Te Hiranga Rū | QuakeCoRE
Aotearoa New Zealand Centre for Earthquake Resilience

2021 Te Hiranga Rū QuakeCoRE Annual Meeting Poster List

7th – 9th December, 2021 – Rutherford Hotel, Whakatū Nelson, New Zealand

Abeling, S. 58

Resilient Buildings Project: Understanding Societal Expectations for Seismic Performance of Buildings

Currently New Zealand building codes and standards are primarily focused on life safety, despite the ability of building designers to achieve earthquake performance outcomes beyond life safety, including low damage design. The purpose of this project is to identify if there is social license to redefine statutory performance objectives by eliciting societal expectations for the seismic performance of buildings through a series of interviews and focus groups. Over 30 interviews have been conducted with the aim of identifying the range of seismic performance objectives that different building user groups have. Interviewees were strategically chosen to represent a variety of relationships with the built environment across the four wellbeings (i.e., human, social, economic and natural) and across different sectors (i.e., private, research, public and public interest). Additionally, the interviewees represent a wide range of industries and ownership perspectives. The next stage of the project will be to conduct 6-8 focus groups with the aim of identifying aspects that drive decisions about seismic risk by contextualising performance objectives. The focus groups are geographically diverse, taking place in both urban and smaller centres in areas of low, medium and high seismicity. Focus group participants will be chosen to represent local community interests in terms of human, social, economic and natural wellbeing. The insights arising from this study will contribute to debate about desired levels of resilience to the impacts of earthquakes and the design approaches and options available to achieve desired performance.

Aigwi, E., Filippova, O., Ingham, J., Phipps, R., Rotimi, F., & Nwadike, A. 66

Role of Government Grants in Enhancing Built Heritage Protection Efforts and Seismic Resilience in New Zealand's Provincial Regions

Investment in the protection of earthquake-prone heritage buildings through incentives in the form of government grants provides a lifeline for sustainable built heritage, which can also boost the seismic resilience and local economy of an urban area. This study sought to evaluate the distribution of heritage buildings in New Zealand, examine the allocation of significant government funding sources for protecting the heritage buildings, and explore the implications of this allocation on future built heritage protection efforts in New Zealand's provincial regions.

The document analysis revealed that although the per capita distribution of heritage buildings is highest in New Zealand's provincial regions, it is the major urban centres that receive the highest share of government funding. Also, three significant themes were identified from the key informant interviews as implications of the current incentive allocation on built heritage protection efforts in New Zealand's provincial regions: (i) disproportionately low allocation of government grants to provincial regions; (ii) "lack of sophistication" among property investors in provincial regions; and (iii) "emergency solution" mindset of government funding regulators.

These findings imply that though the existing government heritage grant systems are the most extensive non-regulatory incentives for the protection of built heritage in New Zealand, the provincial

regions currently struggling with so many underutilised and derelict earthquake-prone historical buildings may not be able to keep up with their preservation efforts if they continue to receive a lesser proportion of the available grant. As a recommendation, the central government can assist by directing more discretionary grants to provincial regions to encourage future efforts towards protecting their earthquake-prone heritage buildings.

Akther, M., Orchiston, C., Johnston, D. 47

What's in a name? Policy implications for developing EQ resilience in low seismic hazard zones of New Zealand

Destructive earthquakes are low frequency, yet high consequence events for lives and livelihoods. Being on the Pacific Ring of Fire, New Zealand is highly exposed to earthquake risk. Yet, some parts of the country are categorized as low seismic hazard zones (LSHZs) based on probabilistic analyses of earthquake occurrence. LSHZs include densely populated urban centres such as Auckland and Dunedin. A major deficiency in the current low-medium-high designation of seismic risk is that it does not apply a deterministic approach to consider the possibility of earthquakes occurring on local active faults that lack historic earthquake events. In LHSZs, there is a 35-year target to bring earthquake-prone buildings (EPB) up to code. It is apparent that such a protracted timeframe is leading to compliance complacency among stakeholders. Given this context, it is important to understand the synergies and conflicts that may exist across current EQ-related legislation and assess awareness and capacity of stakeholders to achieve EQ policy compliance in LSHZs. This research is currently preparing a policy and literature synthesis to understand the strengths, gaps, and opportunities for building EQ resilience in LSHZs in NZ. Focus group discussions (FGD) and questionnaire surveys will be used for mapping stakeholder perceptions, interpretations, and expectations regarding EQ legislation. The research findings will directly contribute to an improved understanding of the EQ policy environment and the challenges and opportunities for local government as they try to make sense of EQ policy and legislation in the context of earthquake risk reduction. The outcomes of this research will give us a better understanding of the resources and capacity needs which then can be translated into action for building EQ resilient communities.

Alger, B., Thomas, K-L., Kaiser, L., Midwood-Murray, A-M., Midwood-Murray, B. 56

Papa Wiri: Te Ao Māori Disaster Risk Reduction through Participatory Design and Co-Design of Educational Tools

Most current Disaster Risk Reduction (DRR) education programmes to build community resilience are designed for Pākehā use and engagement with little connection to Te Ao Māori. There is an opportunity to weave Māori narratives and education pedagogies to create bi-cultural, fun and engaging DRR education resources, community solutions based on diverse knowledge, to empower all to reduce disaster impacts. Currently there is little, true, co-designed research with Māori in the DRR space. This research aims to trial and improve the current journey with Māori partners and present learnings to the wider research community.

This research, co-led by Māori Educational Advisors, uses a qualitative kaupapa Māori research approach to explore Te Ao Māori perspectives around DRR and inform co-designed indigenous innovation of Māori-cantered educational tools for kura and wider communities. An iterative process with research partners and users will shape the research design and wairua journey.

of Christchurch in Aotearoa New Zealand. We observe trade-offs and synergies between multiple objectives, revealing the challenge of balancing potential compromises and utilising co-benefits between risk and other sustainability objectives. This approach and the resulting spatial maps, which identify areas best for development, provide evidence to help guide and support urban planners in identifying strategic areas for relocation and growth.

Avendano, B., Milke, M., Lukosch, H., Beaven, S., Hughes, M. 48

The use of Participatory Modelling to integrate social and Infrastructure resilience.

Resilience planning implies 1) Improving physical infrastructure assets and 2) Improving social resilience. However, disaster experts, planning managers, and policymakers made decisions assuming independence between social and physical systems. There is a need to understand the challenge of integrating social and physical assets, their interactions, and non-linear complexity to make informed decisions.

For example, to prepare for faster recovery after the next earthquake, what would you prioritise for investment today?

(a) building stronger classrooms and school facilities, or (b) training teachers to motivate children to study effectively in post-earthquake settings, or (c) some of both.

The difficulty in making this type of decision highlights the constant tensions between social and infrastructure resilience. The example demonstrates how the level of analysis needs to be at the larger socio-technical system.

The aim of this research as Ph.D. work conducted over 2020-2022 is to develop participatory methodologies to bring stakeholders together to collaboratively analyse and evaluate the interconnections between social and infrastructure resilience. The four goals of the research are to:

(1) Develop a conceptual model and validate with stakeholders,

(2) Develop materials and details for workshops on Participatory Modelling

(3) Conduct trials and refine approach while also considering the added value of gamification

(4) Consider the potential for the approach to be applied to other socio-technical systems

The resulting modelling methodology will have the potential to improve disaster risk governance and disaster resilience planning and practice in New Zealand and internationally by empowering multiple stakeholders through collaborative learning and increasing the efficacy and legitimacy of resilience-building decision making.

Bae, S., Motha, J., Stolte, A., de la Torre, C., Foster, K., Bradley, B. 2

Enhanced estimates of Vs30 via the inclusion of New Zealand Geotechnical Database (NZGD) Cone Penetration Test (CPT) data

Time-averaged shear wave velocity from the ground surface to a 30-m-depth (Vs30) is an earthquake engineering parameter which is used to approximate site amplification. However direct measurements of Vs30 are not readily available on a regional/national scale. Most Vs30 measurements are clustered around urban areas, including Christchurch CBD. Scarcity of Vs30 measurements in other areas can create bias when developing a nationwide data-driven Vs30 model based on geologic categories and terrains.

Cone penetration tests (CPT) data is relatively abundant across New Zealand, and can be used to estimate Vs30 using existing CPT-Vs correlation such as McGann et al. 2015.

A database containing 49323 CPT records has been extracted from the New Zealand Geotechnical Database (NZGD) to estimate Vs30. The CPT-based Vs30 estimates have been filtered, clustered and included, with an appropriate uncertainty, in an update of New Zealand-wide Vs30 model developed by Foster et al. (2019)

The preliminary findings from the experiments and derived recommendations for hollow-core floor retrofits are presented in this poster.

QuakeCoRE Emerging Researcher Chapter (QERC) 79

The QuakeCoRE Emerging Researcher Chapter (QERC) is a network of students and emerging researchers composed of four chapters: Auckland, Christchurch, Dunedin and Wellington. Our aim is to promote networking, collaboration, and knowledge sharing among students and emerging researchers within the earthquake resilience community. QERC does this by organising technical, social, and outreach events.

Cappellaro, C., Cubrinovski, M., Dhakal, R. 3

Liquefaction Risk Analysis of Native and Reclaimed Soil Deposits in Central Wellington

Following the 2016 Kaikōura earthquake, severe and damaging liquefaction was observed at the port of Wellington in areas of reclamation fills built at the beginning of or mid-20th century. However, little or no damage was reported in areas of older reclamation fills, dating back to the 1850s, and in native (natural) soil deposits in central Wellington. Following these events, comprehensive investigations have been performed to characterise the undrained response and liquefaction resistance of the most recent liquefaction-prone gravelly fills and hydraulic fills. However, comparatively little attention has been paid so far to the performance of older reclamation fills and of native soil deposits.

The poster discusses comparatively the characterisation for liquefaction assessment purposes of native soil deposits and reclamation fills in Wellington city using cone penetration test data. Representative soil profiles are defined and representative values (25th-75th percentiles) of cone tip resistance are identified for characteristic soil layers. These soil profiles are subsequently employed to perform simplified liquefaction triggering analyses of the reclamation fills for different earthquake scenarios.

Chang-Richards, A. 60

Quantification of timeframes for post-earthquake recovery

Knowing how to rapidly rebuild disaster-damaged infrastructure, while deciding appropriate recovery strategies and catering for future investment is a matter of core interest to government decision makers, utility providers, and business sectors. This poster shows the underlying critical decision factors and processes that have governed the trajectory of post-earthquake recovery in Christchurch; and quantification of the effect of these critical elements on infrastructure downtime. While the research has improved our understanding of the process of earthquake reconstruction in the infrastructure sector and how to plan for a speedy recovery, it is equally important for this work to extend to multi-storey buildings.

External constraints such as engineering and construction capability and stakeholder requirements are widely associated with the ability for attaining achievable and acceptable timeframes for buildings to restore functions. A new project under the Interdisciplinary Programme 1 (IP1) aims to consider the factors that drive the step changes in functional recovery timeframes for multi-storey buildings and develop data-driven repair time models by using multivariate logistic regression to quantify timeframes for achieving functional recovery.

