Te Hiranga Rū | QuakeCoRE

Aotearoa New Zealand Centre for Earthquake Resilience

Te Hiranga Rū QuakeCoRE 2022 Annual Meeting Poster Abstracts

Poster Abstracts

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2022 Te Hiranga Rū QuakeCoRE Annual Meeting Posters

30th August – 1st September, 2022 – War Memorial Centre, Ahuriri Napier, New Zealand

Abeling, S., Hulsey, A., Brown, C., Elwood, K., Ferner, H., Cowan H. 67

Resilient Buildings Project Workshop: Integrating societal expectations into the seismic design of building.

As part of the ongoing efforts of the EQC-funded NZSEE-led Resilient Buildings Project to explore societal expectations for the seismic performance of buildings, a workshop was held to begin to interpret how societal expectations might be integrated into the seismic design of buildings. The 3-hour virtual workshop had 32 attendees who participated in group activities utilizing MIRO, an online whiteboard tool for collaboration. The groups were specially curated to include a range of social science, engineering, policy, practice and research perspectives. The objectives of the workshop were to (1) explore findings from the Resilient Buildings Project, (2) investigate how societal expectations can be mapped to engineering-based design principles and targets, and (3) identify future research needs to enable integration of societal expectations into engineering design. Key takeaways from the workshop include that societal expectations for time to return to functionality are significantly shorter than the Building Code currently delivers and that building type and occupant vulnerability influence expectations for post-earthquake functionality. Discussions about research gaps reinforced the notion that there needs to be a better understanding of how building level performance objectives relate to community resilience.

Ferner, H., Abeling, S., Cowan, H., Brown, C. 68

Resilient Buildings Project: Using Societal Expectations to Inform Tolerable Impacts for the Seismic Performance of New Buildings.

For the first time in New Zealand, the EQC-funded NZSEE-led Resilient Buildings Project has documented societal expectations for the seismic performance of buildings. Through a series of interviews and geographic focus groups, the research focused on understanding societal tolerance to the impacts of earthquakes on new buildings. The findings reveal that communities expect more from buildings in earthquakes than simply preventing death and injury. Swift social and economic recovery and minimising the environmental impacts of earthquakes are emerging as key building performance objectives.

The next stage of the Resilient Buildings Project aims to use the findings on current societal expectations to establish tolerable impacts for the seismic performance of buildings. Work will also be done to analyse the social and economic implications of changes to building performance objectives. Enabling works for this stage have included workshops to explore (1) how the built environment has changed (and may continue to change) since B1 performance objectives were set, (2) the development of a methodology for articulating tolerable performance and establishing performance objectives in buildings, and (3) options available to address the gaps between societal expectations and current code settings. This poster

presents the preliminary findings from these workshops and discussion about the next stage of the Resilient Buildings Project.

Akther, M, Orchiston, C., Johnston, D. 41

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 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 has prepared 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 better understanding of the resources and capacity needs which then can be translated into action for building towards EQ resilient community.

Alizadeh, F., Ramhormozian, S., Clifton, C. 23

Finite Element Modelling (FEM) of the Asymmetric Friction Connection (AFC)

The Sliding Hinge Joint (SHJ) is a cost-effective, low damage seismic resisting beam-column connection developed for Moment Resisting Steel Framed (MRSF) buildings. The Asymmetric Friction Connections (AFCs) with partially deflected Belleville Springs (BeSs) are the latest version of the SHJ's friction sliding energy dissipating components. The latest version of the SHJ is called the Optimised Sliding Hinge Joint (OSHJ). The AFCs also act as fuses to limit the seismic-induced internal actions in the beams and columns. The AFCs are installed at the beam bottom flange and web bottom bolts level in the SHJ. The OSHJ's AFC bolts are tightened in the elastic range and effectively remain elastic during seismic induced sliding, retaining most of their installed bolt tension after significant sliding.

The current poster provides a background of the research followed by the details of the Finite Element Model (FEM) of the AFC in ABAQUS software. This includes the explanation of the FEM's geometrical, material, and boundary condition characteristics along with relevant justifications. It is followed by presenting the Finite Element Analysis (FEA) research and parametric study plans as well as the initial results, aiming to specify the design parameters for different practical configurations and details.

Amos, A., Fenton, C., Walker, J., Rodgers, G., Logan, T. 1

Fibre Optic Cable Network Vulnerability to Shallow Geohazards

Fibre optic cables are commonly used for communication and data transmission over long distances. Route planning decisions for cable corridors are generally focused on ease of installation and access for on-going maintenance. Ground conditions and potential geohazards usually receive much less consideration. Typically buried no more than 1 m below

the ground surface, fibre optic cables have the potential to be exposed to numerous shallow geohazards, both seismic and non-seismic in origin. A communication network, linking power generation assets in the Mackenzie Basin, crosses a variety of geological terrains with a broad range of ground conditions. The exposure of this cable network to various geohazards was assessed using a combination of remote sensing analysis and ground reconnaissance to develop a series of engineering geological ground models. These models provide an understanding of the spatial distribution of shallow geohazards, thus allowing potentially vulnerable corridor sections to be identified. Strength testing of the cable provides an understanding of fragility. This provides a preliminary understanding of the magnitude of ground deformation that would compromise the fibre optic cable integrity.

