthquake or aftershocks causing unavoidable injuries), action (movement of person during the primary earthquake or aftershocks causing potentially avoidable injuries), and secondary (cause of injury after shaking ceased). The research has found that in general, improved building codes, strengthening buildings and securing fittings will reduce future earthquake deaths and injuries. However, the high rate of injuries incurred from undertaking an inappropriate action (e.g. moving around) during or immediately after an earthquake suggests that further education is needed to promote appropriate actions during and after earthquakes. In New Zealand, as in other countries with earthquake risk, public education efforts, such as the Shakeout exercise are trying to address the behavioural aspects of injury prevention.

Johnston, D., Orchiston, C., Becker, J., Sullivan-Taylor, B., Egbelakin, T., Ingham, J., McBride, S.,
Earthquake Awareness and Preparedness in Low(er) Seismic Hazards in New Zealand: Challenges for Preparedness and Risk Communication 33

Understanding how people interpret and respond to earthquake risks is vital to any strategy for earthquake risk reduction. In a building safety context, understanding people's interpretation of risk is integral to determining how we define acceptable risk, and prompt building safety preparedness and mitigation measures. Acceptable risk in the context of building safety always involves interactions between natural (physical and engineering) and human (behavioural) factors. Policy decisions about mitigation often need to be made in conditions of uncertainty regarding the nature and size of future earthquakes, and the impact of such events on infrastructure and livelihoods. Such decision-making under uncertainty is inadequately described by traditional models of 'rational choice'. Instead, attention needs to be paid to how people's interpretations of risks and consequent decisions are shaped by their own experience, personal feelings and values, cultural beliefs and interpersonal and societal dynamics. The data was gathered using a survey questionnaire. Developed in collaboration with local councils between August and November 2016. Five hundred survey questionnaires were hand delivered to residences in each of the three Auckland suburbs, Hamilton Oamaru and Dunedin. Households were randomly selected within the above communities. Surveyed respondents were asked to be the person in the household aged 18 years or older who most recently had a birthday. The vast majority of all respondents reported not having personally experienced a significant earthquake (Hamilton: 90%, Auckland: 85%, Dunedin: 80%, Oamaru: 65%). However, the majority report having received information on preparing for earthquakes (Hamilton: 86%, Auckland: 85%, Dunedin: 93%, Oamaru: 94%) and a smaller majority feel that they are adequately informed to prepare or plan for a future earthquake (Hamilton: 68%, Auckland: 62%, Dunedin: 63%,

Oamaru: 72%). A future big earthquake near their community was seen as unlikely by 60% of respondents from Hamilton, 53% from Auckland, 31% from Dunedin, and 26% from Oamaru. Conversely, a future big earthquake was seen as likely to very likely by 28% of respondents from Oamaru, 27% from Dunedin, 15% from Auckland, and 8% from Hamilton. The survey explore a range of other issues that will be presented in the poster.

Lee, R., Bradley, B., Graves, R., Rodriguez-Marek, A., & Stafford, P., 8
Investigation of Systematic Ground Motion Effects Through Ground Motion Simulation of Small-to-Moderate Magnitude Earthquakes in the Canterbury, New Zealand Region

This poster presents results of ground motion simulations of small-to-moderate magnitude (3.5<Mw<5.0) earthquake events in the Canterbury region over the past decade, for which centroid moment tensor solutions are available, and an investigation of systematic source and site effects determined via non-ergodic analysis. The simulations are carried out using the GP2010 methodology with the recently developed 3D Canterbury Velocity Model (CantVM). In this study, 144 earthquake ruptures, modelled as point sources, are considered with 1924 quality-assured ground motions recorded at 45 strong motion stations located throughout the Canterbury region. The simulated ground motions, and also empirical prediction equations, are compared with observed ground motions via various intensity measures to quantify their modelling capabilities. The residuals are subsequently separated into between-event and within-event components to determine systematic source and site effects. In particular, this analysis highlights the spatial distribution of the residuals, identifying the areas where bias exists in the ground motion predictions. Lastly, the causes of the biases are identified leading to recommendations which could improve the predictive capabilities of the simulation methodology.

Liu, L., 67
Defining and Quantifying the Resilience of Electric Power Systems to Natural Disasters

In this poster, we quantify resilience for electric power distribution infrastructure to natural disasters in terms of degradation of system function. We show how to build and solve a probabilistic model to quantify the resilience of the infrastructure system to the disasters. Through simple examples, we provide motivation, details of the models, and solution algorithms.

Lu, Y., Henry, R., Elwood, K., Rodgers, G., Gu, A., Xiao, Y., Yang, T., 71
ILEE-QuakeCoRE Proposed Shake-Table Test of a Low-Damage Concrete Wall Building

The increasing need to reduce damage and downtime of modern buildings has led to the development of low-damage design philosophy, where the earthquake loads can be resisted by confining the damage to replaceable components. However, research into low-damage structural systems have typically focused on testing and modelling individual components, at reduced scales, and using in-plane cyclic loading protocols that do not account for the complex system interactions that can occur in real buildings during earthquakes. To provide essential evidence to support the development of low-damage concrete structures, a system level shake-table test of a full-scale low-damage concrete wall building implementing state-of-art design concepts will be conducted on the multi-functional shake-table array at Tongji University as part of the International Joint Research Laboratory of Earthquake Engineering ILEE-QuakeCoRE international collaborative research project. The test building had two stories and was designed with post-tensioned (PT) walls that provide the primary lateral-load resistance in both directions. The concrete moment frame was designed to resisted

predominantly gravity loads. Different floor systems and wall-to-floor connections that have been implemented in constructed buildings in New Zealand were incorporated in the test building to investigate different design concepts and detailing. Precast concrete double tees were used in the first floor and a steel tray composite floor was used in the second floor. Conventional flexible wall-to-floor connections and isolating device-type wall-to-floor connections were used in longitudinal and transverse directions, respectively. A number of alternative energy dissipation devices were also installed at wall base or/and beam-column joints of the building. The test building will be subjected to a large number of tests, with different combinations of wall strength, energy dissipating elements, shaking direction, and ground motions. The tests will provide a rich dataset to verify design procedures and numerical models at a system-level, when subjected to bi-directional loading.