Chigullapally, P. 22

Modelling the response of pile foundations with plain round bars

A number of State Highway bridges that are part of critical life lines in NZ were constructed pre 1970`s with smooth reinforcement and without modern seismic design philosophies. It is important to understand the in-service performance of these bridge foundations as they hold a key to seismic resilience of the country. However, there is limited data on the performance of these foundations in the field or laboratory and no numerical models calibrated on piles from this period. So, numerical models that incorporated the bond-slip effects were developed to understand the lateral and seismic behaviour of piles with smooth round bars. The numerical models developed were calibrated with the isolated single pile tests of the Whirokino Trestle Bridge that were tested under different loading protocols. The models were also loaded under similar loading conditions to field testing to study if they were able to capture the response of these piles over different lateral load ranges. In general, these models with existing material models and p-y springs were able to capture the response of the piles and compared well in all the measurable aspects with the field testing results. The observations and results from this research will be used to improve the assessment approach for existing bridge foundations and seismic design standards.

Clement, R., Bhatta, J., Tripathi, M., Dhakal, R. 23

Investigating the interaction between multiple drift-sensitive non-structural elements during quasi-static cyclic drift demands

As an ongoing effort to improve the seismic performance of non-structural elements, a precast concrete cladding panel system with novel 'rocking' connections has been recently developed at the University of Canterbury. In this system, the cladding panels are attached to the structure through steel-embeds with vertical slots placed at four corners of the panel. The panels sit on the structure at the locations of weld-plates in the panels. The steel-embeds allow the panels to rock under inter-storey drifts while the weld-plates transfer the gravity loads to the structure; thereby accommodating significant drift demands and consequently delaying and minimising the damage to the cladding system. This design was validated as a low-damage solution; however, its interaction with other non-structural elements such as partition walls and glazed curtain walls has not been investigated. Moreover, as air and water-tightness are essential characteristics of cladding systems, the satisfactory weather-tightness performance of the cladding system is also essential.

Therefore, this study investigates the interaction between internal partition walls and glazed curtain wall with the novel low-damage precast concrete cladding system to evaluate its applicability and effectiveness as an alternative to conventional cladding systems. An experimental program that includes testing a condensed section of a standard commercial building is being developed to examine the interaction of these non-structural elements under quasi-static cyclic drift demands. In addition to seismic testing, weather-tightness tests will also be carried out to ensure that the cladding system will be structurally sound and the serviceability issues occurring post-earthquake are minimised. These tests are expected to either prove the novel cladding system's superior performance or identify any required alteration in its design to further improve its overall performance.

Danzi, L., Orchiston, C., Higham, J. 50

Exploring the relationship between tourism and emergency management in New Zealand to build disaster resilience in rural tourist destinations

The main tourist destinations in Aotearoa-New Zealand include rural regions that are highly exposed to disaster risk and limited in emergency response resources and medical care capacities. In case of emergencies, the presence of tourists, who are generally unfamiliar with the local environment, adds pressure on the local communities and response agencies. It also adds complexity to response processes and procedures. Close collaboration between emergency management and tourism organisations is required, but there is currently limited understanding of the nature of their relationship and their actual operation. This research addresses this gap by investigating how tourism and emergency management agencies work together during a crisis, through the perspectives of senior representatives from local, regional and national levels. Data are collected through purposive and snowball sampling, in three different phases, and cross-analysed via 'triangulation'. A mixed methods approach incorporates the qualitative content analysis of policies and plans, the quantitative analysis of survey responses informing a network graph, and the qualitative analysis of case-study interviews with key stakeholders from two major nature-based destinations in New Zealand, Queenstown and Milford Sound. Despite the exposure of these locations to a future Alpine Fault earthquake, tourism operators have been found unprepared and lacking integration with national emergency. Expected results from this research will show how the importance of tourism impacts the level of collaboration between tourism and emergency management, and how this changes across levels of governance and in different types of destinations (e.g. rural vs urban). Findings from this research will help promote collaboration and integration between stakeholders involved in tourism disaster management, and, through improving disaster preparedness, build the resilience and response capability of rural New Zealand.

De Francesco, G., Sullivan, T. 24

P-delta displacement amplification ratios for performance-based seismic design of structures

P-delta forces can worsen the seismic performance of building and bridge structures and potentially lead to dynamic instability and collapse. An accurate characterization of P-delta effects is therefore imperative, for both design and assessment of structures. Utilizing an earthquake database composed of 7032 ground motions, this study presents the results of a large statistical analysis of amplifications of the displacement demand due to P-delta effects for single-degree-of-freedom systems. A large range of fundamental periods, ductility levels, and hysteretic responses are investigated, and limits for dynamic instability are obtained in terms of both elastic and inelastic stability coefficients. Accurate analytical estimates of the median values of the P-delta displacement amplification ratio are proposed that consider the combined effect of stability coefficient, ductility level, fundamental period and hysteretic response.

De La Torre, C., Bradley, B., McGann, C., Stewart, J. 4

Can Modelling Soil Heterogeneity in 2D Site Response Analyses Improve Predictions at Vertical Array Sites?

This study uses a database of 21 vertical borehole arrays in California to validate a 2D site response analysis framework that accounts for soil heterogeneity via spatially-correlated random fields. The main hypothesis is that the overprediction of ground motion at site modal frequencies, consistently observed in many site response validation studies, is caused by the disregard of soil heterogeneity and 2D/3D wave propagation effects in conventional 1D site response predictions. We test whether the proposed approach is capable of capturing some of these 2D phenomena and improving site response predictions at vertical array stations. Results from 2D and 1D analyses are compared to observations using a transfer-function-based taxonomy and residuals of various other intensity measures (IMs) including response spectra. The uncertainty in these IMs is estimated from the many realizations of

2D models. We assess trends in median and standard deviations of IMs with respect to various site parameters (e.g., impedance ratios, shear wave velocities, frequencies of fundamental modes, and depth to the downhole seismic instrument). This 2D approach was found capable of scattering seismic waves and producing transfer function variability resembling the observed event-to-event variability in empirical transfer functions (ETF). For several sites that exhibit less down-going wave effects in ETFs (i.e., flatter peaks) and/or higher variability in ETFs, median transfer functions from 2D analyses provide a significantly better estimate of the median ETF than conventional 1D deterministic analyses, especially at fundamental modes. In contrast, for some of the sites that are well represented by 1D methods (e.g., Wildlife Liquefaction Array and Treasure Island), 2D methods with generic levels of spatial variability may over-represent the heterogeneity and consequently under-predict amplifications at higher mode frequencies.

Delano, J., Stahl, T., Howell, A., Clark, K. 5

Exhuming interest in the 1987 Edgecumbe earthquake

Characterizing seismic hazard relies on information about the expected size, slip type, and frequency of earthquake rupture, but deriving these characteristics from paleoearthquakes is complicated by inadequate pre-earthquake topographic data and post-earthquake surface modification. The 1987 Mw6.6 Edgecumbe earthquake in New Zealand produced widespread, complicated surface deformation from discrete surface rupture, hanging wall subsidence, liquefaction, and sediment compaction. Post-earthquake reconnaissance efforts measured scarp displacements and regional coseismic deformation, but were hindered by incomplete pre-earthquake topographic data, such as the location and size of pre-existing scarps. Similarly, more recent lidar-based studies had difficulty distinguishing between cumulative and single-event scarps, and lack individual event rupture distribution information. We use historical aerial photos to build the first pre- and post-earthquake digital surface models and orthophoto mosaics of the Edgecumbe earthquake to characterize coseismic slip. By differencing the pre- and post-earthquake surface models, we more definitively measure discrete and distributed deformation and compare the effectiveness of the technique to more traditional field- and lidar-based studies. We identified most fault traces recognized in 1987, mapped new traces not recorded in the field, and take denser, detailed remote slip measurements with a vertical separation resolution of ~0.25–0.5 m. Our maximum and average vertical separation measurements on the Edgecumbe fault trace (2.5 ± 0.3 m and 1.4 m, respectively), are similar to field-based maximum and recalculated averages of 2.4 m and 1.1 m, respectively. The resulting horizontal and vertical slip data are used to refine the estimated subsurface fault geometry and slip distribution at depth. Refined paleoearthquake slip behaviour can be integrated into future seismic hazard models and enable better forecasting of fault surface displacement.

Deng, T., Henry, R. 25

Dynamic analysis for RC tall walls designed with the minimum reinforcement contents

Localisation can occur in distributed plasticity fibre models when a strain-softening response at the section restricts the spread of damage due to the stress unloading in adjacent sections/elements. Past studies have developed the regularisation schemes for concrete compression response and reinforcement post-yield response to achieve mesh objective results for the failure of reinforced concrete (RC) walls. However, for the walls designed with low amounts of longitudinal reinforcement, the response and failure are controlled by the tensile behaviour, including concrete cracking and reinforcement fracture. In order to minimise the effect of mesh size on the strain localisation for the lightly reinforced concrete walls, detailed methods for regularisation of both the reinforcement and concrete material properties were proposed for the application in nonlinear analysis. The regularisation techniques were based on the constant fracture energy and were validated against the measured response of test walls designed with lightly longitudinal reinforcement contents to ensure that both the cracking and ultimate response can be accurately modelled. The local strain response

was then investigated to highlight the necessity for the post-process to achieve the objective result. The cyclic response for the lightly reinforced concrete walls was also verified with the proposed regularised technique. The comparable results indicate that the model with the regularisation for the post-softening response in concrete and post-yield response for reinforcement can accurately predict the global response. The post-process for the strain profile with the proposed scaled factor is also emphasised to obtain an objective local response.

Dhakal, R., Cubrinovski, M., Bray, J. 6

Applicability of Simplified CPT-Based Liquefaction Assessment to CentrePort Gravels

The 2016 M_w7.8 Kaikōura earthquake caused widespread liquefaction in the port of Wellington (CentrePort) which produced substantial ground movements, damage to structures and thick surficial manifestation of ejected gravel. Liquefaction assessment of the gravel reclamation poses several challenges due to its large percentage of gravel-sized particles making it difficult to obtain high-quality in situ data. Gravelly soils are also not well represented in current semi-empirical liquefaction procedures, which raises the question of whether state-of-the-practice liquefaction evaluation methods based on sands are applicable to gravelly soils. Subsurface exploration following the earthquake investigated the thick end-dumped gravelly fills by performing over 100 Cone Penetration Tests (CPTs). This data provides an opportunity to scrutinise the applicability of widely used state-of-the-practice simplified CPT-based liquefaction triggering and settlement evaluation methodologies on the end-dumped gravelly fills at CentrePort.

Sensitivity studies of the liquefaction triggering analysis show the uncertainty in the cyclic demand is larger than the uncertainty in the cyclic resistance within a critical layer. However, the modelling uncertainty over the entire depth of the fill is larger for the cyclic resistance, which can vary by over 50%. Sand-based procedures for evaluation of liquefaction-induced settlement are found to be applicable to well-graded gravels that have a dominant silty sand fraction in the soil matrix, though they can overestimate the relative density of gravelly soils. The study emphasizes the importance of dominant soil fraction of the soil matrix, and its effects on the soil packing, penetration resistance, and liquefaction resistance in the context of the principal assumptions in current semi-empirical liquefaction evaluation procedures.