Anderson, M., Logan, T. 87

Utilising risk curves to support adaptive decision-making

Community leaders and authorities around the globe are required to make decisions that will guide the management, location, and operation of their communities. However, risk assessments currently lack the required information to support many decisions around adaptive interventions. This is due to their inability to consider and communicate indirect risk over time. Risk curves, an approach used in medical, nuclear and more recently, hydrology contexts, have yet to be extended into complex situations where indirect risks exist (such as climate change or other hazard scenarios). Therefore, this work aims to explore the use and suitability of risk curves for adaptation planning and decision-making.

We do this by considering the direct (property exposure) and indirect (isolation from critical services) impacts for all properties within 50km of the coastline across the entirety of Aotearoa and use risk curves to evaluate the timing and location of managed retreat.

Our findings show that risk curves can aid the decision-making process in adaptation planning. Additionally, our coastal flooding case study shows that omitting indirect risk may underestimate impacts by up to 5 times.

Archie, S., Fleming, J., Peer, R., Logan, T. 42

Intelligent Retreat: Guiding relocation of residential communities given multiple planning objectives

Communities worldwide will soon be forced to retreat from hazardous areas, driven by the changing climate. Current discussions focus on "managed retreat," which aims to reduce the detrimental impacts on relocated residents. However, it is frequently neglected that there needs to be suitable housing stock to accommodate those retreating and relocating. Managing retreat needs to plan for not only where people should be moved from, but also ensure there is adequate housing stock available to accommodate the shift. However, an opportunity exists that society cannot afford to miss: future development must positively advance other, interrelated sustainability outcomes of economy, environment, health, well-being, and equity (the sustainability outcomes nexus) while simultaneously reducing climate risk. This array of objectives have both synergies and trade-offs, meaning that while there is a significant opportunity, there is also the risk of maladaptation. Here, we use a multi-criteria spatial optimisation framework to demonstrate the importance of considering these broader objectives and show the risks of a narrow "managed" retreat

Assadi, S., Hashemi, A., Quenneville, P. 69

Low Damage Wall to Floor Connections for Seismic Resilient Timber Structures

Rocking timber walls provide superior seismic performance in comparison with conventional light timber structures. Nevertheless, there is an uplift movement at the base of the wall that is translated as vertical displacement and rotation demands at the floor levels. So far, two general approaches have been taken to deal with these demands. Firstly, the coupled

approach where the timber floors (or beams) are rigidly/semi-rigidly connected to the timber walls which are normally plywood shear walls. With this approach, not only floors/connections are prone to damage, but also the rocking movement is compromised. Secondly, the decoupled approach, where the floors are isolated from the walls. The extent of damage is relatively less with the decoupled approach; however, the gravity system is separated, and the wall capacity is not fully utilized. The purpose of this research is to introduce and develop a new wall-to-floor and beam-to-floor connection for mass timber structures that not only transfer the lateral loads but also dissipates the seismic energy without damage. With this new system, there is potential for increasing the damping capacity of the structure and reducing the size and number of the walls. A new system is proposed, to both safely allow wall uplift relative to floor and at the same time dissipate energy.

Avendano, B., Lukosch, H., Milke, M. 80

Playing With Uncertainty: Facilitating Community-Based Resilience

It is hard to make decisions about earthquake resilience projects with multiple stakeholders. It is even harder if those decisions imply multiple plausible scenarios and even worse if uncertain/unpredictable circumstances directly affect communities. Resilience has become a fundamental paradigm for communities to deal with disaster planning. 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. To make informed decisions, there is a need to understand the challenge of integrating social and physical assets, their interactions, and non-linear complexity. Formal methods are used to prioritise and decide about investments for resilience. Participatory modelling or modelling with stakeholders has been proven to be a powerful approach to enhancing the understanding of complex systems. This research aims to develop a proven and scalable participatory modelling methodology with the potential to improve disaster resilience planning. We created Playing with Uncertainty: Facilitating community-based resilience building. This methodology could help policymakers, infrastructure providers, and communities engage in decision-making processes about trade-offs of planning future investments in adaptation strategies to hazards and plausible disaster risks—Eg. Earthquakes and Tsunamis, using simulation models while playing role games. We conducted trials with students to understand the potential of the methodology as a decision support tool (DST) for communities dealing with negotiations that involve multiple stakeholders, critical comprehension of trade-offs, and multiple-criteria analysis in a complex context. E.g. Sea level rise in Christchurch City, New Zealand. This methodology can be applied to other disasters in Aotearoa-New Zealand and overseas.

Bae, S., Jeong, S., Kim, J., Kim, K. 2

Broadband Physics-based strong ground motion simulations for the southern Korean Peninsula

Korean peninsula is placed in a stable continental region (SCR), which means moderate to large earthquakes do not occur frequently. However, like many other places in SCRs, Korea has suffered from infrequent yet damaging earthquakes in the past. Among the instrumented earthquakes, the largest was the 2016 M5.5 9.12 earthquake. The 2017 M5.4 Pohang earthquake was the second largest; it was also the most damaging earthquake, likely due to the combination of its proximity to urban areas, its shallow hypocentral depth of 5km, and the amplification of ground motion within the Pohang basin.