Malla, M., Fenton, C., & Davies, T., 11
Development of Vs30 Profiles in Regions with Sparse Site-Specific Data: Examples from South Island Of New Zealand

Development of Vs30 Profiles in Regions With Sparse Site-Specific Data: Examples from South island of New Zealand Malla, Manesh Pratap; Fenton, Clark Henderson; Davies, TimOrganisation(s): University of Canterbury, New Zealand Shear wave velocity (Vs) of the subsurface material is an important input for earthquake seismic design and is commonly used to account for site effects when assigning a site class according to national standards or codes of practice. Although site-specific in situ Vs measurements are desirable for site-specific studies, in many parts of the world the gathering of such data is either expensive of logistically problematic. In such regions a number of proxy methods used for assessing Vs commonly using topographic and/or geological data. The latter requires extensive data relating Vs not only to the geological material, but also the material condition, in particular the macro-scale structure (discontinuity geometry and spacing) and degree of weathering. We discuss a number of approaches that have been used in the South Island of New Zealand; which is a plate boundary setting dominated by highly tectonised and fractured bedrock and mix of colluvial and proglacial surface deposits. The south island of New Zealand has cities like Christchurch, Dunedin, Invercargill and others with significant population concentration and is a geologically active landscape as a whole. South island has a high seismic risk due to the presence of several major fault systems, with the active alpine fault literally running across the whole island. Varying depth of soil and bed rock and properties in combination with the presence of active faults mean that in a large earthquake rupture event, ground shaking amplification is expected to occur. The influence of macro-scale structure and weathering on Vs is discussed and recommended approaches to ground profile development are presented.

Markhvida, M., & Baker, J., 58
Post-Earthquake Decision-Making: Modelling a Commercial Building Owner's Decision to Repair or Replace a Property using Real Estate Investment Analysis

This poster provides a framework for modelling a commercial building owner's decision-making in a case where repair is feasible but replacement might offer greater economic value – a situation not currently modelled in engineering risk analysis. The proposed methodology incorporates real estate investment analysis – a means of modelling financial decision-making – into modern probabilistic seismic loss estimation frameworks, namely FEMA P-58. The P-58 procedure currently predicts demolition based on structural collapse, excessive residual drift (such that the building would be difficult to repair), and exceedance of a repair cost threshold (such that the building is uneconomical to repair). While the level of damage and repair cost are key factors in the decision to repair or replace a building, the 2010-2011 Canterbury earthquakes showed that a significant number of modern buildings with low

apparent repair costs were deemed uneconomic to repair and were subsequently replaced. To address this observation, the proposed methodology uses FEMA P-58 and REDi to estimate a joint probability distribution of repair cost and time. Given a set of repair costs and times, present value analysis is then used to determine whether repair or replacement of a building is more financially viable. The analysis considers initial required investment, anticipated future cash flow, and liquidation value of the property, for both repaired and replaced buildings. The goal of this framework is to better understand and model factors that drive post-earthquake decisions, and to support the development of engineering and recovery policies that lead to better post-earthquake recovery outcomes. In addition to the analytical framework, the poster uses a case study to illustrate how post-earthquake decisions may vary with differing building properties, levels of damage, and real estate market conditions.

Massey, C., Townsend, D., Rathje, E., Kaneko, Y., Lukovic, B., Horspool, N., Villeneuve, M., 68

Landslides Triggered by the 14 November 2016, MW 7.8 Earthquake, Kaikoura, New Zealand

The 14 November 2016 MW7.8 Kaikoura earthquake generated more than ten thousand landslides over a total area of about 10,000 km2 with the majority concentrated in a smaller area of about 3,600 km2. The number of medium to large landslides generated by this earthquake were less than those generated in other similar style and magnitude earthquakes both in New Zealand and overseas. The complex multifault rupture during this earthquake is reflected by the landslide distribution. The largest landslides occurred either on or within 1.5 km of the more than 20 mapped faults that ruptured to the surface. The majority of landslides occurred in two geologically and geotechnically distinct materials: Neogene sedimentary rocks (limestones, sandstones and siltstones), and Cretaceous Torlesse "basement" rocks (sandstones and argillite). The most frequently occurring landslide types correlate to these materials, where reactivated planar and rotational rock-slides are the dominant landslide type in the Neogene sedimentary rocks, and first time rock and debris avalanches are the dominant landslide type in the basement materials. We have mapped more than 9,000 landslides including 200 "significant" valley blocking landslides. The largest landslide has an approximate volume of 23 (±2) M m3 and the debris from this travelled about 2.7 km down slope where it formed a dam blocking the Hapuku River. Ten other valley blocking landslides with volumes ranging from 1 M to 10 M m3are also known to have been triggered by the earthquake. A noticeable aspect of this event is the high density of small landslides that occurred on the steep coastal cliffs north and south of Kaikoura.

Maurer, B., Bradley, B., & van Ballegooy, S., 18

Predicting Liquefaction in Real-Time: An Assessment of Geospatial Models During the Canterbury Earthquakes

Semi-empirical models based on in-situ geotechnical tests have become the standard of practice for predicting soil liquefaction. Since the inception of the "simplified" cyclic-stress model in 1971, variants based on various in-situ tests have been developed, including the Cone Penetration Test (CPT). More recently, prediction models based soley on remotely-sensed data were developed. Similar to systems that provide automated content on earthquake impacts, these "geospatial" models aim to predict liquefaction for rapid response and loss estimation using readily-available data. This data includes (i) common ground-motion intensity measures (e.g., PGA), which can either be provided in near-real-time following an earthquake, or predicted for a future event; and (ii) geospatial parameters derived from digital elevation models, which are used to infer characteristics of the

subsurface relevant to liquefaction. However, the predictive capabilities of geospatial and geotechnical models have not been directly compared, which could elucidate techniques for improving the geospatial models, and which would provide a baseline for measuring improvements. Accordingly, this study assesses the relative efficacy of liquefaction models based on geospatial vs. CPT data using 9,600 case-studies from the 2010-2016 Canterbury earthquakes. While the top-performing models are CPT-based, the geospatial models perform surprisingly well given their simplicity and low cost. While further research is needed (e.g., to evaluate the portability of geospatial models to other settings), these findings suggest that geospatial models could provide valuable first-order predictions of liquefaction occurrence and consequence. Towards this end, performance assessments of geospatial vs. geotechnical models are ongoing for more than 20 additional global earthquakes.

McGann, C., Bradley, B., Jeong, S., & Lagrava, D., 81
QuakeCoRE and OpenSees (Year 2): Optimisation of Source Code, Pre- and Post-Processing Tools, and Community Development

The OpenSees finite element platform (Open System for Earthquake Engineering Simulation) is the principal collaborative software identified by QuakeCoRE for use in detailed seismic response modelling of individual infrastructure components. OpenSees was selected for this purpose due to capabilities as an open-source platform for sequential and parallel analysis of both structural and geotechnical systems. To facilitate the use of this simulation platform by QuakeCoRE researchers, several key tasks involving both human and computational resources have been identified as strategic objectives for QuakeCoRE Year 2. On the human resources side, OpenSees training workshops were held in Christchurch and Auckland, and a monthly web conference has been established, to give emerging researches a solid starting point for performing OpenSees simulations and to gather information from the QuakeCoRE simulation community on the nature and scope of simulation needs. In regard to the computational tasks, efforts have been undertaken to implement and optimise OpenSees on National e-Science Infrastructure (NeSI) computational resources, to optimise workflows for running parallel OpenSees simulations on NeSI resources, and to develop a suite of pre- and post-processing tools to streamline OpenSees use for QuakeCoRE researchers.