Dudek, T., Noy, I., Ulm, E. 37

Demand for fixed-price multi-year contracts: Additional experimental evidence from insurance decisions

Governments often need to provide financial assistance after a severe disaster strikes a region. These need for government assistance can be mitigated with adequate insurance coverage. Yet, people often fail to purchase insurance, even if it is subsidized. Several behavioural reasons have been investigated why people fail to insure. Some researchers suggested using long-term insurance contracts to increase insurance penetration and to mitigate underinsurance generally and the negative effects stemming from behavioural biases and heuristics specifically. We examine insurance decisions in a computer-administered online experiment that makes several contributions to our understanding of insurance decisions. First, we replicate previous studies showing that many people have a preference for long-term insurance. Offering this type of insurance might increase coverage overall. Second, we find that underinsurance can result from outdated insurance contracts. There might be a need to help people make more informed insurance decisions. Long-term insurance contracts that take into account price and value changes of an insured property over time could be helpful to mitigate underinsurance. Third, we find that people repeat the choices they made in a previous period. It seems that once people made a decision, the decisions become "sticky", so that the first period's choice explains future insurance choices to a large degree. Fourth, we find that New Zealanders, where house insurance penetration is extremely high, are more likely to insure their house in the experiment, especially with multi-year contracts. Our research suggests that reminding people of their previous decision and letting them

know what many others are doing might be effectively increasing insurance penetration and mitigating underinsurance that develops over time, while subsidies seem to be ineffective.

Dupuis, M., Lee, R., Bradley, B. 7

Insights from ground-motion simulation validation of New Zealand small magnitude subduction earthquakes

Subduction interface and slab earthquake simulation models were developed for small magnitude subduction earthquake ground-motion prediction in New Zealand using a hybrid broadband simulation approach. The subduction earthquake models are based on: (i) statistical analysis of a global database of finite-fault rupture models created from source inversions of historical earthquakes; (ii) analysis of global empirical ground-motion models for subduction earthquakes; and (iii) review of global ground-motion simulation studies which have considered subduction earthquakes. The subduction simulation models include source-specific representations for stress parameter and rupture velocity with significant depth dependence of stress parameter for slab earthquakes. Volcanic arc effects on anelastic attenuation are included through source-to-site azimuth and hypocentre depth dependent modification factors to the rock quality in the simulation velocity models. Ground-motion predictions from the simulations were validated on observed subduction interface and slab earthquake ground-motion records in New Zealand using a mixed-effects regression framework. The subduction-specific models were found to significantly improve the predictive performance of the hybrid broadband ground-motion simulation approach and provide predictive performance which exceeds that of empirical subduction earthquake ground-motion models for small magnitude subduction earthquakes in New Zealand.

Eade, C. 38

From Disaster to Resilience: A Comparative Study of Legal Frameworks for Managing the Seismic Risk of Existing Buildings

This research compares the legal framework used to reduce the seismic risk of existing buildings in New Zealand, Italy, and Japan. These frameworks are examined through the Sendai Framework for Disaster Risk Reduction 2015-2030, which aims to reduce risk and improve resilience against hazards. The Sendai Framework, which each of the case study countries have committed to and thus have obligations under, forms the legal basis of the need for states to reduce disaster risk in their jurisdictions. In particular, the legal frameworks for the risk reduction of existing buildings are examined in the context of the Sendai priorities of understanding disaster risk, strengthening disaster risk governance, and investing in resilience. The comparative section of this research explores both operational features of legal frameworks and enforcement mechanisms used to impose risk reduction obligations. This includes the types of buildings targeted within legal frameworks, the role of seismic hazard zones and seismic building assessments for risk reduction, financial investment, timeframes for planning, and the intersection of seismic risk reduction with duties of care owed by building owners to protect public safety. While this research illustrates that the case study countries have each adopted more proactive risk reduction frameworks in recent years in anticipation of future earthquakes, the frameworks currently focus on a very narrow range of existing buildings and thus are not sufficient for promoting the long-term resilience of building stocks. In order to improve resilience, it is argued, legal frameworks need to broaden the opportunities for understanding seismic risk over time and to mandate clear expectations for periodic risk reduction practices instead of one-off obligations.

Eskandarighadi, M., McGann, C. 8

Parallel scalability of OpenSees on NeSI HPC for 2D/3D site response analysis

This study investigates the parallel scalability of the OpenSees finite element analysis platform in the context of 2D and 3D ground response analyses. A series of 2D and 3D models ranging from 7500 to 480000 elements are developed and analysed using National e-Science Infrastructure (NeSI) high-performance computing (HPC) resources. These models are analysed using two different approaches for running large models in parallel in OpenSees: OpenSeesSP, which performs the parallel domain decomposition as part of the analysis, and OpenSeesMP, which requires the domain decomposition in the input model file. It is demonstrated that the OpenSeesMP tool results in reduced analysis times and increased parallel efficiencies relative to OpenSeesSP for both simple 2D and 3D problems. Trends in the parallel scaling and efficiency are also analysed and recommendations are made for running parallel OpenSees analyses on NeSI HPC resources.

Fakhruddin, B., Huges, J., Russell, J., Robertson, R. 39

Assessing and improving resilience for the transport network

Recent events around the globe, including significant seismic events in developed countries such as New Zealand, Chile and Japan, have increased the awareness and importance of infrastructure resilience, and particularly transport networks. Resilience relates to the ability of a roading network to continue to provide an acceptable level of service and meet the community's social, economic and environmental needs, following a major hazard event. In New Zealand, the National Infrastructure Plan developed by the Treasury places "Resilience" as one of the six principles that underpin the plan, and has a vision that by 2030 New Zealand's infrastructure is resilient and coordinated and contributes to economic growth and increased quality of life. The concept of resilience is broadly applied throughout many different fields of study (e.g., engineering, psychology, sociology, and economics). Resilience can be defined as the transport system's ability to enable communities to withstand and absorb impacts of unplanned disruptive events, perform effectively during disruptions, and respond and recover functionality quickly (Waka Kotahi). Tonkin + Taylor has carried out several transport resilience studies in New Zealand and other countries (e.g. Cambodia, Thailand, Solomon Islands, Samoa). This poster will share good practice and lessons learned to enhance resilience in the transport sector.

Fakhruddin, B., Shankar, N. 72

Coastal Community Resilience Index- A Systemic Framework for Cascading and Compounding Risk

Climate change and natural disasters are considered as a wicked threat as it affects various groups of people, and destroys community's physical, social, economic, and environmental elements. Coastal community resilience refers to the ability of the communities alongside the coast to be able to deal with climate change and risks from natural hazards. Resilient communities are better able to prevent, prepare, respond, and recover from the event of a crisis. However, with the unpredictable nature of the hazards and complications involved in the socio-economic and technical systems of a community, analysing the disaster and climate risks, and creating resilience can be a challenging task. Besides, the impact varies from a community to community as each has its own livelihoods, identities, characteristics, and level of coping mechanisms. Currently, there are numerous frameworks, plans and works of literature with various benchmarks and indicators available across the globe to support nations and organisations in planning and implementing the measures for climate change and disaster risks and to enhance the resilience of coastal communities. However, most of them failed to cover all the key aspects comprehensively as governments tend to value various aspects of coastal community resilience differently. The lack of a standard could lead to an environment where no definite solutions can be applied across all communities to solve climate change and disaster issues. To achieve consistent risk reduction, a comprehensive guide or a standard that concentrates on key

"must haves" that are applicable across varying scales or community sizes is critical to represent resilience as a process-oriented and achievable.

Faulkner, H., Hopkins, J., Wilson, T. 40

Governing Disaster Recovery in Aotearoa New Zealand – An Auckland Volcanic Field Case Study

Building upon existing work in the field, this project will examine the resilience of New Zealand's legal and constitutional framework in the wake of an Auckland Volcanic Field event. It has become clear that the role of law and governance in disasters is increasingly recognised, but still poorly understood. This project is part of a movement to assess the legal and governance frameworks before a disaster, in order to increase risk mitigation and decrease the vulnerability of New Zealand, in relation to an Auckland Volcanic Field event. This movement has been reflected in the international sphere with the introduction of the Sendai framework.

This project will begin by identifying and mapping the existing legal and governance framework which exists in New Zealand's disaster law and would be applicable to an Auckland Volcanic Field event. The first step will be outlining the context of 'disaster law' and existing disaster law frameworks, with law being the rules which govern the function of society. This framework will include legislation, rules, codes, policy documents, international policy frameworks and other instruments. This framework will then be applied to several volcanic scenarios developed by DEVORA to assess the ability of the current framework to respond. DEVORA has created scenarios of potential future Auckland Volcanic Field events. Applying the identified legal and governance framework to several of these scenarios will allow us to assess the current framework. The focus will be on what the current frameworks would allow us to do, rather than focus simply on what it lacks.

Fauzi, U., Dai, C. 9

Seismic Hazard and Seismic Ground Response Analysis for Snowy 2.0 Project

A seismic hazard analysis (SHA) has been completed for the proposed Snowy Hydro 2.0 site area located in the Snowy Mountains of New South Wales, Australia. The SHA covers the Tantangara intake (148.6523°E longitude and 35.7926°S latitude), Talbingo intake (148.3776°E longitude and 35.768741°S latitude), the ~26km tunnel, upstream surge shaft, powerhouse and downstream surge shaft between the two intakes. The SHA was derived for Site Subsoil Class B, rock with UCS 1 to 50 MPa and Vs30 = 760 m/s. This is based principally on the 2018 National Seismic Hazard Assessment for Australia (NSHA18). The seismic source zones and earthquake activity parameters are based on the NSHA18 model. The site-specific seismic source models include background (large area source zones), regional (detailed area source), seismotectonic (models that include both fault and area sources), and smoothed seismicity models. This includes the nearby neotectonic faults in National Fault Source Model (NFSM) following ANCOLD Guidelines for Design of Dam and Appurtenant Structures for Earthquake (ANCOLD, 2019). The PSHA results of this study are for the Site Subsoil Class B (Rock) condition. However, Snowy 2.0 is not always underlain by Site Subsoil Class B conditions. Therefore, to estimate earthquake ground motions at the present-day ground surface, a soil amplification factor is needed to adjust the PGA from Subsoil Class B conditions to the actual site conditions. A Seismic ground response analysis (SGRA) has been completed for the proposed Powerhouse of Snowy 2.0 project. The SGRA comprised development of site-specific ground profile, development of input acceleration time histories, deconvolution, and conducting 1D total stress non-linear and equivalent linear SGRA to assess the PGA and Sa de-amplification factors.

Fenton, C. 10

Fault Rupture Hazard Zonation: Options for Best Practice in New Zealand

Clark Fenton, School of Earth & Environment, University of Canterbury

Engineered structures crossing active faults are vulnerable to damage during surface faulting earthquakes. New Zealand is a transpressional plate boundary where many of the active surface-rupturing fault zones display broad, complex zones of deformation (e.g., Darfield 2010; Kaikōura 2016). The design and location of mitigation measures to counteract fault rupture requires detailed knowledge of the location of the active fault traces, fault geometry, including the width of the fault zone at the surface, and the distribution of strain within the fault zone. The current understanding of fault geometry and displacement profiles is based on predominantly subsurface data through essentially isotropic ground conditions. Although empirical relationships among fault parameters, such as rupture length, earthquake magnitude and average or maximum displacement, can be used to characterise potential surface rupture hazard for an entire fault zone, the behaviour of a fault at a specific location, as is required for engineering design, can be harder to forecast. For hazard planning and front-end engineering design, rupture zonation is a useful approach (e.g., NZ Ministry for the Environment; California's Alquist-Priolo Zonation maps). To produce meaningful fault rupture zonation maps requires an integration of data on tectonic geomorphology, paleoseismology, and both crustal and near-surface fault geometry. Rather than define narrow prescriptive fault avoidance zones, potentially a better approach is to develop a broader zonation that highlight areas where there is the need for detailed fault rupture mitigation studies to be performed for all significant developments.