Being in a SCR with a short history of instrumentation, South Korea has not collected sufficient instrumental data for data-driven ground motion models. In an attempt to address this limitation, we implemented the physics-based hybrid broadband ground motion simulation method of Graves and Pitarka (2010, 2016), by heavily modifying the simulation platform of

QuakeCoRE, to simulate earthquakes in South Korea accounting for the crustral velocity structure and seismological characteristics of the Korean peninsula.
For crustal velocity models, we implemented a three-dimensional velocity model by Kim et al. (2017) and a one-dimensional velocity model by Kim et al. (2011). To generate kinematic source models, we implemented Graves and Pitarka's rupture generator, with a magnitude-area scaling relationship developed for SCR by Leonard (2014).
Using the implemented simulation platform, we successfully simulated the 2016 M5.5 9.12 earthquake and the 2017 M5.4 Pohang earthquake and compared results with recorded ground accelerations at strong motions stations, which demonstrated the potential of physics-based ground motion simulation for earthquake engineering applications in South Korea.

Bal, A., Evangelio, C., Wotherspoon, L., Hogan, L., Stephens, M. 88

Are Our Bridges Fragile? Investigating the Seismic Performance of the State Highway Network

Wall-type pier bridges are the most common bridge type in the state highway system. Wall-type piers were used extensively until the mid-1970s, and a majority were designed to resist a lateral load equivalent to 10-35% of the current standard. The ageing infrastructure highlights the need for large scale research on the seismic performance of bridges in the State Highway System. Due to their fundamental role in the State Highway System, wall-type pier bridges were selected for the initial phase of work. Wall-type pier bridges were modelled for three scour conditions: insitu, scour on one side of the bridge, and no scour. Fragility functions were created using Incremental Dynamic Analysis with a suite of 39 ground motions for three damage states. The generated fragility functions emphasize the robustness of wall-type pier bridges and the negative effects of scour on fragility. This case-study analysis is the first step in understanding the vulnerabilities in the highway network. To continue this investigation, fragility models will be developed for the other common bridge types. In addition, large scale experimental testing on reinforced piles and columns will be performed to validate models and investigate the effects of corrosion.

Bloom, C., Singeisen, C., Stahl, T., Massey, C., Howell, A. 3

Strong ground motion and landslides from the 2016 Mw 7.8 Kaikōura earthquake

Typically, strong ground motion parameters are one of the most influential features in regional earthquake induced landslide susceptibility models. Following the 2016 Mw 7.8 Kaikōura earthquake, however, Massey et al. (2018) found that distance to a surface fault rupture was more important than modelled Peak Ground Velocity (PGV) or Peak Ground Acceleration (PGA). Distance to a surface fault rupture is highly correlated with strong ground motion and this result calls into question the efficacy of modelled near-fault ground motion from the Kaikōura earthquake. Here we conduct a sensitivity analysis using several published ground motion models and ground motion derivatives to train logistic regression models on the same landslide inventory from the 2016 Kaikōura earthquake. Preliminary results suggest that, in Pahau Terrane greywacke, Arias intensity performs better than PGA or PGV. In line with previous observations, however, we find that distance to a surface fault rupture is a better predictor of landslide density than any tested strong ground motion parameter. Mapped off fault deformation, which is shown to correlate with higher landslide density around surface fault ruptures, does not fully account for the higher importance of fault distance. Interestingly, in Tertiary and Quaternary sediments, we find that lower predicted ground motion values correspond with higher landslide susceptibility. It is possible that strong seismic site effects, outside of those currently considered in regional ground motion models, heavily influence local ground motion and the regional landslide distribution in proximity to surface fault ruptures from the Kaikōura earthquake. Indeed, on the Kaikōura coast, away from most surface fault

ruptures, we find that modelled PGA is a much stronger predictor of landslide susceptibility than distance to a surface fault rupture.

Boston, M., Dunlap, E., Owen, M. 65

Māori Resilience: Deriving resilience frameworks from Māori historical and modern practices

To mitigate the effects of climate and the history of unsustainable development, the United Nations derived the seventeen sustainable development goals. Goal eleven aims to create inclusive, safe, resilient, and sustainable cities. Aligning with these goals, many governments and organisations have sought to grow capabilities to improve community resilience, especially regarding disaster management and the built environment. Extensive research has been conducted to ensure comprehensive frameworks are created to meet the needs of the community, reducing vulnerabilities, the perspective these frameworks are derived from fails to address the vulnerabilities of marginalized communities like the indigenous Māori people. The nature of Māori culture and values presents an opportunity to reimagine the scope of community resilience and the frameworks that derive from them. The history of Māori has seen resilient practices weaved into the very nature of their culture, which knowledge has survived through the oral transmission of songs, proverbs, and stories. Deriving this information from a people so aligned and immersed in nature is the knowledge required to improve the frameworks to better respond to natural disasters while expanding the literature on what community resilience is. To do this a comprehensive analysis of traditional Māori resilience will be conducted by evaluating a variety of songs, proverbs, and stories that relate to the resilient nature of Māori. This information will be compared to modern Māori perceptions of community resilience using a derived earthquake scenario for the local Iwi Ngati Toa, located in the city of Porirua within the Wellington region. This information will enable the expansion of what community resilience is defined as and improve disaster response frameworks to be more inclusive, safe, sustainable, and resilient.