McMahon, R., & Wotherspoon, L., 9
Nelson Tasman Site Characterisation Study

The Nelson-Tasman population is expanding significantly, and with this comes increased investment in buildings and infrastructure. Flat land close to the coast is the preferred location for development and therefore more multi-storey structures are likely to be constructed to better utilise this area. The region is bounded by a number of faults and has been impacted by a number of large magnitude events in previous years. Deep soil and gravels deposits are present in this area which may lead to significant amplification of ground shaking and basin effects. However, there is currently little information available on the dynamic site characteristics across the Nelson-Tasman region, and the potential site amplification effects. This project aims to fill that knowledge gap and provide engineers, councils, asset owners and emergency planners with quality, consistent data to base their designs, assessments and response plans upon. Field investigations were carried out to define the shear wave velocity profile and site periods across the Nelson-Tasman region using active source surface wave testing, ambient wave field (passive) and H/V spectral ratio methods. Initially, existing subsoil information across the region was collated to characterise near surface deposits and constrain their extents. This data was used to constrain the shear wave velocity profiles at a number of sites and has been used to develop representative shear wave velocity-depth relationships of regional deposits. H/V spectral ratio peaks related to

site period were defined across the region to provide an indication of the basin structure beneath the Nelson-Tasman urban regions.

Misnon, A., Abeling, S., Hare, J., Ingham, J., & Dizhur, D., 34
A Case Study of Heritage Hotel: Performance after 2010/2011 Canterbury Earthquake

The Heritage Hotel (previously known as Old Government Building) is one of the heritage buildings listed as a Category I historic place of New Zealand. The building was seismically retrofitted to full code in 1995 with cost approximated to be NZ$3.75 million. The 2010/2011 Canterbury sequence caused minor damage to the building and was easily repaired. The building was fully functional on September 2013 as serviced and residential apartments. The seismic retrofit of the Heritage Hotel allowed for an important heritage aspect of the city to be retained for future generations.

Mohammadi, K., Jeong, S., Asimaki, D., & Bradley, B., 10
Simulation and Validation of Topographic Effects on Mt Pleasant, Christchurch, New Zealand

Damage distribution maps from strong earthquakes and recorded data from field experiments have repeatedly shown that the ground surface topography and subsurface stratigraphy play a decisive role in shaping the ground motion characteristics at a site. Published theoretical studies qualitatively agree with observations from past seismic events and experiments; quantitatively, however, they systematically underestimate the absolute level of topographic amplification up to an order of magnitude or more in some cases. We have hypothesized in previous work that this discrepancy stems from idealizations of the geometry, material properties, and incident motion characteristics that most theoretical studies make. In this study, we perform numerical simulations of seismic wave propagation in heterogeneous media with arbitrary ground surface geometry, and compare results with high quality field recordings from a site with strong surface topography. Our goal is to explore whether high-fidelity simulations and realistic numerical models can --contrary to theoretical models-- capture quantitatively the frequency and amplitude characteristics of topographic effects. For validation, we use field data from a linear array of nine portable seismometers that we deployed on Mount Pleasant and Heathcote Valley, Christchurch, New Zealand, and we compute empirical standard spectral ratios (SSR) and single-station horizontal-to-vertical spectral ratios (HVSR). The instruments recorded ambient vibrations and remote earthquakes for a period of two months (March-April 2017). We next perform two-dimensional wave propagation simulations using the explicit finite difference code FLAC. We construct our numerical model using a high-resolution (8m) Digital Elevation Map (DEM) available for the site, an estimated subsurface stratigraphy consistent with the geomorphology of the site, and soil properties estimated from in-situ and non-destructive tests. We subject the model to in-plane and out-of-plane incident motions that span a broadband frequency range (0.2-20Hz). Numerical and empirical spectral ratios from our blind prediction are found in very good quantitative agreement for stations on the slope of Mount Pleasant and on the surface of Heathcote Valley, across a wide range of frequencies that reveal the role of topography, soil amplification and basin edge focusing on the distribution of ground surface motion.

Noy, I., & Filippova, O., 28
Increasing Earthquake Resilience: Internalising Externalities Through Regulation and Financial Risk Transfer Tools

How can we better finance the retrofitting of earthquake-prone buildings? One of the most significant barriers to community resilience in the event of a major earthquake is

earthquake-prone building stock. Often, the biggest obstacle to earthquake strengthening is cost; in many cases, EQPB owners perceive strengthening as prohibitively expensive. Because of this, government mandates may not be enough to lead to adequate retrofitting and may in fact lead to wide-scale abandonment and unnecessary demolitions of the existing building stock (including buildings of historic, heritage or aesthetic value). This project will use a case study approach to test the effectiveness of various financial mechanisms and incentive programmes in enabling wider take-up of EQPB retrofitting. Focusing on a central area precinct in a provincial town (Whanganui) with distinctive function and character, we will investigate how insurance contracts and other financial and regulatory incentives can serve as useful policy tools to promote risk mitigation by property owners.

Ntritsos, N., Cubrinovski, M., & Rhodes, A., 19
Liquefaction Performance and Characterization of 55 Christchurch Sites

Detailed geotechnical characterization is presented for 55 case histories (level ground free-field sites) from Christchurch that showed vastly different performance during the 2010–2011 Canterbury earthquakes. The sites are first grouped with regard to their liquefaction manifestation (performance) into: (i) sites that manifested liquefaction in both 4 September 2010 and 22 February 2011 earthquakes (YY-cases); (ii) sites that did not manifest liquefaction in the September event but manifested liquefaction in the February earthquake (NY-cases); and, (iii) sites that did not manifest liquefaction in either event (NN-cases). The YY-, NY- and NN-sites are shown to have practically identical critical layer characteristics, with low CPT resistance (q_{c1Ncs} = 80 – 90), silty sand to sandy silt soil behaviour type (I_c = 1.9 – 2.3) and shallow location of the critical layer at approximately 2 m depth. As a result, neither the simplified triggering analysis nor the evaluation of damage indices, such as LPI or LSN, could explain the different liquefaction performances. However, further scrutiny of the 55 sites shows that there are significant differences between the YY-, NY- and NN-sites with regard to the thickness and vertical continuity of their critical zones and liquefiable materials. Characteristic YY-, NY- and NN-soil profiles are presented and key ground features that potentially led or contributed to different liquefaction performances are discussed. The 55 sites are further characterized using a robust statistical approach with probabilistic treatment of the various uncertainties. More specifically, a probabilistic soil model is developed and calibrated using the geotechnical characteristics of the 55 sites. The probabilistic model essentially consists of two main components: a model that describes the random stratigraphy at the site (i.e. the location of the layer boundaries over depth), and a model that describes the variation of cone penetration tip resistance and friction resistance at each layer (i.e. variation of soil behaviour type, and density of the soil). Future work will involve both deterministic and probabilistic effective stress analysis of the 55 sites with the aim to elucidate and quantify key contributing factors and mechanisms that led to the different performances for the three types of sites.