Filippova, O., Rehm, M., Grimes, A., Cheung, W., Yiu, E. 41

Pricing of earthquake risk: Evidence from Wellington's inner-city apartment rents and property values

Understanding risk aversion of individuals in the face of known natural hazards is important in emergency planning and hazard mitigation. We analyse the pricing of earthquake risk in Wellington's inner-city apartments. We investigate the differences in risk perceptions between property investors and tenants. More specifically we construct two datasets using housing transactions and housing rents to estimate the differences in seismic risk pricing between buyers and renters and examine their level of risk aversion.

Francis, T. 68

A value case for the base isolation of residential buildings in New Zealand

Base isolation is an effective technology for significantly reducing damage to buildings and building contents. However, its application to light-frame wood buildings has previously been unable to overcome cost and technical barriers such as the susceptibility of isolated, lightweight buildings to movement under high-wind loading. The 1994 Northridge Earthquake (6.7 MW) in the United States, 1995 Kobe Earthquake (6.9 MW) in Japan and 2011 Christchurch Earthquake (6.7 Mw) all highlighted significant loss to light-frame wood buildings with over half of earthquake recovery costs allocated to their repair and reconstruction. Therefore, urgent improvements to the seismic performance of New Zealand's residential building stock are justified. This poster presents a value case to highlight the benefits of a novel base isolation system for light-frame wood buildings which has been tested at the University of Canterbury. Performance is compared to the standard fixed-base dwellings used for residential construction. A model of both fixed and base-isolated building types is made in Timber3D, a state-of-the-art light-frame wood modelling software. Nonlinear time history analysis results of these buildings are then used to create vulnerability functions in the software PACT. Using these vulnerability functions, the expected annual loss is shown to dramatically reduce for isolated buildings compared to an equivalent fixed-base building, justifying the value case. Future research will look to

compare and validate the results of this study with vulnerability information obtained from Canterbury earthquake loss data.

Ghasemi, A., Stephens, M., Elwood, K. 26

Application of Unsupervised Machine Learning Clustering for City-Scale Seismic Response in the Wellington CBD

Following the Canterbury earthquakes, indicator buildings were used to inform building reinspection criteria in the period following the earthquakes. These buildings were selected to include representative building typologies in Christchurch (e.g. unreinforced masonry bearing wall, reinforced masonry shear wall, reinforced concrete shear wall), and were reinspected following aftershocks to determine if additional damage had occurred. Any additional damage to an indicator building that exceeded a predefined damage threshold triggered a reinspection of other nearby buildings within that typology. Due to the success of the indicator building approach following the Canterbury earthquakes, this research aims to extend the concept to Wellington. In this application, the indicator buildings will be selected during peacetime (prior to any moderate or large earthquake) to help inform the performance of the building stock following both the earthquake and subsequent aftershocks. Selecting the indicator buildings ahead of time has several advantages in that these buildings can be targeted for instrumentation and high-fidelity model development to provide a near-real time indication of the seismic performance, and their damage states following strong shaking can be used to help inform inspection priorities. Ongoing work conducted through QuakeCoRE and the Resilience to Nature's Challenges (RNC) programme has used the Wellington Building Database (which consists primarily of concrete buildings with 4+ stories in the Wellington CBD) to cluster buildings in the Wellington CBD into typologies based on structural and site characteristics. For this purpose, the notion of Unsupervised Machine Learning clustering has been utilised to cluster the buildings in the Wellington Building Database and also select the indicator buildings based on numerical methods as well as the verification of senior structural engineers in Wellington.

Gonzalez, R., Stephens, M., Toma, C., Elwood, K., Dowdell, D. 61

Quantifying the carbon cost for resilient building designs in New Zealand

Structural engineers around the world have historically designed buildings for collapse prevention during and following earthquakes. Recently, major earthquakes have shown that the philosophy of designing buildings for life safety protection results in structural and non-structural damage having wide-ranging social, economic, and environmental impacts. This research is focused on evaluating the lifecycle environmental impacts of buildings subjected to earthquakes. In the first phase of this research, the environmental impact of demolishing buildings from the 2010/2011 Canterbury Sequence has been estimated to provide evidence of the necessity of incorporating seismic damage into the traditional life cycle assessment. The remaining phases of research will provide policy makers and stakeholders with evidence-based environmental incentives for designing structures in New Zealand for higher seismic performance. This will be accomplished through life cycle assessment and seismic response history analysis using a number of case-study buildings. Those buildings will be redesigned considering two approaches: (1) A higher seismic performance above building seismic code (2) Using Low Damage methodologies. Next, environmental impact assessments of the different designs will be performed. The results of this project will be used to quantify the environmental incentives for enhancing the seismic performance of buildings within the New Zealand building stock.

Haymes, K., Sullivan, T., Chandramohan, R. 27

Seismic design of non-structural components by explicitly considering nonlinear structural and non-structural responses

This study develops a practice-oriented method to design the strength of non-structural components and their restraints to resist earthquake ground motions of any intensity by explicitly considering their nonlinear response and that of the supporting primary structure. Traditional methods to design non-structural components using elastic floor acceleration response spectra were generally observed to be simplistic and inaccurate. Hence, this paper proposes a framework to design non-structural components to predicted inelastic floor response spectra instead.

The proposed approach builds upon a method recently developed by the authors to predict elastic floor response spectra using structural modal characteristics. Provisions for predicting the nonlinear response of non-structural components are developed and verified using floor motion records from instrumented buildings in New Zealand. Provisions for predicting the nonlinear behaviour of the primary structure are based on numerical simulations of their nonlinear dynamic response. The proposed approach is shown to be more accurate than current international non-structural design practices without compromising on simplicity, to facilitate adoption in practical design applications.

The broader motivation for developing this framework is to encourage the adoption of a more rational non-structural design philosophy, and thereby help limit seismic losses, which were shown in recent New Zealand earthquakes to be governed by damage to non-structural components. The findings also highlight the potential benefit of providing non-structural components with the ability to deform in the nonlinear range, either via inelastic behaviour or the provision of low-damage friction or rocking mechanisms.

Horsfall, S., Hatton, T., Collins, T., Brown, C., Brunsdon, D. 42

Earthquake Risk Reduction Behaviours in Organisations: Understanding what organisations are doing to stay safe in New Zealand's seismically active environment.

Creating a resilient New Zealand requires effort from all of society. Organisations, in particular, have the potential to be a catalyst in building a resilient nation. Organisations that effectively manage natural hazard risk provide safety for their employees, minimise economic losses through downtime, and are able to support community recovery by providing key services, employment, and economic stimulus.

Organisations have a number of regulatory obligations to protect their employees and other stakeholders, such as those in the Health and Safety at Work Act 2015 (HSWA). The HSWA has a core purpose to "protect workers and other persons against harm to their health, safety, and welfare by eliminating or minimising risks arising from work…." . On the surface, the legislation is well placed to promote seismic risk reduction activities, however we currently have little understanding of how organisations interpret and act on obligations within the HSWA to reduce seismic risk. Similarly, it is unclear how the HSWA would be enforced in relation to seismic hazards.

In our 2020 EQC-funded project, we found that organisations were driven to undertake earthquake risk reduction by both the HSWA and their concerns on how an earthquake might endanger their staff and customers. However, there is a gap between organisations wanting to do the right things and the actual implementation of earthquake risk reduction activities. Organisations struggle to access relevant information on what and how they should be reducing earthquake risks. These challenges combined with a lack of time and money to implement these activities (especially in small and medium sized enterprises) were found to be the greatest barriers to organisations becoming more earthquake resilient.

Horspool, N., Vinnell, L., Hogan, L., Johnston, D. 51

Meet Eddie – QuakeCoRE's new earthquake test dummy

Crash test dummies or Anthromorphic Test Devices (ATD) have long been used in the automobile sector to determine the risk of injury and death from vehicle accidents. ATD's can be used to estimate the human kinematics and injury potential for different impact forces. In QuakeCoRE2 under DT4 (Human Behaviour and Injury Project) we will be creating an ATD and using it for experiments at the University of Auckland Structural Engineering Lab to estimate the injury risk from being hit by objects in earthquakes. Our dummy, named Eddie, will be fitted with force pads and accelerometers, and used in experiments to estimate the injury potential of being hit by objects such as typical content items (e.g. furniture) and non-structural elements (e.g. ceiling tiles) in an earthquake. The results from these experiments will help reduce injury risk in earthquakes by identify improvements in seismic design of non-structural elements and demonstrate the risk of injury from different protective or non-protective actions of individuals. We are keen to hear from the QuakeCoRE community on ideas to include in our experimental plan or other uses for Eddie!

Johnston, D., Tan, M., Tapuke, K., Kaiser, L., Prasanna, R., Becker, J., Campbell, E., Mestel, E., Illsley-Kemp, F., Smith, B., Leonard, G., Alger, B., Thomas, K-L., Stewart, J. 52

Improving earthquake resilience in the Taupō Volcanic Zone (TVZ) using school-based seismometers and connected education programmes

Over the past decade "seismometers in schools" programmes have been developed in Aotearoa New Zealand and overseas, by a range of organisations, for a variety of reasons and aiming to achieve a range of educational outcomes. With the enhancement of digital seismic networks, the decreasing cost of sensors, cheaper and faster internet, and the increasing interest in "citizen science" a range of opportunities exist to further expand participation of schools and other institutions in this space. This poster explores the recent development of a "seismometers in schools" programmes in the Taupō Volcanic Zone (TVZ), as part of the QuakeCoRE/ECLIPSE project.

Lee, R., Bradley, B., Paterson, J., Motha, J. 11

Preliminary ground-motion simulation validation of moderate magnitude active shallow crustal earthquakes in New Zealand

Hybrid broadband ground motion simulation validation has been an ongoing effort in NZ with recent studies focused on active shallow crustal earthquakes of large magnitude ($M_w>7.0$) and small magnitude ($3.5<M_w\leq5.0$). Naturally the next step is to consider moderate Mw earthquakes ($5.0<M_w\leq7.0$) which bridge the gap between previous studies. Relative to small Mw earthquakes, moderate Mw earthquakes introduce additional complexities in the simulations that are important in the prediction of ground motions, due to their finite rupture size, which may have been previously obscured by the simplistic source modelling of small Mw earthquakes. Recent analyses have examined the influence of fault dimension assumptions, kinematic slip generator, and choice of centroid moment tensor nodal plane on the simulated ground motions. This study builds on the previous analyses by performing the hybrid broadband simulations with a transition frequency of 1 Hz between comprehensive and simplified physics components (higher than previous analyses), as well as including consideration of multiple slip distribution realisations. The dataset considered comprises 2042 ground motion records from 75 earthquakes recorded across 220 stations in New Zealand. The earthquake fault ruptures are kinematically modelled as single-plane finite faults given there are no detailed source inversion studies for these events (with few exceptions). Comparisons with observed records through ground motion intensity measures quantify the predictive capability of the simulations and examination of residuals highlight source, path and site biases which are present in the prediction.