Brunner, L., Logan, T. 89

Natural Hazards and Their Cascading Impacts on Our Interdependent Infrastructure

Infrastructure is increasingly interconnected. This offers many benefits but means that our utilities are vulnerable to cascading failures from natural hazards. This particular study looks into the impacts of coastal flooding on the electricity, water supply, and wastewater networks in Ōtautahi Christchurch given several sea-level rise scenarios. This is performed by connecting the utilities to each other and households, assessing the initial impacts from the natural hazard, cascading the impacts through the dependent networks, and then analyzing the outages. Simulating natural hazards on our infrastructure in this manner can help determine where the most vulnerable areas would be under various scenarios. Initial modelling shows how disturbances to the utilities reach beyond the extent of the direct impacts in the form of cascading impacts. This method can be applied to other hazards to help inform the development of resilient infrastructure and enhance community preparedness in the face of a changing climate.

Buck, N., Clarke, G. 70

Structural Resilience and Functionality Implications of Designing to Various International Standards

This research compares the seismic performance of reinforced concrete buildings designed to various international codes in terms of economic loss and functionality as a way to improve the resilience of structures designed in New Zealand. The framework is developed through the design and assessment of three 10-storey concrete moment frame and shear wall buildings

designed using New Zealand material properties and seismic hazards for a building located in Wellington, NZ with site class D soil conditions, but with design procedures and detailing requirements following New Zealand, United States, and Japanese standards, respectively. The outcomes of this research are to quantify post-earthquake losses and building functionality of modern code conforming buildings, identify structural and non-structural components that drive functionality, and recommend potential design strategies currently used in other countries that would improve the resilience of concrete structures in New Zealand.

Büker, F., Elwood, K., Hogan, L., Brooke, N., Bull, D., Sullivan, T. 24

Experimental Validation of Novel Precast Hollow-core Floor Retrofits

The collapse risk of existing precast hollow-core floors in earthquakes is well recognised in New Zealand. Equipping the industry with robust retrofit solutions to address this life-safety threat is therefore crucial. This poster presents two comprehensive new hollow-core floor retrofit techniques developed as part of the 'ReCast Floors' project. The first retrofit ('strongback retrofit') provides an alternative load path through a combination of short steel beams and a seating angle. The second retrofit ('cable catch system') uses an arrangement of cables that catches the floor if it collapses. Experimental validation of these retrofits was conducted in a full-scale super-assembly test at the University of Canterbury. Key observations of the successful performance of the retrofits are outlined in this poster. Both retrofits add to a pool of techniques practitioners can use to make New Zealand's hollow-core floor buildings safer.

Carradine, D., Liu, A. 81

Full-Scale Testing of Light Timber Frame Walls and Floor-Ceiling Diaphragm System

Floor and ceiling diaphragm stiffness and the interaction of different bracing systems is an area that requires further investigation particularly for light timber frame (LTF) diaphragms and hybrid LTF structures. This is due to the complex nature of the way seismic loads in diaphragms are distributed among bracing walls of varying stiffness. This research seeks to better understand the behaviour of LTF diaphragms and wall systems subject to seismic loading to improve the ability to predict LTF and LTF hybrid building performance as well as inform numerical modelling of these systems for design purposes.

To investigate the performance of diaphragms within LTF building systems a full-scale test specimen was constructed and tested to destruction. Fully reversed cyclic loads were applied at the floor level in the plane of the diaphragm. The specimen was instrumented extensively which provided load-deflection data for the walls, diaphragm and between various system components. Observations of damage were recorded throughout testing and allowed for correlations between drift levels and damage to be established.

This poster provides descriptions of the tested specimen and loading protocol along with strength and stiffness of walls, in-plane stiffness of the floor diaphragm and relative stiffness between the walls and floor. Hysteretic behaviour of the walls and floor are presented, and data and observations are used to develop a proposed damage state methodology for New Zealand LTF and hybrid LTF buildings. This information will be important moving forward with the design of hybrid bracing systems as well as accurately modelling the behaviour of bracing systems having different stiffness to better understand potential issues around deformation compatibility and performance-based approaches using these systems.

Chandrakumar, C., Prasanna, R., Stephens, M., Holden, C., Punchihewa, A., Becker, J., Jeong, S., Tan, M. 97

An Ecosystem of Low-cost Sensors toward Earthquake Early Warning: - An Earthquake Early Warning System (EEWS) with multi-sensor capability

This study expands upon the previous project of implementing an experimental EEWS using low-cost Micro Electromechanical Systems (MEMS) - based sensors to detect earthquakes in the Wellington region led by the CRISiSLab – Massey University. The CRISiSLab has implemented a unique EEW network architecture using the PLUM (Propagation of Local Undamped Motion) based algorithm at the sensor nodes to detect earthquakes. However, the PLUM algorithm has limitations, as the algorithm is mostly limited to issue warning to a 30-kilometre radius which only can give maximum of 10-second warning time. Having considered the limited warning time of 10 seconds, this study aims to improve the performance of the CRISiSLab's experimental EEW sensor network by (i) detecting earthquakes using the P-waves (primary waves), and (ii) developing an ecosystem of sensors where the sensor network supports the integration of different types of low-cost ground motion sensors rather than supporting only a single type of sensor. The team believes detecting an earthquake using the P-waves could increase the warning time by a significant amount since the P-waves are generated at first during an earthquake, and constructing an EEWS capable of working with different types of ground motion sensors can be a promising approach toward having a dense sensor distribution where the system can use the already installed different types of ground motion sensors in addition to the newly installed sensors. Further, it can generate benefits in having a large community-engaged EEW network where people can plug and play with their available ground motion sensor rather than limiting it to a single type of sensor.