Ogden, M., Wotherspoon, L., & Van Ballegooy, S., 20
Scrutiny of the Simplified Liquefaction Assessment Frameworks Based on Historical New Zealand Case Histories

Liquefaction induced land damage has been identified in upwards of 13 notable New Zealand earthquakes within the past 150 years. Following the 2010-2011 Canterbury Earthquake Sequence, the severe consequences of liquefaction were witnessed first-hand in the city of Christchurch and as a result the demand for understanding this phenomenon was heightened. Government, local councils, insurers and many stakeholders are now looking to research and understand their exposure to this natural hazard. This study, operating within a greater collaborative research focus, aims to deepen the understanding of liquefaction through a number of key objectives. Firstly, all known case histories of liquefaction induced

land damage across New Zealand will be compiled into a single geospatial database providing insights into the temporal and spatial occurrence of this natural hazard. Following the creation of this database, the study will then focus on one region in particular, Marlborough. This is motivated by the widespread liquefaction manifestation during the 2016 Kaikoura earthquake and other historical events in this region. The second objective will be to generate or leverage existing models so that the current state of the art practise in liquefaction assessment can be employed. Combining these liquefaction assessment frameworks with the observational database created will then provide a greater understanding of the predictive efficacy of the frameworks. Areas or conditions where the simplified CPT-based methods are consistent or inconsistent with the observations will be readily identified, along with root causes for over or miss-prediction of the frameworks. The ultimate goal being the provision of a sufficient number of case histories to facilitate refinement in the assessment procedures, such that the overall number of false predictions can be reduced.

Orchiston, C., Ingham, J., Stovall, W., & Vallis, S., 59
Tourism and The Oamaru Victorian Heritage Precinct: Decision-Making for Resilient Solutions Associated with Heritage, Earthquake-Prone Buildings

The 2016 Building (Earthquake Prone Building) Amendment Act aims to improve the system for managing earthquake-prone buildings. The proposed changes to the Act were precipitated by the Canterbury earthquakes, and the need to improve the seismic safety of New Zealand's building stock. However, the Act has significant ramifications for territorial authorities, organisations and individuals in small New Zealand towns, since assessing and repairing heritage buildings poses a major cost to districts with low populations and poor rental returns on commercial buildings. Oamaru lies in the Waitaki District on the east coast of the South Island. It has a small but diverse tourism offering, largely focussed on heritage attractions including the Victorian Heritage Precinct, arguably the best collection of Victorian buildings in New Zealand. Waitaki District has approximately 695 earthquake-prone buildings, with estimated costs of up to $180 million required to undertake just the initial assessment required to fulfil the requirements of the Act. The project has undertaken a collaborative approach with cross-flagship support and supervision by QuakeCoRE researchers, to understand the current heritage tourism product in Oamaru, and the progress of current local owners and authorities in undertaking seismic assessments within the tourism precinct. This has taken the form of open-ended semi-structured interviews of tenants, tourism stakeholders and property owners. The final phase of research will entail the application of a Decision Support Tool developed by Flagship 5 researchers in 2016 to assist tourism stakeholders to navigate the challenges of decision-making for tourism growth, visitor safety, building safety and costs associated with meeting the requirements of the Act. The project has relevance to the cross-flagship Alpine Fault case study, since a future Alpine Fault magnitude 8 earthquake has the potential to cause some damage in Oamaru.

Pettinga, D., Bradley, B., Fraser, J., & Tarbali, K., 2
Response History Analyses of Structural and Geotechnical Systems using Simulated and Recorded Ground Motions

This project builds on a 2016 QuakeCoRE guidance document ('utilisation of ground motion simulations in engineering practice) through the application of simulated and recorded ground motions for response history analyses of four structural and geotechnical systems. The principal scientific question examined is whether the distribution of seismic response metrics (e.g. peak drifts, floor accelerations, embankment displacements, settlements) is consistent between simulated and recorded ground motion time series. Two types of

comparative studies will be performed, examining the distribution of seismic response metrics: (a) ground motions simulated for historical earthquakes vs. those recorded at strong motion stations; and (b) simulated and as-recorded ground motions which are consistent with a response spectrum from code-based design and/or probabilistic seismic hazard analysis.

Rad, A., MacRae, G., Hazaveh, N., & Ma, Q., 45
Shake Table Testing of Low Damage Steel Building with Asymmetric Friction Connections

Recently, a number of techniques have been developed around the world in order to minimize the possibility of structural damage using friction connections and energy dissipaters. As a result, a building may have almost no structural damage after an earthquake. However, there may be out-of straightness as a result of post-earthquake residual deformations. This issue may detrimentally affect structure performance in subsequent seismic events. This study develops a method for such buildings to be dynamically straightened, rather than have increasing displacements that may lead to collapse, if they experience strong aftershocks. The paper looks at the shake table performance of a half-scale two-storey steel building with asymmetric friction connections (AFC) at the base of steel columns and at the beam to column joints. The testing investigates the residual response of a building with structural intervention devices between the events to dynamically straightening the building. Different type of structural intervention devices were used with different strength and stiffness such as simple steel rods and tension-only braces. It is shown that depending on the ground motions, a building with an initial displacement in one direction has a tendency to have increased displacements in that direction, although it may dynamically straighten with some motions. By inserting tension-only devices (TODs) in appropriate locations, the building may be modified to have a tendency to have reduced displacements during aftershocks. Peak and residual drifts may be further reduced by increasing the stiffness and strength of the TODs. The shaking table tests behaviour observed was consistent with the numerical analysis results developed considering energy concepts.