Lew, S., Wotherspoon, L., Hogan, L., Al-Ani, M., Stephens, M., Chigullapally, P. 73

Assessment of Key Factors Controlling Modal Properties of An Instrumented Bridge After Multiple Earthquakes

The performance of a highway bridge in New Zealand during a series of large earthquakes and the change in dynamic characteristics due to structural and foundation related damage are presented. Superstructure damage was evident following multiple large earthquakes in 2013 and 2016, including spalling and cracking at the top and bottom of multiple piers. System identification based on data from accelerometers installed after each earthquake showed that there was a permanent increase in the fundamental transverse mode period following the second earthquake. Response during a range of smaller aftershock events showed that fundamental transverse period was heavily dependent on excitation level. Repair of damaged piers after the 2016 event had slightly reduced the bridge period. A numerical model of the bridge was able to capture the key modal response characteristics, with sensitivity analysis showing that soil stiffness and the reduced cross-sectional characteristics at the pier damage locations had a significant influence on mode shape and period. Irregularity of scour depth along the length of the bridge was also a key aspect controlling the transverse mode shape and fundamental period, highlighting a design case that could be incorporated into design and assessment.

Lin, A., Wotherspoon, L., Zorn, C., Bradley, B., Motha, J. 74

Liquefaction and landslide hazards across New Zealand State Highways

New Zealand State Highways are exposed to a range of natural hazards including earthquake triggered liquefaction and landslides. Using statistical models, the research aims to estimate the liquefaction and landslide probability across the State Highway network for 500 potential earthquakes. Hazard exposure for each network section is measured by counting the number of seismic events that are expected to cause liquefaction or landslides. Further research needs to consider the criticality of the State Highway sections in order to assess the overall impact. The findings can support decision making processes for emergency preparation and response planning.

Liu, A., Carradine, D. 69

Seismic Behaviour of Hybrid Residential Building

In New Zealand, most residential buildings are low-rise light timber-framed (LTF) buildings where both the gravity and lateral seismic load-resisting systems are LTF sheathed walls. In the Canterbury earthquake sequence, LTF residential houses all achieved the New Zealand Building Code (NZBC) objective of "safeguarding people from injury caused by structural failure". However a house damage survey undertaken by BRANZ after the Canterbury Earthquake revealed that hybrid bracing systems in residential houses, namely the mixed use of typical sheathed LTF wall bracing systems with other specifically designed bracing systems, significantly exacerbated the seismic damage to the LTF residential houses.

As the demand for higher density housing grows, more and more multi-unit and multi-storey medium density houses (MDH) of mainly LTF construction are being built, and these buildings often have hybrid bracing systems consisting of LTF sheathed walls and other seismic bracing systems. As LTF buildings with hybrid bracing systems get bigger and taller, potential seismic issues will certainly increase. Currently, there is not an engineering basis, which could be used for seismic designs of hybrid residential buildings.

The objective of the BRANZ project "Seismic behaviour of Hybrid Residential Buildings" is to develop a technical guideline to help inform the seismic design of LTF hybrid residential buildings. This presentation outlines the suggested scope, the proposed research method, and the contemplated design methods to be developed at the completion of the project.

Loghman, V., Bradley, B., Chandramohan, R., Lee, R., McGann, C. 12

Validation of NZ ground motions simulations using complex structural systems

This study assesses the need to consider complex structural models in ground-motion simulation validation. It develops a novel statistical framework to quantify the proportion of the differences in structural responses under simulated and observed ground motions that can be explained by corresponding differences in simple ground motion intensity measures.

Two steel special moment frames are analysed under simulated and observed ground motions from 567 events across New Zealand. The seismic responses of the structures are quantified using peak inter-storey drift ratio and peak floor acceleration. Application of the statistical framework to the analysis results identifies the simple intensity measures whose difference is responsible for the difference in the structural responses. It also quantifies the proportion of differences that can and cannot be explained by the differences in simple intensity measures. The proportion that cannot be explained by simple intensity measures is quantified and classified based on the type of complexity such as nonlinearity and phasing effect. The results show that 10 to 15 percent of the unexplained portion is due to the phasing effect. The proportion of the unexplained part that corresponds to nonlinearity varies depending on the level of nonlinearity a structure may experience. The estimation is up to 15% in the case of highly nonlinear responses.

Loporcaro, G., Patel, M., Phillips, T. 62

Augmented Reality as an Aid Tool for Building Inspection and Repair

The construction industry is one of the largest industries in New Zealand and contributes significantly to the economy. However, the construction industry compared to other industries has shown no significant increase in productivity over the same timeframe. A lack of innovation and technological developments within the industry is a reason for this. A potential technological innovation for the construction industry is Augmented Reality (AR). This research investigates the feasibility of AR as a digital tool for building inspection and repair. Two Microsoft HoloLens based software named Trimble Connect and Microsoft Dynamics Guides 365 were investigated. These were investigated through a case study where instructional holographic guides were produced using each software. These guides provided a user with instructions to inspect and repair the shear wall system in the Trimble building in Christchurch. The investigation outlined the advantages and disadvantages of each software. But a consensus was made that each software was not feasible in their current state to be used by the construction industry as an aid tool for building repair and inspection tasks. Recommendations for improved software have been given. These recommendations encapsulate the best features from Microsoft Dynamics Guides 365 and Trimble Connect along with other recommended features. Future research would involve the development of software with these recommendations and an end-user test of the developed software should be conducted to check its feasibility.

MacRae, G., Jia, L-J., Clifton, C., Dhakal, R., Xiang, P., Rodgers, G. 28

Three-story Friction Building Performance – The Robust Test Overview

This paper describes the shaking table testing of a full-scale three storey resilient building. The building has a steel frame and cold formed streel-concrete composite deck. Energy is dissipated by means of friction connections. These are arranged in a number of structural configurations. Typical building non-structural elements are also included. Testing is conducted on the Jiading Campus shaking table at Tongji University, Shanghai, China. This RObust BUilding SysTem (ROBUST) project is a collaborative China-New Zealand project sponsored by the International Joint Research Laboratory of Earthquake Engineering (ILEE), Tongji University, and a number of agencies and universities within New Zealand.

Friction devices used include the asymmetric friction connection (AFC), symmetric friction connection (SFC), and the resilient friction connection (RSFJ). These are placed at beam ends, column bases, in braces, and in the tension-only "GripNGrab" device. Structural configurations include, moment frames, braced frames, rocking frames, and rocking columns. The non-structural elements include different configurations of ceiling, glass curtain wall, internal partition walls (with access holes), precast concrete cladding, and contents. These are subject to unidirectional and bidirectional horizontal shaking.

This paper describes the testing of this full scale multistorey resilient and reparable full scale steel structural building system representative of a realistic New Zealand building (i.e. with a representative floor diaphragm, friction connections and the full range of non-structural elements) subject to 2-D horizontal shaking. Progress over the past year is described.

Miranda, C., Toma, C., Becker, J., Elwood, K., Johnston, D. 70

Building Typology of Wooden Houses

Using distinct typology classes to categorize buildings has become an essential tool for earthquake loss estimation studies. Classifying buildings allows a more manageable and efficient study by considering the definition of common terminologies to sort and group the variations in structure characteristics and construction practices. Wellington's geographic landscape at the head of Te Ika a Maui is dominated by steep slopes, which when combined with the high seismicity due to its proximity with the alpine fault, makes it a unique challenge for the performance of residential housing. The objective of this study is to provide a typology in order to inform the structural modelling based on characteristics that have been identified as influencing the seismic response i.e., torsion, wall length, positioning, and concentration of openings.

Motha, J., Bradley, B., Paterson, J., Lee, R., Thompson, E., Tarbali, K., Bae, S., Schill, C., Polak, V., Lagrava, D. 13

Cybershake NZ v21.6: New Zealand simulation-based probabilistic seismic hazard analysis

This poster presents the computational components and results of the June 2021 version (v21.6) of probabilistic seismic hazard analysis (PSHA) in New Zealand based on physics-based ground motion simulations ('Cybershake NZ'). A total of 11,875 finite fault simulations were undertaken and seismic hazard results are computed on a spatially-variable grid of 25,948 stations with distributed seismicity sources considered via conventional empirical ground motion models. In this latest version, a NZ-specific modification of the Graves and Pitarka (2010,2015) hybrid broadband ground motion simulation approach was utilized based on improvements identified from extensive validation efforts (including the inclusion of moderate magnitude in our validation dataset). Specific simulation features include a transition frequency of 1 Hz (previously 0.5Hz), a detailed crustal model (NZVM v2.06) that represents 22 distinct sedimentary basins in NZ using a grid spacing of 0.1 – 0.2 km, and an empirically-calibrated local site response model. A Monte Carlo scheme is used to sample variability in the seismic source parametrization (i.e. varying the hypocentre location, slip distribution and magnitude for each realization) with the total number of ruptures for each source being a function of the source magnitude. The generated non-uniform hazard maps across the country are presented. Comparisons with previous versions also highlight the advancements that have been made. Immediate near-term plans associated with new features associated with crustal velocity modelling, simulation methodology, and treatment of modelling uncertainty are also discussed.

Mou, J. 29

Modelling uncertainty induced by plastic hinge length in lumped-plasticity analysis of RC structures

An estimation of plastic hinge length is required to establish moment-rotation envelope used in lumped plasticity model in structural analysis of RC structures. Different expressions for estimation of plastic hinge length have been proposed by different researchers and used in different standards/guidelines. The values of plastic hinge length obtained from these expressions vary over a wide range. However, there are limited studies quantifying the effect of using different plastic hinge length on the characteristics of the lumped plasticity element and the resulting member/structure behaviour.

This research focuses on quantifying the modelling uncertainty in RC member response arising from the variation in plastic hinge length being used. For this purpose, simple RC structures with typical member sections are modelled using lumped-plasticity approach in Opensees. Different methods of estimating plastic hinge length used in different guidelines and published literature are used in conjunction with section analysis of the members to generate the inelastic moment-rotation relationship of the lumped-plasticity spring elements. Propagation of the variation in plastic hinge length on the lumped plasticity characteristics and member/structure behaviour (including the

pushover response) will be investigated through nonlinear static and dynamic analysis. Based on the results, the contribution of plastic hinge length on the modelling uncertainty in the predicted nonlinear response of RC structures will be quantified. Statistical measures (mean/median value and standard deviation/dispersion) of the plastic hinge length will also be presented to help designers to know in advance whether their chosen plastic hinge length estimation approach is likely to over or under estimate the structure's strength and ductility.

Mowll, R. 76

Infrastructure planning minimum levels of service for the Wellington Region

There are known vulnerabilities in the various lifeline utilities networks in the Wellington Region. These are across the energy, telecommunications, transport (and therefore also food delivery) and water sectors. The vulnerabilities have been documented by the Wellington Lifelines Group (WeLG) (2012), and in subsequent WeLG documents. While these documents outline anticipated outages, these should be also be considered alongside any emergency plans that either the lifeline utilities or CDEM has to mitigate against outages. If community needs of delivery of utility services requirements (or infrastructure planning minimum levels of service) can be defined, the gap between requirements and delivery of services by the lifeline utilities can then be defined at suburb level. The identification of any gaps will then aid the lifeline utilities and CDEM to refine emergency and mitigation planning for the affected suburbs. Similarly, this information would be useful to the communities themselves, setting expectations of delivery and allowing detailed local planning to take place. Essentially, can a framework be developed that defines planning minimum levels of service across utilities for following an emergency event? Can this framework then be used to define the gaps of delivery of services?