Chandramohan, R., Pledger, L., Pujol, S. 25

Can we mitigate seismic loss by designing stiffer buildings?

This study seeks to investigate whether increasing structural stiffness is an effective and practical strategy to minimise seismic loss. The ductile design philosophy adopted in countries like New Zealand and USA permits significant nonlinear deformations in buildings, while placing a strong emphasis on detailing to maintain structural integrity under these large deformations. The large losses incurred in buildings under the recent 2010-11 Canterbury earthquakes and the 2016 Kaikōura earthquake, however, highlight the potential shortcomings of this design philosophy. Alternatively, the limited losses incurred under comparable earthquakes in countries like Japan and Chile, whose seismic design codes stipulate more stringent drift limits, suggest that seismic losses could be mitigated by increasing structural stiffness. This study will seek to answer this question by numerically simulating the dynamic response of a suite of buildings designed to a range of drift limits, and by examining field and experimental data. As part of a preliminary study, a four-storey buckling-restrained-braced-frame (BRBF) was designed for a site in Christchurch, to three different drift limits: 1.0%, 1.5%, and 2.5%. Nonlinear models of these three buildings were created in OpenSees, and their performance was evaluated using the performance-based-earthquake-engineering (PBEE) framework. A clear improvement in structural performance was observed with decreasing design drift limit or increasing structural stiffness. The next steps will entail a closer examination of the damage incurred by acceleration-sensitive nonstructural components like suspended ceilings due to the larger floor accelerations typically experienced by stiffer buildings. Methods will be developed to more accurately relate the damage and loss incurred by these nonstructural components to the floor demands, and to mitigate these losses by proposing cost-effective alternative design strategies for nonstructural components.

Chaneva, J., Kluger, M., Melchert, R., Moon, V., Lowe, D., Orense, R. 4

Cyclic undrained behaviour and liquefaction resistance of a lacustrine pumiceous sandy silt, North Island, New Zealand

Experimental data related to the mechanical behaviour of crushable pumiceous soils are quite limited compared with those for hard-grained soils. The main focus of previous studies has

been on pumiceous sands, whereas pumiceous silts have not been investigated to date. A series of monotonic and cyclic triaxial tests were therefore performed to investigate the cyclic undrained behaviour and liquefaction resistance of a pumiceous sandy silt from northern New Zealand. The material tested, comprising tephra fallout from a volcanic eruption c. 7,600 years ago and preserved in Holocene lake sediments in the Hamilton Basin, is non-plastic sandy silt with pumice content of 45-48%. The samples were reconstituted in the laboratory using the under-compaction method and tested at two different consolidation stresses (20 kPa and 100 kPa) and three different relative densities (medium, medium-dense, and dense). The silt material tested exhibited three significant differences when compared with pumice sand. Firstly, it was more contractive even at medium to high relative densities, leading to a lower resistance to static (flow) liquefaction. Secondly, while it exhibited similar trends in excess pore pressure and axial strain accumulation (when relative density was used as a basis for comparison), the relative density had an only slight influence on the cyclic undrained behaviour. Thirdly, the material exhibited a significantly lower cyclic liquefaction resistance. In general, the cyclic undrained behaviour of the pumiceous sandy silt was similar to that of hard-grained silt. The difference in the response between pumiceous sandy silt and pumiceous sand may be explained by the lower degree of particle crushing the former experienced during cyclic shearing.

Keywords: pumice; volcanic soil; silt; liquefaction; undrained triaxial tests; state parameter; lake sediment.

Cui, A., Tan, M., Prasanna, R., Syed, Y., Hong, B., Viggers, Z. 50

CRISiSLab Challenge – hands-on learning with Raspberry Shake seismometers

The CRISiSLab Challenge is a resilience education engagement with college-level students in the Wellington region that encourages young scientists to experience the fields of Technology and Crisis Management. With the support of our project team, student groups work with personal seismometers called Raspberry Shake sensors. The students work hands-on with the sensors, learning how to create innovative devices, connecting the sensors and devices, and practising their skills in communicating earth sciences and earthquake preparedness. In the final stage of the competition, the student groups compete and showcase their work during a demonstration day. The hands-on approach to the competition gives students first-hand experience in understanding how seismometers work. Moreover, the engagement goes beyond just the seismograph and its readings; as the students utilise data from the seismometers during the entire competition. The students get to develop an alerting device or other innovative products that utilise the data generated by the Raspberry Shake. The experience throughout the Challenge show students how technology allows us to observe and measure our surroundings, how science helps us understand how the world works, and how science and technology have practical applications for our everyday lives. Moreover, the Challenge winners got the opportunity to complete a month-long internship with CRISiSLab. During the end of the internship period, students engaged in developing a dashboard for an experimental peer-to-peer Raspberry Shakes sensor network. The poster summarises the CRISiSLab Challenge concept, the results of our 2021 event, the dashboard developed by the winners, and the ongoing 2022 competition.