Ramhormozian, S., Abeling, S., Sarrafzadeh, M., Aquino, H., & Clifton, C., 47
The 2016 IDEERS Seismic Design World Conference and Competition: A Report by New Zealand Postgraduate Team from the University of Auckland (UoA)

Developed by the University of Bristol, Introducing and Demonstrating Earthquake Engineering Research in Schools (IDEERS) is a shaking table competition with an aim to communicate the challenge and excitement of earthquake engineering research to young people from senior school to tertiary postgraduate level. IDEERS 2016 was supported by the British Council in Taiwan and the University of Bristol, and jointly organised by the National Applied Research Laboratories (NARL), the National Centre for Research on Earthquake Engineering (NCREE), and the National Science and Technology Centre for Disaster Reduction (NCDR) in Taiwan. The competition and conference was held in Taipei, Taiwan .A total of 104 teams attended the IDEERS2016 conference/competition. New Zealand was represented by a postgraduate team from the University of Auckland (UoA). The main objective of the postgraduate student teams' competition was to design and build an earthquake-resistant model building by applying advanced and innovative technologies. Moreover, the model building had to meet the practical issues such as space availability, feasibility, and cost-effectiveness. A conference was held only for the postgraduate teams in which the building geometry, seismic design concepts and philosophy, validation procedure, and experimental results were presented and assessed by the IDEERS2016 judges. The UoA team based their model on the Sliding Hinge Joint (SHJ), an earthquake resistant alternative for the traditional

seismic Moment Resisting Steel Frames (MRSFs). This paper reports the UoA team performance at the IDEERS2016 competition which resulted in receiving the 5th place, and describes the concept and model development and the model performance.

Ramhormozian, S., Clifton, C., Takayama, Y., Lam, J., & MacRae, G., 46
Self-Centering Capability of the Seismic Friction Dampers: A Conceptual Study on the Static and Dynamic Self-Centering Requirements for the Single Degree of Freedom (SDOF) Asymmetric and Symmetric Friction Connections (AFC and SFC)

The use of seismic friction devices in damage resistant buildings is rapidly growing. The Asymmetric Friction Connection (AFC) and the Symmetric Friction Connection (SFC) are examples of the seismic friction devices developed initially for the Sliding Hinge Joint (SHJ) and the Rotational Slotted Bolted Connection (RSBC) respectively, the first for seismic Moment Resisting Steel Frames (MRSFs) and the second for both MRSFs and Eccentrically Braced Frames (EBFs). One of concerns expressed about the use of these friction devices in seismic resistant buildings is the possibility of increasing the likelihood of the building having noticeable residual inter-storey drift following a design level earthquake. The lessons learned from recent past severe earthquakes has not shown such residual inter-storey drift experienced by any building, hence a conceptual research project was undertaken to investigate the potential for self centering of these systems as a function of a number of building response parameters. A possible way of providing the AFC and SFC with a flag shape self-centred hysteresis curve is to add a pre-compressed spring to these systems. This paper first presents the required characteristics of such springs to make the AFC and SFC statically self-centre, followed by the result of non-linear time-history direct integration dynamic analysis of conceptual Single Degree of Freedom (SDOF) AFC and SFC models. The dynamic analyses look at the effect of vibration's wind down and frequency, spring's stiffness and pre-compression, and seismic mass. The paper discusses the significant difference between the self-centering capability of these systems in static and dynamic conditions.

Razafindrakoto, H., & Bradley, B., 12
Insights on the Effects of the 2010 MW 7.1 Darfield Source Uncertainty on Ground Motion Simulations

This study aims to assess earthquake source modelling uncertainties on physics-based ground motion simulations via a case study of the 4 September 2010 Mw7.1 Darfield earthquake. Monte Carlo simulations are utilized to incorporate model uncertainties, and their correlations, in the geometric, kinematic and dynamic description of the source rupture; based on the kinematic rupture generator of Graves and Pitarka (2015). In addition, marginal parameter sensitivity on near-source ground motion was assessed through varying each parameter, while holding others constant at their mean values. Our results reveal that the magnitude and stress parameters are the main contributors for the between-event variability. The sensitivity to rupture length and width are comparable, and notably less than Mw because an increase/decrease in fault geometry result in stations closer/farther to the causative fault, but a lower/higher moment/area ratio, which have opposite effects on ground motion amplitudes. The results also show that the effects of different source representations from four different source inversion studies are most pronounced at the east end of the multi-segment rupture, and the rupture initiation time on the Charing Cross segment also significantly effects the consistency of the arrivals at near-source stations.

Rhodes, A., Cubrinovski, M., & Ntritsos, N., 21
Liquefaction Evaluation in Stratified Soils

The Canterbury Earthquake Sequence (2010-2011) caused widespread liquefaction across areas of Christchurch city. Observations of liquefaction manifestation show a geographic

grouping of sites that manifested liquefaction in the two main earthquake events (the Mw7.1 4 September 2010 Darfield earthquake and the more damaging Mw6.2 22 February 2011 Christchurch earthquake) and sites that did not. Furthermore, comparisons with predictions made by the simplified method (Boulanger & Idriss, 2014) show a 94% over-prediction of liquefaction for sites that did not manifest liquefaction, and a 50% under-prediction of liquefaction for the sites that did. Thus, the purpose of this research was to explain some of these discrepancies by investigating the effect of soil stratification on the development of liquefaction, and whether the effects of stratification are properly accounted for in the simplified method. First, the case study sites (55 sites around Christchurch) were categorised based on which sites manifested liquefaction in the September 2010 and February 2011 earthquakes (YY sites) and which did not (NN sites). CPT and borehole data for each site was then used to develop characteristic soil profiles representative of the general soil stratification in each category of liquefaction manifestation. From this analysis, the key difference between the YY and NN sites was identified to be the vertical continuity of liquefiable material. The YY sites displayed vertically continuous layers of liquefiable material, whereas the NN sites had vertically discontinuous layers of interbedded liquefiable and non-liquefiable material. An effective stress analysis (ESA) was used to thoroughly assess the response of each characteristic soil profile to different levels of earthquake loading. They key result was the effect of the system response of the soil deposit on the development of liquefaction (interaction between dynamic responses of layers, excess pore water pressures and water flow effects). In the case of the YY sites, the system response acted to increase the severity of liquefaction manifestation through water flow and pore water pressure redistribution. On the other hand, for the NN sites the system response acted to the opposite effect, reducing the liquefaction susceptibility of the soil deposits when there was a combination of ground motion modification (damped accelerations due to the presence of deeper liquefied layers) and partial saturation of the shallow soil layers. It is key to note that the simplified method assesses each soil layer as independent of those surrounding it, and therefore is incapable of quantifying the effects of the system response of deposits.

Riffault, J., & Dempsey, D., 13
Ground Motion Simulations for Hauraki Rift Earthquakes

The 2010-2011 earthquake sequence in Christchurch was a solemn reminder of the hazard posed by New Zealand's low strain-rate regions. The Kerepehi Fault in the Hauraki Rift and its offshore extension is another example: 40% of New Zealand's population lives within 50 km of a fault that may be capable of generating up to an Mw 7.4 event. In this work we present the steps engaged toward the development of ground motion simulations for earthquakes originating in the Hauraki Rift. A 1D vertical model constructed with the SCEC Broadband Platform Ground Motion Simulation developed by Graves and Pitarka (2010, 2015) is calibrated against the strong motion response for several small to moderate magnitude events that occurred in the rift. One earthquake of magnitude 3.9 was observed in 2005 in Te Aroha, and another one of magnitude 3.6 occurred in 2014 in Matamata. This project allows us to identify the obstacles encountered by non-seismologists and distant users of the software when setting up ground-motion simulations. As it the project progresses, accessibility and user-friendliness of the QuakeCoRE platform are improved.