Mueller, S., Orchiston, C., Bond, S. 53

Exploring Rural Communities' Resilience to Natural Hazards in New Zealand

Resilience of rural communities to natural hazards is a vital research focus in New Zealand, highlighted by the recent 2016 Kaikōura earthquake and West Coast flooding of 2019 and 2021. Hazard events are often followed by a sequence of secondary or cascading hazards, such as landslides following earthquakes, and the medium to long-term consequences of secondary hazards can be just as devastating as the immediate impacts.

My research focusses on community resilience to natural hazards in rural places, including a consideration of the secondary hazards that can continue to affect communities well after the triggering event, into the disaster recovery and reconstruction phases. To explore community resilience in depth, I held three participatory workshops with community leaders in Hokitika and Westland District. Using participatory methods, we explored existing community resilience and worked through a disaster simulation scenario based on an existing scenario of a major earthquake on the Alpine Fault. We considered potential hazards and landscape changes, likely impacts, and possible resilience actions in the decade following a major Alpine Fault earthquake. Maps were co-created within the workshop setting, and the outputs were digitized using GIS. Ultimately, we discussed realistic actions and strategies for building community resilience in Hokitika and across Westland District. I present my methods and preliminary findings from these participatory workshops in Hokitika and contextualize these findings within conversations about preparedness, planning, and resilience among New Zealand's researchers and practitioners. This research aims to provide proactive solutions for rural communities to help them become more resilient to future disasters.

Muñoz, G., Henry, R., Elwood, K. 30

Residual capacity of earthquake damaged reinforced concrete walls

After the 2010-2011 Canterbury earthquakes, 60% of the multi storeys Reinforced Concrete (RC) buildings were demolished. Many of these buildings used RC walls as the primary resistant system against the earthquake demands. Despite the agreement between structural engineers and researchers in a successfully seismic performance, there was a lack of knowledge about the behaviour of the damaged structures. The residual capacity of RC buildings is hard to address and is part of the high demolition rate after the Canterbury earthquakes. In the same direction, the effectiveness of different repair techniques is still not properly identified.

This study will identify the residual capacity of ductile slender RC walls according to current standards in New Zealand, NZS 3101.1 2006 A3. First, a database of repaired RC walls was created to gather previous studies and evaluate them with existing international guidelines. Then, an archetype building was designed, and the wall was extracted and scaled. Four half-scale walls were designed, constructed and tested at the Structures Testing Laboratory at The University of Auckland. The overall dimensions are 4 [m] height, 2 [m] length and 0.175 [m] thick. All four walls will be identical, with differences in the loading protocol and the presence or absence of simple repair techniques. Results will be useful to assess the residual capacity of a damaged wall compared to the original behaviour. Also, the effectiveness of epoxy injection as a simple repair technique will be studied. The results will contribute to the development of guidelines to assess earthquake damaged RC buildings.

Nwadike, A., Aigwi, E., Wilkinson, S. 43

Impacts of Covid-19 pandemic in building consents and construction industry activities in New Zealand

The novel coronavirus (SARS-CoV-2), known as Covid-19, is a world pandemic that has changed the trajectory of economic and construction industry perspectives globally. The construction industry significantly contributes to the economy, and any construction work starts by obtaining building consent. This study explored the impacts of Covid-19 in building consent and how it affects the New Zealand construction industry. Document analysis was used to explore the impacts of Covid-19 in building consent activities, while integrative literature reviews were used to examine the activities of the construction industry in New Zealand. Although the Covid-19 pandemic affected the construction industry activities and initiated stop-work orders through different lockdown stages and less cash inflow, there was an unexpected outcome in New Zealand building consent. The study findings showed that building consents increased significantly across New Zealand, which may result from changes in the building consent regulations as part of the building system reform program. Also, the finding shows that the new rules eliminate obtaining building consent for low-risk building works, which makes housing construction much easier, less time-consuming, and cheaper to start construction work with less compliance cost. Based on the study findings, it is expected that these changes will increase productivity and supports the construction industry's Covid-19 recovery plans by the government. The study concludes that adequate measures should be applied to ensure that construction works under the exemption category are closely monitored based on the New Zealand building standard.

Pascua, C., Henry, R., Clifton, C., Toma, C. 31

Design and testing of concrete wall-steel beam bolted connections

Mixed-material buildings consisting of concrete walls and steel frames have recently become popular in New Zealand. However, current design standards are compartmentalised according to material, and therefore design procedures for concrete wall to steel beam connections are not explicitly indicated. In a previous study, it was found that bolted or pinned connections were most common among Auckland and Christchurch buildings. However, these pinned connections can still generate bending moments. In this study, four concrete wall-steel beam connection specimens will be tested to quantify their rotation capacities. The influence of the floor starters, slotted holes in the bolted connection, and use of deformed bar anchors for improved anchorage will be investigated. Outputs will be used to develop a design procedure for concrete wall-steel beam connections.

Paterson, J., Bradley, B., Lee, R., Motha, J. 14

Effect of Hikurangi subduction interface geometry on simulated ground motion intensities

The Hikurangi subduction fault runs under the eastern side of the North Island and has a large down dip curvature (Williams et al. 2013). The six current Hikurangi fault rupture scenarios provided by the National Seismic Hazard Model (NSHM) all provide for a planar fault geometry that is adopted in predictions using both empirical ground motion models (GMMs) and also prior simulations performed by the authors.

In this poster we examine the effect of more realistically representing the curved geometry in the source description, and its influence on simulated ground motions. The mathematical approach by which a 2D planar geometry is mapped onto a curvilinear surface is described, followed by a comparison of the results obtained through ground motion simulations.

Prasanna, R., Nandana, R., Punchihewa, A., Holder, C., Becker, J., Jeong, S., Chandrakumar, C., Sampath, R., Liyanage, N., Syed, Y. 77

A Distributed Community-Engaged Low-cost Sensor Network for Earthquake Early Warning

This poster presents ongoing research that explores emerging sensor technologies and digital communication for earthquake early warning (EEW). Currently, New Zealand does not have access to early warnings for earthquakes for communities or the public at large. A recent survey revealed that more than 90% of the New Zealand public support having an EEW. By taking a Design Science driven multidisciplinary socio-technical approach this research aims to investigate the feasibility and efficacy of low-cost earthquake sensor networks to generate alerts to warn the public about earthquakes. In the initial phase of this research project, a distributed low-cost sensor network has been deployed and software has been developed to process data within each sensor connected in a distributed mesh network topology. Sensors can communicate peer-to-peer to improve the reliability of earthquake detection. Moreover, a software interface is developed on an online platform to visualise the sensor data and alerts. Further research will be carried out to find the efficacy of the proposed framework of low-cost EEW alerts and mechanisms of communication that has been deployed with the engagement and collaboration of communities.

Rangwani, K., MacRae, G., Rodgers, G. 63

Rocking Frame Behaviour with Tension only Device

The implementation of a friction tension-only "GripNGrab" device attached to a rocking steel frame is described. The device, when subject to significant tension dissipates energy via sliding in the frictional component. When the device is loaded in the compression direction, almost no compressive force is carried, but displacement occurs in the ratchetting component. This means that the rocking frame will always recentre after earthquake shaking. The device is implemented in a full scale 9m tall 4.75m wide 3-storey 2D rocking frame designed for a high seismic zone. The GripNGrab (GNG) device hysteresis loop developed considers the effect of free travel in the ratchet device due to the ratchet tooth pitch. Modelling of the rocking frame, pushover, and inelastic dynamic time history (TH) analysis was implemented in OpenSees software. Parameters varied in the study include the GripNGrab characteristics (stiffness, strength, and tooth pitch), slab/beam uplift, and structural period.

It was found that the effect of the slab significantly reduced the displacements of the short period frame considered, especially at high levels of shaking. Also, the response became less sensitive to GNG strength and stiffness when the slab was considered. However, for GNG tooth pitch sizes of 1mm and 10mm, at DLS level, for the structure with a slab, the roof and uplift displacements increased from 28mm (0.3% drift) to 73mm (0.8% drift) and 9mm (0.19% base rotation) to 28mm (0.59% base rotation) respectively. For the case studied, the increase in base shear was almost 3 times higher than that obtained from equivalent static method and permanent displacements resulted due to slab yielding.

Ridden, J., Lee, W., Tuckey, T., Douglas, C., Lee, R., Stolte, A., Motha, J., Bradley, B. 15

Inclusion of additional sedimentary basins in the New Zealand 3D Velocity Model

Earthquake ground motions are strongly influenced by the regional geology through which seismic waves propagate. Sedimentary basins have been observed, and fundamentally understood, to amplify ground motions which can cause significant damage to the built and natural environment. This poster presents recent efforts driven by Undergraduate Studies in Earthquake Resilience (USER) students within QuakeCoRE to rapidly develop sedimentary basin models using simplified methods. These methods utilize regional datasets such as surficial geology maps, including interpreted cross sections, and topography from digital elevation models. Over the past two years, basins have been added in the Central Otago, Southern Canterbury, Northern West Coast, Tasman, Greater Wellington, Hawke's Bay, and Gisborne regions. These basins have been included in the latest version of the New Zealand Velocity Model (NZVM 2.07) for use in physics-based ground motion simulations.

Rincon, J., Pujol, S., Dhakal, R. 32

Active Confinement of Reinforced Concrete Columns

The majority of older buildings in most of the world do not meet the current seismic design standards. This is especially so in earthquake-prone regions, as, even there, seismic design of structures is relatively recent. With a large number of buildings in need of strengthening, many alternatives to retrofit of reinforced concrete (RC) columns have been studied. Popular retrofit techniques such as steel jacketing and fibre-reinforced-polymer (FRP) have been proven to be effective in increasing shear strength and improving deformability of RC columns. Nevertheless, those techniques have been also reported as labour-intensive with involved installation procedures. A new retrofit technique consisting of post-tensioned external clamps fastened around the column is proposed. The proposed technique is easy to design and implement and does not require specialised workmanship. In addition, the lateral pressure provided by the external clamps can restore the seismic performance of older RC buildings.

Rodgers, G., Vishnu, P., Henry, R., Lu, Y. 64

Initial low-cycle fatigue testing of energy dissipating steel fuses.

The assessment of damage and residual capacity following an earthquake is crucial to low-damage structural designs and the development of reliable repair strategies to expedite recovery and limit repair costs. The biggest factor delaying recovery and incurring additional costs is uncertainty in repair strategies and in the performance of repaired buildings. The issue has been most prevalent in low-cycle fatigue of reinforcing steel. Grade 300E reinforcing steel can undergo large inelastic deformations, either when used to reinforce concrete buildings, or within sacrificial energy-dissipating fuses. While this energy dissipation method is cost-effective and improves structural response, uncertainty in the residual capacity creates a huge challenge for engineers. There is a scarcity of research and guidance on this topic to provide a solid evidence-base upon which low-damage design decisions, as well as repair and re-occupancy decisions, can be based.

This paper presents an initial low-cycle fatigue assessment of sacrificial steel fuses made from Grade 300E reinforcing steels. It provides an initial indication of how to quantify low-cycle fatigue performance. Displacement-controlled low-cycle fatigue testing is undertaken at a range of design strain targets, from 1% through to 5%, using both unipolar and bipolar (fully-reversed) cyclic testing. Results are presented in terms of both overall amplitude ratio (comparing input loading amplitude to the active length of the fuses) and in terms of inelastic deformation ratios, where the elastic elongation of the fuses is subtracted off the input loading.