Das, M., Becker, J., Hudson-Doyle, E. 51

Communication, Community Action, and Disaster Resilience - Understanding the role of communication in supporting community action for disaster resilience

Aotearoa New Zealand is vulnerable to multiple natural hazards like earthquakes, tsunamis, floods, and storms. Impacts of these hazards can be substantially reduced if community members at risk from the hazards are involved and empowered to take preparedness actions much before a hazard strikes. Such preparedness actions can be both at an individual level

benefitting a single person or a household, or at the community level in the form of community actions where community members collectively address a hazard risk to safeguard the community's well-being. Existing research has shown that targeted communication can encourage disaster preparedness amongst people. However, most of such research focuses on how communication can encourage individual actions for disaster preparedness. Limited research explores the role of communication in encouraging community actions for disaster preparedness. My research addresses this question. By studying preparedness related community actions in Aotearoa New Zealand, I am trying to understand what motivates people to engage in community actions for disaster preparedness and how communication can be used to encourage and support community action in the country. The study findings will help improve communication initiatives for disaster preparedness and will advance risk communication research.

Del Rey Castillo, E., Hogan, L., Stephens, M., Allen, T. 26

Strengthening concrete diaphragms with FRP

Horizontal (floor) diaphragms are key elements in the lateral load resisting systems of building structures. Diaphragms distribute inertial forces to and between elements of the vertical lateral force resisting system (LFRS) through in-plane diaphragm action; they are part of the primary seismic load path. This load path is compromised if floor diaphragms are unable to develop adequate diaphragm action, preventing seismic inertial forces from being transferred to the intended elements of the LFRS resulting in unanticipated or undesirable structural behaviour. In structural retrofit scenarios, floors may be under-designed for these demands due to changing design requirements over time. Additionally, elements of the LFRS may be stiffened or new elements added to a structure, resulting in increased (or modified) demands on the diaphragms.

Historically, the design and construction of diaphragms in New Zealand relied heavily on the use of precast concrete members such as double tees or hollow-core planks, especially in Wellington during the 1980s and 1990s. Diaphragm action is normally achieved with a reinforced concrete topping slab (often using brittle mesh) placed over the hollow-core units. Common problems with such precast flooring systems include a lack of adequate seating for the units, deformation incompatibilities with global building movements and inadequate connections between the supporting perimeter frame and the floor diaphragm.

Fibre reinforced polymers (FRP) are being extensively used in the seismic strengthening of existing concrete structures, including diaphragms, to provide or increase tension capacity despite the lack of design guidelines or, indeed, little relevant supporting research.

Funded by MBIE, we are currently investigating the use of FRP for diaphragm strengthening and invite all interested parties to join us in this project.

Dhakal, R., Cubrinovski, M. 5

Applicability of Simplified CPT-Based Liquefaction Assessment to CentrePort Gravels

The 2016 Mw7.8 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.

Dhungana, A., Doyle, E., Prasanna, R., McDonald, G., Paton, D. 43

Model Uncertainty - Where and What should we know in Hazard/Risk Modelling

We present a conceptual structure for considering model uncertainties, enabling us to identify those that should be the focus for improved communication between scientists and policy decision-makers. Scientists and modellers design different mathematical and computational models with an aim to support decision-making for hazard and risk management. However, uncertainties are manifested at different stages of the modelling process- starting from input data and information, during the model run, and when generating output. Additionally, decision-makers and scientists' or modellers' values and judgments add another layer of uncertainty along with the underlying deep uncertainties in the model. Effective communication of these model uncertainties is not just helpful to manage the risk but also helps to inform more robust and adaptive decision-making, while also enhancing trust in the model itself.
Hence, based on a series of interviews with modellers, scientists; and hazard or risk managers and policymakers, this study has developed a structure for considering these uncertainties, represented by a doughnut depicting where and what should be known about uncertainties in hazard and risk models. This doughnut consists of four sections- input, modelling, output, and decision values and impact. Expert knowledge, societal values, governing mathematical equations, key assumptions around model development, use of parameter variables, and key inputs are highlighted as the key aspects relating to model uncertainty that needs improved communication. This work-in-progress doughnut once finalized will be tested with the case studies for two different hazard and risk models used in New Zealand towards the end of this Ph.D. research.

Dong, C., Sullivan, T., Pettinga, D. 27

Risk-Oriented Design of Base-Isolated Buildings in New Zealand

The objective of this Ph.D. research is to perform risk analysis and quantify the risk of base-isolated buildings designed using the new NZSEE/MBIE guidelines, where the risks are expressed in terms of the annual rate of failure, rate of loss exceedance, and expected annual loss. In addition to these three risk metrics, post-earthquake functionality is another important performance objective. However, it is considered that there are currently not enough tools available to quantify the post-earthquake repair time confidently. The results from the risk analysis provide information on the seismic performance of these buildings, also give insight into which factors (such as design criteria) have more significant impacts on building risk. These results will be useful for future updates of the guidelines and for engineers who wish to improve the isolated building performance beyond the minimum requirements. This research also aims to increase the uptake of base isolation technology by encouraging using risk as a communication tool between stakeholders and engineers to better describe the desired

building performance. Ultimately, a risk-targeted design framework will be developed to allow for a less iterative and better performance-controlled design method.