Roeslin, S., Ma, Q., & Elwood, K., 48
Key Parameters in Pre-Event Data Collection for Emergency Response and Loss Estimation in Buildings

Recent earthquake events, as the ones in Christchurch in 2010 - 2011, led to numerous building damages and changes in the New Zealand insurance sector (ICNZ, 2012). Significant amount of data was gathered but quantitative studies following the earthquakes are sparse

(Kim, Elwood, Marquis, & Chang, 2017). Progress has been made in risk estimation and loss assessment related to natural earthquakes. Nevertheless, the experience has highlighted the need for improving tools to better assess and predict the outcomes of buildings subjected to moderate to strong earthquakes as well as induced seismicity (Broccardo, Danciu, Stojadinovic, & Wiemer, 2017).This study leads to a simplified methodology for pre-event data gathering allowing a faster and more accurate loss estimation. Existing pre-event data collection frameworks are reviewed. Data gathered after the Canterbury earthquake sequences are analysed and used to find the different sources driving building damage. Conclusion drawn are used to explore new approaches to conduct the pre-assessment of buildings.

Saunders, W., & Becker, J., 60
The Christchurch Recovery: An Example of Resilience and Sustainability

The term 'resilience' is increasingly being used in a multitude of contexts. Seemingly the latest 'buzz' word, it can mean many things to many people, in many different situations. In the natural hazard context, the terms 'sustainable planning', and 'resilience planning' are now being used, often interchangeably. But from a natural hazard perspective, is a resilient community a sustainable one? In order to be sustainable, does a community need to be resilient? This poster provides an overview of resilience and sustainability within a land use planning and natural hazard context, and discusses how they are interrelated. With a focus on the earthquake impacted city of Christchurch, New Zealand, it presents the planning response to the earthquakes, and the sustainable and resilient planning options being implemented. Due to the amount of liquefaction and land instability (i.e. rockfall and cliff collapse) that occurred in parts of Christchurch – and likelihood of continuing susceptibility to future events – a specific planning response was implemented. This included the introduction of the residential red and green zone system. Red zones were developed for the flat land subject to liquefaction, and for areas in the Port Hills susceptible to cliff collapse and boulder roll; green zones were developed for areas generally considered to have a sufficiently low risk to life, and the land could be remediated independently of surrounding properties. This response has created both a sustainable and resilient approach to land use planning.

Savarimuthu, S., Lagrava, D., Bradley, B., Huang, J., Motha, J., Polak, V., & Bae, S., 75
SeisFinder: A Web Application for Extraction of Data From Computationally-Intensive Earthquake Resilience Calculations

SeisFinder is an open-source web service developed by QuakeCoRE and the University of Canterbury. It aims to promote further research and collaboration by sharing the computationally-intensive resilience calculations produced by QuakeCoRE researchers. SeisFinder allows users to select amongst a number of past or future earthquake events and serves the ground motion simulation data for requested specific locations. This data can be used as input for other resilience calculations, like dynamic response history analysis. SeisFinder also provides sample codes and detailed instructions on how to manipulate and process the data. In this poster, we present the current features and usage of SeisFinder, as well as future ideas.

Shahmohammadi, A., Clifton, C., & Lim, J., 49
A Novel Cold-Formed Section for Mid to Long Span Portal Frame Buildings

Steel portal frame are considered as an efficient solution for warehouses and building. Current available popular solution is the I-section tapered portal frame. Another solution that has been proposed is nested tapered channel section (NTB) frame .NTB has been demonstrated to be able to solve bird issues, is more aesthetically desirable, and require less

lateral bracing due to inherent characteristic of box section and preventing premature lateral torsional buckling during the strong earthquakes. A large-scale test is being implemented in university of Auckland to investigate the behaviour of the frame against seismic and Gravity load. This poster introduce the system, advantages and describe the test setup erected.

Stringer, M., Orense, R., Pender, M., Cubrinovski, M., & Asadi, S., 22
Undisturbed Sampling of Pumiceous Soils in New Zealand

Pumiceous deposits are found in many areas of engineering interest on the North Island. Due to the lightweight and crushable nature of pumice, it is likely that conventional characterisation methods will either need to be altered in order to be used in pumice bearing soils. A key element in developing these adapted methods will be advanced laboratory testing of natural soil specimens. In this poster, the authors will present the results from an undisturbed sampling campaign carried out in Whakatane in 2016, with the aim of benchmarking the performance of different techniques to obtain high quality samples of pumiceous soils for advanced laboratory testing. It is intended that the results from this study will highlight some of the considerations which engineers and researchers need to consider when attempting further sampling in these soils.

Sullivan, T., MacRae, G., Clifton, C., Elwood, K., & Orumiyehei, A., 50
Would Loss Estimation Help Motivate The use of Low-Damage Steel Building Design Solutions?

A majority of new buildings constructed in Christchurch following the 2010-11 Canterbury earthquake sequence are supported by steel or steel-composite construction. These include traditional moment-resisting frames, eccentrically-braced frames, and use of buckling-restraint braces. However, seismic resilient solutions for steel buildings based on friction connections developed in New Zealand are not often used; despite their excellent performance in Wellington during significant earthquakes in 2013 and 2016. This study investigates whether the usage of seismic loss estimation could help motivate the implementation of low-damage solutions (e.g. steel buildings with friction connections) over traditional systems. The monetary losses due to earthquake shaking for a four-storey traditional moment-resisting frame designed for Christchurch subsoil class D conditions are compared with those for an equivalent frame designed with low-damage friction beam-column and column-base connections. The design assumptions, modelling approaches, and key findings from this study are summarized in the poster. It is anticipated that the approach adopted can also be applied to a wider-range of low-damage solutions to encourage their usage.