Royal, K., Sullivan, T., Fa'aui, T. 57

Revisiting seismic engineering performance objectives for indigenous communities

Recent earthquakes in Aotearoa New Zealand have prompted the community to reconsider what should be the performance requirements for buildings and other infrastructure in earthquakes. The traditional focus on life-safety under a specific intensity of ground shaking is no longer considered sufficient, not only because this approach does not limit the cost and disruption caused by an earthquake but also because earthquakes don't generate a single intensity of ground shaking. The engineering community is now considering new design criteria aimed at reducing likely repair costs (Sullivan, 2020) and lost functionality (EERI, 2019) of a building. However, it is also appreciated that different stakeholders and mana whenua, will have different values, interests and needs. To this extent, this project proposes the re-examination of seismic engineering performance objectives for indigenous communities. Via community engagement and collaboration with Māori, the research is looking to co-create performance objectives for different building types and identify improved means of briefing engineers and other design professionals to achieve these specific performance objectives recognising the wider perspective of performance and resilience within an earthquake environment. The research proposes to utilise a series of case-study examples to aid the discussion process. This poster reports on relevant prior research, the proposed research methodology and considerations emerging from initial meetings.

Sadashiva. V., Wang, X., Lin, S., Lukovic, B., Heron, D., Suppasri, A. 16

Demonstrating the effects of explicit inclusion of buildings in tsunami inundation modelling

Tsunami hazard Intensity Measures (IMs) such as flow depth are commonly estimated through tsunami inundation modelling using an Equivalent Surface Roughness (ESR) method. In this approach, ground surface features (e.g. buildings, vegetation) are removed for inundation modelling. Instead, to account for the retarding effects provided by such features to the incoming tsunami waves, spatially averaged equivalent surface roughness values are applied in tsunami simulations. While this 'roughness approach' can be computationally efficient for large scale simulations, it can result in less accurate tsunami flow patterns, especially in populated areas, and subsequently (via fragility model) affect the reliability of risk impact results (e.g. loss estimates). An alternate to ESR is Explicitly Represented Building (ERB) approach. As the name suggests, the buildings exposed to tsunami flows are represented in the inundation modelling as solid blocks with zero permeability, constructed with building footprints and heights on top of the bare ground DEM data. ERB approximation is seen to better capture the tsunami flow patterns, and hence provide more realistic hazard estimates. To demonstrate the effects of explicit inclusion of buildings in inundation modelling, comparative tsunami simulations are performed, and loss modelling results for a pilot study area are presented in this poster.

Sampath, R., Prasanna, R., Hudson-Doyle, E., Punchihewa, A. 78

Accelerated decision making on earthquake early warning from community hosted intelligent Internet of Things (IoT) devices

Seismic shaking waves can reach a point on earth far from the earthquake epicentre within seconds. Therefore, identifying and alerting earthquake hazards earlier may help to save lives or even reduce the probability of such incidents for many. However, the lack of reliable detection systems without autonomy hinder such decision making and cause significant delays in alert generation. Moreover, such resource-intensive systems are equipped with high-cost devices and costly communication infrastructure. The rapid advancement of hardware and software technologies such as virtualization for efficient and high computing resource deployments, connectivity mechanisms and Artificial Intelligence (AI) could pave the way for making cost-effective intelligent devices with high detection accuracy and accelerated communication.

This poster presentation aims to communicate our early work of differentiating and identifying earthquakes in real-time using IoT sensor devices with intelligence embedded in them to drive AI. The established community hosted Micro-Electro-Mechanical System (MEMS) based low-cost sensor network set up by the CRISiSLab (Crisis Response and Integrated Simulation Laboratory) at Massey University collects data in the New Zealand context. The existing large amount of earthquake data from different sources with AI-based data augmentation furthers the data requirements to train and test the AI models. The combined hardware and software setup with an AI model is undergoing a rigorous test procedure using the shake table hardware-based testing facility at Massey's CRISiSLab. Purposed and tested in the New Zealand environment context, developed AI models can be used to differentiate earthquake signals from natural or anthropological events in the community. With these advancements, the project proposes a candidate voting system of such intelligent devices to decide the trigger of an earthquake. Mesh network layout and a dense arrangement of the aforementioned intelligent sensor devices will help to detect earthquakes swiftly and alert the warning system that earthquake waves are in propagation, with a further potential to identify characteristics such as acceleration.

Sarwary, S. 44

Institutional structures and community resilience: can legislative and governance arrangements facilitate community influence on disaster resilience and recovery decision making?

The impact of natural hazards around the world on lives, livelihood and environment has been devastating. In order to respond to this ever-growing threat, governments - including New Zealand - have increasingly decentralised operational responsibility for Disaster Risk Management (DRM) and community resilience to regional, local and community levels in the last two decades. This global trend has been supported by scientific evidence that community involvement in DRM can enhance community capacities to withstand, cope, recover and adapt to impacts of disasters. Evidence also shows that the capacity of communities to directly influence DRM decision-making at higher levels, including central government, is seen as a key element in enhancing community resilience against disaster risks and impact.

However, the global trend to decentralise operational responsibility for DRM is not just normatively driven. It is also driven by political drivers where governments choose to transfer risk and responsibility in relation to DRM to local government and community levels in the absence of the required financial resources and a share of the decision-making authority to communities. In New Zealand, for instance, it is well established that local risk is a local responsibility. The question is - to what extent do the legislative and governance arrangements that transfer risk and responsibility to local governments and communities should also provide the access to decision-making and resources that communities require to build their resilience?

Case studies from Greater Christchurch will be used to investigate the extent to which legislative and governance arrangements at the time of Canterbury Earthquake Sequence (CES), and those in place now, enabled/inhibited or continue to enable/inhibit community capacity to influence DRM decision-making and access resources after CES.

Scheele, F., Lukovic, B., Moratalla, J., Dunant, A., Horspool, N. 65

Estimating fire following earthquake risk for Wellington City

Fires are a common secondary hazard following earthquakes and, on rare occasions, can develop into major events with severe consequences. Wellington City has many characteristics that make it susceptible to fire following earthquake (FFE), including the potential for conflagrations and significant losses (e.g. property, infrastructure and casualties).

We have modelled ignition and fire spread for five potential earthquake scenarios that could affect Wellington City. In each scenario, we account for uncertainty in the resulting ground motion by running hundreds of simulations to sample the distributions of the peak ground acceleration (PGA) from each event. The fault sources used for the scenarios are the Wellington, Wairarapa and Wairau faults and the Hikurangi subduction zone's interface fault. Wind speed and direction is sampled from wind rose data for each simulation run to account for important weather conditions affecting fire spread.

We developed a suppression model to account for ignitions over time, suppression by residents and emergency services, water availability and road access.

Our results show the areas of Wellington City at greatest risk of FFE, and the potential losses are estimated for each scenario. This work is ongoing and in the coming year we will assess the impact of mitigation options such as alternative water sources and further investment into specialist firefighting equipment.

Shrestha, S., Orchiston, C., Elwood, K., Johnston, D., Becker, J., Tomassi, I. 45

Understanding wider social and economic context of Cordons: A comparative case study between Christchurch, Aotearoa (New Zealand) and L'Aquila, Italy

Post-earthquake cordons have been used after seismic events around the world. However, there is limited understanding of cordons and how contextual information such as geography, socio-cultural characteristics, economy, institutional and governance structures affect decisions and operational procedures, including aspects related to spatial and temporal attributes of cordon establishment. This research aims to fill the gap in cordon knowledge through a qualitative comparative case study of two cities: Christchurch, New Zealand (Mw 6.2 earthquake, February 2011) and L'Aquila, Italy (Mw 6.3 earthquake, 2009). Both cities suffered comprehensive damage to their city centres and had cordons established for extended periods of time. Data collection was done through purposive and snowball sampling whereby 23 key informants were interviewed in total. Research participants held expert knowledge in their roles and responsibilities i.e., council members, emergency managers, politicians, business/insurance representatives, academics, and police. Results illustrate that cordon were primarily established to ensure safety of people and to maintain security. In both sites, the lengthy timeframe that the cordons were in place was met with resistance and civil protests. The extent and duration of the cordons were affected by the recovery approaches taken in the two cities i.e., in Christchurch demolition was widely undertaken which supported recovery and allowed for faster removal of cordons. In contrast, authorities in L'Aquila placed high value on heritage buildings and its historical importance. As such, the approach to recovery was based on preserving and restoring most of the buildings which extended the duration of cordon. Cordons do share similar patterns, especially in the early phase but over time they evolve. This evolution of cordons is affected by site specific needs, thus, cordons should be understood and planned in accordance with contextual realities of each case.

Siddiqui, U., Moselen, H. 33

Managing Earthquake-prone Buildings on Shaky Grounds – Wellington City Council's Approach

The nationally consistent system for identifying and managing earthquake-prone buildings (EPBs) came into force on 1 July 2017, including standardised notices and a national public register. It provides a single national policy framework for managing EPBs and informing people using them.

With Wellington being a highly seismically active region, Wellington City Council have been at the forefront of EPB management prior to the 2017 national policy. The Council had an active Earthquake-prone Building Policy in place from 2006, however in response to the Christchurch Earthquake a small but dedicated Resilient Buildings Team was created to ramp up efforts in assessing the city's buildings. In view of the legislative change and its impact on the EPB owners, the Council have taken people-centric approach to managing the EPBs. Apart from the legislative duties of identifying and issuing EPB notices for buildings, the Council offers a range of support options for building owners and this includes rates remission, building-consent fee rebates, the Built Heritage Incentive Fund and the Building Resilience Fund. The Resilient Buildings team can provide strategic advice to building owners at any stage of their project with a view to support owners being fully informed and equipped with the pathway to getting their EPB status resolved. The Council are also in the midst of city-wide EPB owners engagement project to actively engage with building owners through one-on-one meetings to know the state of progress and to make sure they get the right advice and access to support to help them meet their EPB notice deadline. It also helps Council understand the challenges and barriers that building owners face during this process.

The response so far has been positive and numerous earthquake-prone building owners have benefitted from the funding and incentives.

Stephens, M. 75

How Fragile Are Our Bridges?

New Zealand's highway network consists of over 2500 bridges, many of which were designed and constructed prior to the implementation of modern seismic design standards which provide detailing requirements to ensure a ductile seismic response. Recent earthquakes in New Zealand (2011, 2012, and 2016) resulted in damage to a number of bridges in the highway network, highlighting the potential vulnerability of several common New Zealand bridge archetypes to seismic damage – this research is focused on identifying these vulnerabilities. The focus of the study here is short span wall-pier type bridges, which make up a majority of the New Zealand bridge stock. A representative case study bridge was selected and modelled using the opensource structural analysis software OpenSees, accounting for nonlinearity in the structural elements in the superstructure and substructure as well as soil-structure interaction. The model was used to perform an incremental dynamic analysis which resulted in fragility functions for a range of damage states and collapse. Results indicate that bridges within the short-span, wall-pier archetype are extremely robust when subjected to seismic loading in the transverse direction of the bridge. Ongoing work is focused on repeating this study for additional archetypes common in New Zealand.