Faulkner, H. 44

Governing Disasters in Aotearoa New Zealand: An Auckland Volcanic Field Case Study

Over the past decade, New Zealand has experienced a series of severe disasters which have acutely tested its legal and governance frameworks. These events have highlighted the important role that such frameworks play in successful response and recovery. In addition, there is widespread recognition that these frameworks need to be understood and improved to respond more effectively to future disasters.

The experience of the Canterbury earthquake sequence in 2010/2011 provides a good example of the limits of the existing model. This soon proved to be un-fit for the purposes of long term recovery and was swiftly replaced by an entirely new and untested bespoke framework (the CER Act) in the chaotic aftermath of the disaster.

One hazard which has the potential to create large-scale multi-hazard disaster is the Auckland Volcanic Field. This hazard is globally unusual and unique to New Zealand. As a volcanic field located in a densely populated urban area it presents a high impact, low probability event with ongoing, long-term impacts and the possibility of multi-hazard events. This hazard thus presents particular challenges to the legal frameworks required to address the needs of an effective response and recovery.

This project analyses the current legal and governance frameworks around emergency management in Aotearoa New Zealand, using the Auckland Volcanic Field as a case study. It considers the lessons that previous disasters in New Zealand and world-wide can teach us about developing holistic disaster law frameworks capable of dealing with volcanic risk and wider multi-hazard disasters. In doing so it will provide guidance on how legal frameworks can be developed to improve community resilience to both major volcanic events (such as the Auckland Volcanic Field) and other major risks in Aotearoa New Zealand.

Fenton, C. 6

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

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; Kaikoura 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., Tong, Q., Cheung, W. 45

Lost in translation: Investigating the interplay between seismic policy language and commercial property listings

Anecdotal evidence suggests that %NBS communicates the degree to which the building can be repaired following a major earthquake. However, the term is used to set the minimum standard of 34%NBS with the intention of protecting life. In other words, the structure may safeguard lives, but the sustained damage may not be repairable. Therefore, measuring the differences between the interpretation and the intention of %NBS is important for future policy design.

Real estate agents play an essential role in interpreting and communicating %NBS to the market. Time series data of 54,963 commercial lease listings of the three major centres (Auckland, Wellington, and Christchurch) is collected. Auckland has the largest and longest period of data from 2009, while Christchurch has the smallest size of data from 2012. This study will examine how real estate agents signal the structural characteristics of commercial spaces to the market in the construction of property descriptions in their listings. Using textual analysis techniques allows us to identify commonly used descriptive words for %NBS and examine the positioning of this information within the listing. The descriptors and the positioning of the term will indicate how accurate the agents interpret %NBS and how willingly they communicate it to the market. Agents are more likely to express the most significant features of the property at the beginning of the listing description, for instance, "The building has an A+ seismic grading and is rated at 220% of NBS (new building standard)". In contrast, they may lightly brush over the fact the building has a lower rating by quietly mentioning it as a "Solid B grade seismic rating" at the end.

Francis, S., Stock, K., Prasanna, R., Jones, C., Hudson-Doyle, E., Aflaki, N., Medagoda, N., Mowll, R., Tregoweth, A., Treadgold, G., Waterreus, A. 98

QuakeText: Mapping Earthquake Impacts from Text

The rapid growth of social media has resulted in substantial disruption to society through increased online social interaction, access to participative, informal media and highly targeted advertising, among other things. However, the disruptive potential of social media for disaster response has yet to be realised. People readily describe disaster events in "real-time" on social media, including information about specific impacts such as infrastructure damage, injured people or dangerous situations, and their geographic locations, but the vast potential of this information to accelerate recovery and restoration post-event is currently lost. Furthermore, real-time access to this information with accurate georeferences (latitude and longitude) would enable better targeted earthquake response and faster recovery. Current methods are limited both in their inability to identify details of fine-grained impacts and to link those impacts to mentioned locations. The QuakeText project will develop methods to automatically extract and georeference impacts from social media. It will provide substantial scientific advances over previous work by: (1) applying the latest deep-learning methods in novel ways to extract impact details (type of impact, object affected and quantity/severity) and link them to mentioned locations, advancing on current methods that typically categorise an entire posting or fail to associate impacts with locations; and (2) developing new machine learning regression models to significantly improve accuracy over standard georeferencing methods, by interpreting complex forms of location description (e.g three houses near the cinema are on fire).

Goltz, J. 52

Operational Earthquake Forecasting for the Nankai Trough in Japan: Local Government Planning for Receipt of a Warning from the JMA

Following the Great East Japan Earthquake and Tsunami of March 11, 2011, the focus of seismic policy in Japan shifted to the southern region of the Japan Trough. This area,

comprising 707 municipal governments in 29 prefectures, is at risk of casualties and damage from a large subduction zone earthquake and 139 jurisdictions are also vulnerable to a major tsunami. Our project, funded by the US-Japan Foundation, will conduct both a survey and in-depth interviews with disaster managers and other stakeholders to assess the level of planning for receipt of a notification from the Japan Meteorological Agency that potential precursory seismic activity has raised the short-term probability of a major earthquake in the region. Three scenarios have been developed that, if they were to occur, would result in such a notification: a magnitude 8 "partial area rupture", a magnitude 7 event in the region considered a "limited area rupture" or a slow slip event. Our study will examine the extent to which local governments in the Nankai region have prepared plans, the content of those plans, the challenges in planning for a low probability, high consequence event, the extent to which guidance from the national government has assisted in planning and other factors. By the timeframe for the 2022 QuakeCoRE meeting, we anticipate having preliminary data from both the survey and the in-depth interviews and this meeting will provide us the first opportunity to share results.