Sullivan-Taylor, B., Livschitz, S., & Johnston, D., 61
Exploring NZ's Historical Heritage Risks and the Policy Implications. Linking Risk Mitigation, Cultural Values and Sustainable Communities

New Zealand's historic heritage is under threat from both exogenous and endogenous risks. Due to New Zealand's dynamic landscape, unpredictable hazards pose a potentially catastrophic threat to historic sites. Additionally, historic heritage is under constant development pressure (Rouse & McCracken, 2014). Transformational change can be achieved through protecting the urban characteristics which affect tūrangawaewae, civic pride, cultural well-being and community resilience. Currently, there are a number of critical and concerning inconsistencies in the management of heritage buildings and Māori taonga tuku iho, or "treasures handed down". These primarily revolve around a lack of appropriate recognition of their public good value. As a source of financial and public good, or non-financial, value (Cowell, 2004), tūrangawaewae and civic pride play key roles in the cultural well-being and resilience of communities. These should be considered equally alongside

economic value, but are often under-represented or entirely ignored because of the difficulties in their quantification. Protecting the urban characteristics which influence community well-being can be aided by determining their non-financial value. We hypothesise that tūrangawaewae, civic pride, cultural well-being and community resilience is associated with the protection and effective management of heritage buildings and Māori taonga tuku iho. Incorporating non-financial aspects into the economic value of these assets will enable urban planning decision-making logic to build better communities which prioritise the holistic well-being of residents and mitigate the risks associated with natural hazards and development pressure. By gaining a better understanding of the public good value inherent in our historic heritage, both local councils and developers will be able to make more systematic, informed, consistent and improved decisions.

Syed, Y., Uma, S., Prasanna, R., Horspool, N., & McDonald, G., 69
'End to End' Linkage Structure for Integrated Impact Assessment of Infrastructure Networks under Natural Hazards

The aim of this report is to develop a linkage structure framework to link various models necessary for the assessment of infrastructure network performance due to natural hazards. The models include those necessary for the estimation of Geospatial hazard intensities, infrastructure component performance, network performance and interdependencies, and socio-economic metrics. By understanding input and output characteristics for each of these models, a more integrated framework for the assessment of impacts can be developed. This report is prepared to assess the format of inputs and outputs from each computational model, and identify what data needs to be fed into each successive model so that there are consistency and continuity in the impact assessment processes.

Taborda, R., & Isbiliroglu, Y., 1
A Preliminary Study about the Influence of Building Clusters on the Variability of the Ground Motion During Earthquakes

Spatial variability and ground motion uncertainty during earthquakes can significantly influence both our interpretation of seismic data and the behaviour of structures and infrastructure systems, especially those susceptible to differential motions, or those that benefit from more diffuse wave-fields. Spatial variations typically observed in ground motions are mostly the consequence of wave interferences, refraction, scattering and other phenomena resulting from the three-dimensional nature of the crust, the surface topography, site conditions, and heterogeneities in the transmitting media. Also influential but regularly ignored is the presence of the built environment, especially in the case of densely urbanized regions. We are interested in investigating the extent to which the presence of building-foundation systems can modify earthquake ground motions and contribute to their variability. We present preliminary results from a series of three-dimensional simulations using a finite element software for seismic wave propagation problems, with and without the presence of simplified building (block) models. We explore the level of influence exerted by the built environment on the ground motion through comparisons between the simulations with building models and equivalent simulations without them. This is the initial step of a project in which we seek to identify parameters that can serve as proxies to characterize site-city interaction effects.

Tan, M., Prasanna, R., Stock, K., Leonard, G., Hudson-Doyle, E., & Johnston, D., 62
Usability of Disaster Apps: Insight from the App Markets

The general public has access to multiple mobile applications (apps) for disasters through App Markets like iTunes and Google Play. These 'disaster apps' intend to provide value to the general public during disaster situations. Apps have great potential to improve the

public's resilience to disasters. However, limited research has studied these disaster apps and how the public perceives their usability. Taking the perspective of users, this project proposes a mobile app usability conceptualization to suit the 'disaster apps' context

Tarbali, K., Bradley, B., & Polak, V., 14
Simulation-based PSHA (Cybershake) for the Canterbury Region

In this poster, we present preliminary results from physics-based broadband ground motion simulations are utilized to conduct probabilistic seismic hazard analysis (PSHA) for the Canterbury region, New Zealand. Ground motions are simulated using the hybrid broadband simulation approach of Graves and Pitarka (2010, 2015) considering a transition frequency of 0.25 Hz, a detailed crustal model with a grid spacing of 0.4 km, and an empirically-calibrated local site response model. Deaggregation of the results from empirical PSHAs is utilized to identify dominant sources in the region from modelled faults, and the variation in hypocentre location and slip distribution are considered to partially account for the variability in ground motion characteristics. Seismic ruptures which represent small contributions to the hazard (e.g., small magnitude ruptures from distributed seismicity model) are considered in the total hazard via empirical ground motion models. Discussion is also provided about improvements regarding: a larger number of ruptures simulated; finer spatial resolution; comprehensive treatment of modelling uncertainties; and extension to the South Island region.

Thomson, E., Bradley, B., Cox, B., Wotherspoon, L., & Wood, C., 15
Generalised Parametric Functions and Spatial Correlations for Seismic Velocities in the Canterbury Region Based on Dynamic Site Characterisation

This poster presents generalised parametric functions to compute seismic velocities within the sedimentary deposits of the Canterbury region, with spatial correlations to represent unexplained velocity variability in space. The primary purpose of the developed functions is to prescribe velocities within the sedimentary units of the Canterbury region for physics-based ground motion simulations as adequate characterisation of the velocities are critical in accurately capturing wave amplitudes. The functions make use of recent surface wave investigations which detail the velocity structure at 23 sites throughout Christchurch and Canterbury. However, the stratigraphy in Canterbury is comprised primarily of terrestrial gravel layers in the inland regions with an increasing number of interbedded fine grained marine sediments closer to the coast, which presents additional complexity. This soft-over-stiff layering results in velocity reversals at sites located in the Christchurch city area due to the significantly different lithology of the interbedded terrestrial gravel and fine grained marine sediments. The velocities determined from surface wave investigations within eight interbedded layers from the Quaternary period and three layers from the Tertiary period were analysed, and generalised parametric equations prescribing seismic velocities as functions of depth are derived in addition to correlations for their spatial dependence. The resulting models allow more realistic velocity structure representation, which is expected to result in improved ground motion simulation accuracy and precision in the region.