Stolte, A., Wotherspoon, L., de la Torre, C., Bradley, B. 17

Recent Site Characterisation at Strong Motion Stations

An important asset in the development of Earthquake Resilience in Aotearoa New Zealand is the nation-wide network of strong motion stations (SMS) deployed and maintained by GeoNet. Each year, these sensors help to locate and record the ground shaking of the over 15,000 earthquakes near New Zealand, of which about 100 are felt. The SMS network was deployed to provide spatial coverage over the country and include a variety of geologic conditions. However, the ground conditions have not been characterised or the existing data is not suitable for analytical purposes at many of these SMS. Leveraging the capabilities of QuakeCoRE Technology Platform 2, recent site characterisation efforts have targeted 34 SMS sites in the Wellington, Upper & Lower Hutt, Gisborne, Napier/Hastings, Marlborough and Dunedin. Several testing methods were utilised, based upon accessibility and expected ground conditions; these methods included seismic cone penetration testing (SCPT), downhole (DH) seismic testing, active & passive surface wave (SW) testing, and microtremor horizontal-to-vertical spectral ratio (mHVSR) testing. This poster presents the initial results of these site characterisation studies, which may be used to improve understanding of historical ground shaking, strengthen the underlying analyses in the National Seismic Hazard Model (NSHM) update, and support ongoing efforts to validate ground motion simulations.

Ta, Q., Noy, I. 46

New Zealand firm investment following the Canterbury earthquake sequence

This paper investigates the economic effect of the 2010/2011 Canterbury earthquake sequence on New Zealand firm investment in the short-to-medium term. Almost a decade since the first quake in September 2010, the Canterbury economy has been reasonably resilient to the impact of the earthquakes; however, the real repair and rebuild activities might still exist for some specific industries. Using the disaggregated level data of New Zealand firms spanning over the period 2001-2019 in a difference-in-difference approach, this paper quantifies the impacts of these earthquakes on business in the region, paying an attention to heterogeneity in firm-level outcomes. Our findings show that the average annual investment ratio of Canterbury firms since 2011 is 2.2% higher than the nationwide, ceteris paribus. The results are driven by the impacts on manufacturing and construction sectors, followed by services industries. This pattern is supported by the expansion in firm assets and fixed assets in the region in addition to the potential channels in which those firms could use to mobilize funding for the reinvestment, including insurance claims, debt, shareholder funds, and

government subsidy. Besides, conditional on firm survival, the average effect seems to be significantly larger for surviving firms while non-productive firms might reduce investment before exit.
Disclaimer:
The authors take full responsibility for the paper, that Stats NZ will not be held accountable for any error or inaccurate findings within the paper or presentation, and acknowledgment that access to data is in accordance with the Statistics Act 1975.

Tan, M., Brown, A., Prasanna, R., Becker, J., Stock, K., Kenney, C., Cui, A., Lambie, E., Parkin, T., Reade, A., Tobin, A., Matt Law, M.

54

An earthquake early warning for Aotearoa New Zealand? High-level findings from community engagement

Earthquake early warning systems aim to warn end-users of incoming ground shaking. Potential benefits of earthquake early warning include reducing injuries and fatalities and protecting infrastructures. Here in Aotearoa New Zealand, we are exploring how earthquake early warning systems might be developed and implemented to mitigate our seismic risks. Current research looks into the technical feasibility and the social acceptability of earthquake early warning. Our project focuses on investigating people's perceptions of earthquake early warning systems.

The project involved eight in-person workshops with a cross-section of communities involving 140 participants. The workshops were held in different locations in Aotearoa New Zealand (Wellington, Orewa, Nelson, Lower Hutt, Gisborne, Seddon, Upper Hutt, and Waikanae). In the workshops, participants were asked to share their level of trust and their corresponding level of comfort in response to hypothetical EEW scenarios. The workshops set out to understand people's needs and expectations for earthquake early warning and explored the opportunities and challenges for such a system to work in Aotearoa New Zealand.

Several overarching themes and principles emerged from the conversations in the workshops. A consistently arising principle was identified on 'people, place, and protection'. Participants thought that any system should be holistic yet localised; it should prioritise protecting people in the places they live. This principle also intersects with three other thematic lenses – (1) human behaviour, (2) services and technology, and (3) communication. The workshop results highlighted the need for an inclusive and evidence-based approach to earthquake early warning that incorporates public education programmes that engage with communities to prepare for disasters. This poster presents the high-level findings from the workshops, and it details the themes and their intersections.

Vinnell, L., Inch, P., Johnston, D., Horspool, N. 55

Behavioral responses to earthquake shaking: Video footage analysis of the 2016 Kaikōura earthquake in Wellington, Aotearoa New Zealand

Initiatives such as the ShakeOut earthquake drill teach protective actions which can reduce the likelihood of injury during earthquakes. However, our understanding of human behaviour during actual shaking is limited. Previous work using retrospective self-reports to explore what actions people take during and immediately after an earthquake is informative but it is important to complement these findings with more objective data. This research builds on previously-developed methods of analysing Closed Circuit Television (CCTV) footage to examine actions taken during the 2016 Kaikōura earthquake at Wellington International Airport, Aotearoa New Zealand. Only one of the 68 observable individuals was observed to undertake "drop, cover, hold" as recommended in New Zealand, although a quarter took some kind of protective action (e.g., dropping or covering). The majority responded by standing, walking, looking around, or helping those near them. Because this earthquake had distinct P-wave and S-waves, we were able to examine changes in behaviour due to increases in shaking intensity. Of the 36 individuals who could be observed during the strong S-wave jolt, 27 changed their behaviour; 11 changed from not protecting themselves to taking at least one protective action and a further 8 who were already undertaking at least one protective action took a further one or more steps to protect themselves. Of the ten people observed to have an uncontrolled response to the sudden increase in shaking intensity, nine were taking no actions to protect themselves demonstrating the importance of taking protective actions before the arrival of strong shaking. This paper presents key considerations for CCTV analysis and useful observations of behaviour during earthquake shaking which can help to reduce injuries and fatalities.

Vishnu, P., Rodgers, G., Chase, G. 34

Computational modelling of HF2V lead extrusion dampers using ABAQUS

Supplemental energy dissipation devices are increasingly used to protect structures, limiting loads transferred to structures and absorbing significant response energy without sacrificial structural damage. High Force-to-Volume (HF2V) lead extrusion devices are supplemental dampers that dissipate significant seismic energy by deforming lead plastically. This study develops a generic finite element (FE) modelling approach for these dampers to accurately predict device forces to optimize device designs for implementation into structures.

Design parameters from 19 experimental HF2V device tests are used to create a 2D axisymmetric large-deformation FE model with adaptive meshing using ABAQUS. The model has a rigid shaft and deformable working material. The analysis is run using in multiple small step times with automatic increments, to balance higher accuracy and computational time. The total force output is the sum of the contact frictional forces and contact pressure forces acting between the moving shaft and the displaced lead in the devices. Results of these highly nonlinear, high strain analyses are compared to experimental device force results.

FE modelling methodology for HF2V lead extrusion dampers accurately predict device force capacities within obtained from the FEM have forces within ±10% for 14 of 19 devices (74%), which is within ±1 SD of manufacturing variability of ±14%. Between ±14-28% or 2 SEs there are 3 of 19 devices (21%). Finally, 1 of 19 devices has -39% error, which is within ±3 SE = 42%. The overall modelling methodology is objective and repeatable, and thus generalisable. Model force-displacement hysteresis plots exhibit good prediction capacity corresponding to experimental results. The results validate the overall approach with relatively very low error, providing a general modelling methodology for accurate design of HF2V devices.

Yan, Z., Bagheri, H., Clifton, C., Quenneville. P., Ramhormozian, S., Rangwani, K., MacRae, G., Dhakal, R., Xie, J., Xiang, P., Jia, L., Zhao, X. 35

ILEE ROBUST Project Update: Experimental Testing of Optimised Sliding Hinge Joint (OSHJ)

The concept of designing for controlled damage in a severe earthquake has been well developed and implemented for four to five decades. It is beneficial to make buildings operational rapidly or preferably immediately following a severe earthquake.

A 9 m high, full-scale three-storey configurable steel frame composite floor building incorporating friction-based connections is being tested using two linked bi-directional shake tables at the International joint research Laboratory of Earthquake Engineering (ILEE) facilities, Shanghai, China. This RObust BUilding SysTem (ROBUST) project includes the testing of 9 different structural configurations and the optimised sliding hinge joint (OSHJ) in moment resisting steel frame (MRSF) is one of nine. The OSHJ is a low damage, resilient and cost-effective seismic resisting connection investigated as the optimised version of the traditional Sliding Hinge Joint (SHJ) with Asymmetric Friction Connections (AFCs).

Experimental testing of the OSHJ was undertaken on a full-scale subassembly, comprising four real scale tests at quasi-static rates of displacement-controlled loading, representing the connection at level 1 of the prototype building (the one to be tested on the shake table). The loading regimes were designed to investigate the behaviour of the OSHJ under as-built condition (freshly assembled for first run), post-slide condition (following runs without any repair actions taken) and as-new condition (after inspection and repair). Sufficient time was given between each loading case to allow the specimen cool down in room temperature. It was observed that the experimental tested OSHJ sliding shear strength matches well with the designed capacity and the strength degradation is almost negligible even without any repair action (i.e. replacing new bolts). An update of the fabrication and erection progress is also reported in this poster.

Zakerinia, M., Hayden, C., McGann, C. 18

Stress-Density Model Validation: 2-D Liquefaction Analysis Using OpenSees

Liquefaction has induced severe and widespread damages in recent earthquakes. The equivalent linear method for site response analysis cannot capture pore water pressure generation and dissipation that accompanies liquefaction. By contrast, fully coupled effective stress analyses can capture the effects of liquefaction on the seismic response of geotechnical systems. Constitutive models govern the response of the soil to ground shaking, boundary and initial conditions in an effective stress analysis. Due to the complexity of liquefaction behaviour, it is crucial to validate a constitutive model against high-quality laboratory or real-world data before its further application in research or industry. Well documented validation studies provide engineers and researchers with insight into selecting the best model for each problem encountered. The stress density model is a liquefaction-tailored constitutive model for effective stress analyses, which has been recently implemented in OpenSees. This study compares the stress density model results against two sets of centrifuge tests and also the PM4Sand model, which serves as a well-known reference. The results of the 1D free-field site response analysis are compared with the 2D simulations. Moreover, the response affected by nearby structures are compared with the centrifuge test results. The model predicts the acceleration time histories and pore water pressure response with reasonable confidence.

Zhou, H., Wotherspoon, L., Hayden, C., McGann, C., Stolte, A. 19

Applicability of existing empirical CPT-Vs correlations for shallow Christchurch Holocene soil deposits

This paper assesses the applicability of two existing empirical cone penetration test-shear wave velocity (CPT-Vs) correlations for Holocene soils using a dataset of over 1000 CPT-Vs measurement pairs for depths less than 10 m from Christchurch, New Zealand. While most existing correlations are developed using seismic CPT (sCPT) or downhole based Vs measurements, the dataset assessed in this paper was based on co-located CPT and direct push cross-hole (DPCH) based Vs measurements. Based on this dataset, the Andrus et al. correlation, developed using an international database, was better performing than the McGann et al. correlation, which is based on sCPT data from the Christchurch region. The McGann et al. correlation underestimated Vs across all variables, with more significant underestimates in the near-surface (depths less than 3-5 m). The underestimation at shallow depths may be due to the difference between sCPT and DPCH techniques, with the DPCH based Vs likely to be more representative due to potential issues with the wave path direction assumptions from source to receiver for the sCPT. The underestimates at greater depths are likely a result of soil anisotropy, with the Vs measured by the sCPT based on vertical wave propagation, compared to horizontal wave propagation for the DPCH. These results highlight the importance of having a good understanding of the characteristics and reliability of the datasets that inform the development of any geotechnical correlation.