Vallis, S., Galvez, P., Giovinazzi, S., Abeling, S., & Ingham, J., 35
Unreinforced Masonry Churches in New Zealand: Towards a Holistic Framework for the Identification of Optimal Seismic Retrofit Intervention

Unreinforced masonry churches in New Zealand, similarly to everywhere else in the word have proven to be highly vulnerable to earthquakes, because of their particular construction features. The Canterbury (New Zealand) earthquake sequence, 20102011 caused an invaluable loss of local architectural heritage and of churches, as regrettably, some of them were demolished instead of being repaired. It is therefore critical for New Zealand to advance

the data collection, research and understanding pertaining to the seismic performance and protection of church buildings, with the aim to promote conservation of churches and of church precincts, and to assure public safety within churches, and community wellbeing in post-disaster circumstances, as churches proved to be critical social hubs. With specific reference to the case study of the Anglican Diocese of Waikato and Taranaki, a project is ongoing in New Zealand to define an holistic approach for assessing the seismic vulnerability of unreinforced masonry churches and for identifying retrofitting innervations that, further to be effective from a seismic engineering point of view, are conceived with respect to the conservation philosophy and best practices set by the ICOMOS, International Council on Monuments and Sites, New Zealand Charter. In the proposed framework, "Social Value" and "Cultural Value" of churches are included as added incentives for selecting, among interventions with equal seismic protection levels, the ones that respect conservation principles (e.g. respect structural authenticity, non-intrusiveness, non-obtrusiveness, etc.) although this might not be the best choice from an economic point of view. Furthermore, in conjunction with the seismic vulnerability, "Social Value" and "Cultural Value" are regarded, within the proposed framework, as possible criteria for identifying priorities for seismic retrofitting within a group of churches and/or for prompting private and public investments on seismic retrofitting intervention. The poster provides an overview on the on going project and on the preliminary definition of the framework.

Yakubu, E., Egbelakin, T., Ingham, J., & Glavovic, B., 36
Economics of Strengthening and Redeveloping Buildings for Adaptive Reuse Purposes

The cost-benefit implication of strengthening and redeveloping existing buildings is important in urban regeneration decision-making approaches adopted by local authorities. Accordingly, this research commences a critical exploration of the effectiveness of using the adaptive reuse approach to balance the varying objectives of seismic resilience, sustainability, built heritage preservation, and building demand, towards achieving a resilient and sustainable town centre living. The mixed methods approach comprising of both the qualitative and quantitative data collection techniques will be adopted in this study. A focus group interview with relevant stakeholders will be used to address objectives one and two in order to capture local experiences from selected case studies. Furthermore, objectives three and four will be addressed using the analysis of existing documents and face-to face interviews with subject matter experts respectively. The qualitative research phase will be analysed using the Multiple Criteria Decision Framework (MCDF) technique, while that of the quantitative research will be done using the Structural Equation Modelling (SEM) technique. The outcome from this study will offer building owners and relevant stakeholders of the selected cases, additional evidence-based information upon which to justify investment choices. The study will also give rise to the development of an adaptive reuse framework that will guide policy regulators in balancing the cost-benefit of seismic resilience, sustainability, built heritage preservation, and building demand, towards achieving a resilient and sustainable town centre living. Furthermore, the framework will be transferable to other New Zealand local councils, also striving to achieve town centre regeneration.

Yeow, T., Sullivan, T., & Elwood, K., 51
Component Damage Fragility Functions for use in New Zealand

Seismic loss estimation is a powerful tool to predict the performance of structures during earthquakes in terms of monetary damage-repair costs, business interruption, and injuries. While this tool is widely used in the USA to provide resiliency ratings, it has not received much uptake in New Zealand. This may be due to a lack of data applicable to New Zealand practice that links building response to damage and losses. This study takes a step in addressing this

need by proposing fragility functions for a range of building components for use in New Zealand. Common details used for building components in New Zealand practice were obtained from discussions with industry and research groups. A literature review was then performed to source any fragility functions or experimental data applicable for these component details. Where fragility functions are not readily available in literature, these were derived in this study following methods proposed by Porter et al. (2006). The derived fragility functions are all based on a lognormal distribution fit, which was found to be adequate using goodness-of-fit tests. The fragility functions sourced or developed thus far are (i) light gauge steel framed partitions, (ii) suspended ceilings, (iii) precast concrete panel cladding, (iv) stairs, (v) elevators, and (vi) sprinklers. More information on the methodology adopted and the key outputs are available in the poster.

Ziotopoulou, K., 23
Seismic Response of Liquefiable Sloping Ground: Numerical Predictions of the LEAP Centrifuge Model Responses

Nonlinear deformation analyses (NDAs) are being increasingly used for evaluating the potential effects of liquefaction on the performance of soil deposits and geo-structures that contain liquefiable soils. Confidence in the accuracy of such numerical simulation predictions or the quantification of their uncertainties can be significantly improved through validation. Validation is the assessment of the accuracy of a computational simulation by comparison with experimental data. The Liquefaction Experiments and Analysis Project (LEAP) is an international effort aiming at validating numerical tools commonly used for predicting liquefaction responses. Within LEAP, simulations can provide a basis for evaluating the strengths and weaknesses of the constitutive models and numerical modelling protocols used, and for identifying likely causes of differences between different centrifuge recordings. The response of a uniform, saturated, medium-dense Ottawa sand profile with a 5o slope is the focus of this project. In this poster, selected results and lessons learned will be presented from Class A and Class C (Lambe 1973) numerical simulations of the LEAP centrifuge tests in FLAC 8.0 (Itasca 2011) with the constitutive model PM4Sand Version 3 (Boulanger and Ziotopoulou 2015). The calibration and model setup processes are introduced. A comprehensive database of laboratory testing will be presented and the data will be discussed. A lower and upper bound of cyclic strength for the liquefiable material were selected and found to reasonably envelop the recorded and targeted responses. The rationale behind the selection of the two cyclic strengths will be discussed. Results in terms of acceleration and pore-pressure time histories as well as final horizontal and vertical displacements will be presented in comparison to recordings from the six participating centrifuge testing facilities. Differences between Class A and Class C predictions will be used to demonstrate the significant improvement in the predictions when utilizing reported measurements of achieved properties and motions. Sources of variability between analysis results and recordings will be discussed and conclusions will be drawn about differences between recordings at different facilities. It will be concluded that critical examinations of NDA models and modelling procedures are necessary for identifying weaknesses, fostering improvements, and increasing confidence in their use for evaluating the seismic performance of geo-structures affected by liquefaction.

Zorn, C., Thacker, S., Pant, R., & Shamseldin, A., 70
Vulnerability of Interdependent Infrastructures to Spatially Localised Hazards

Critical infrastructure networks are geographically distributed systems spanning multiple scales. These networks are increasingly interdependent for normal operations, which causes localised asset failures from natural (or intentional) hazards to propagate across multiple networks, potentially affecting those far removed from an initiating failure event. Here we

present methodology to identify such failure propagations by quantifying and observing the spatial variability in magnitude, frequency, and disruptive reach of failures between national infrastructure networks. To achieve this we combine physical interdependencies of functional infrastructure networks with geographic interdependencies by simulating complete asset failures across a national scale grid of spatially localised hazards. A range of metrics are introduced to directly compare the systemic vulnerabilities of infrastructure systems and the resulting spatial variability in both the potential for initiating widespread failures and the risk of being impacted by distant hazards. Our investigations highlight the importance in considering critical infrastructure interdependencies when assessing infrastructure risks and prioritising investment decisions for enhancing resilience of national networks.