Gonzalez, R., Stephens, M., Toma, C., Dowdell, D. 71

Carbon Risk - A new green seismic performance metric

Past events have shown devastating results after major earthquakes including in economic, social and environmental losses. The aftermath from the 2010/2011 Canterbury Sequence resulted in demolitions to large parts of the building stock within central Christchurch. In terms of environmental consequences, the premature demolition of buildings following earthquakes results in losses associated with the demolition process, waste management, and reconstruction. In the first stage of this research, the environmental consequences after the Canterbury Sequence were estimated using 142 concrete buildings as a case study to provide evidence that the probability of seismic damage should be included in traditional building life cycle assessments for buildings in moderate and high seismic. The remaining phases of this research will develop a methodology to include environmental metrics in traditional seismic loss estimation methods, and subsequently incorporate seismic losses into the building life cycle assessment for buildings in seismic regions. As part of this work, the lifecycle environmental impacts of buildings designed for multiple performance objectives will be compared. This includes buildings designed to current standards, as well as stronger/stiffer buildings and buildings with low damage technologies. The results of this work will provide valuable insight into the environmental trade-offs of resilient seismic design.

Gu, A., Rodgers, G., Henry, R., Lu, Y., Yang, Q., Zhou, Y. 72

Simulation of a 2-storey low-damage concrete wall building considering system level interactions

A system-level shake-table test of a 2-storey low-damage concrete wall building was conducted in 2019. The test building consists of unbonded post-tensioned (UPT) walls as the lateral resisting system and perimeter frames mainly carried gravity loads. The UPT walls were vertically decoupled from the beams in the short-span direction and the UPT walls were connected to the floor slab via a flexible link slab. The test results verified the seismic performance of the low-damage concrete wall building and the measured lateral strength of the test building notably exceeded that expected from design. This over-strength was largely attributed to the out-of-plane deformations imposed on the floor slab. Previous simulation results from planar frame models under predicted the building global response, so modified models were developed to improve accuracy of this simulation analysis. Evaluation of the floor slab out-of-plane strength contribution was assessed with the floors modelled using shell elements to quantify their response when subjected to deformations induced by the UPT wall uplift in the longitudinal direction of the test building. The unintended effects of the beam-to-

slab connection flexural strength was also calculated. The strength contributions from the floor and connections were included in the models. The updated models also included connection flexibility for the energy dissipation devices at the wall bases. Nonlinear time history analysis of the updated models in unidirectional loading cases displayed an improved agreement with the test results for both the global and local responses. For the updated models, the relative errors of peak base moments reduced by 14% from 35% to 21% on average in EW direction, and 8% from 24% to 13% on average in NS direction.

Harris, L., Robinson, T., Wilson, T. 53

Agent-based modelling of evacuation scenarios for a landslide-generated tsunami in Milford Sound.

Landslide tsunami are a rare but potentially devastating hazard that result from large landslides entering a body of water and triggering displacement waves. Previous analysis has identified at least 20 large landslide deposits within Milford Sound that would almost certainly have generated large local tsunami. These studies have estimated that these landslide-generated tsunamis in Milford Sound could have had wave heights ranging from 0.2 meters to 82 meters. Currently there is a 44% chance that a landslide in Milford Sound would enter the fiord, with the resulting tsunami reaching the township in 2-7 minutes. During the summer months Milford Sound can host up to 6,000 people per day, highlighting the potential landslide-generated tsunami risk here. Despite this risk, there are limited formal evacuation procedures in place.

This study aims to develop an agent-based model to understand how the time taken to safely evacuate Milford Sound varies according to different factors, including: hazard dynamics, temporal variation, and population demographics. An agent-based model is a useful pre-event planning tool because it can highlight potential evacuation dynamics such as areas of congestion and bottlenecks. Understanding these dynamics can allow for better response planning and mitigation to improve evacuation routes and reduce the total evacuation time, potentially saving lives.

Haymes, K. 73

Floor Response Spectra in Buildings with Low Damage Technologies

Innovative technologies that reduce structural damage through geometric nonlinearity instead of material damage offer high seismic performance of buildings. Functionality is only maintained if there is low damage to non-structural and secondary-structural elements, however. The peak demands upon acceleration-sensitive elements are represented by floor response spectra. Spectra were obtained from numerical and shake table testing of steel controlled rocking braced frames and base isolated structures. The modal properties of the structure were observed to have significant influence on these demands. Apparent reductions of the corresponding elastic structural demands were observed for some, but not all, element periods. Lengthening of the structural modal periods altered the demands. These observations support the use of a modified multi-modal approach to enable practitioners to accurately predict the demands on these elements to improve their performance.

Holden, C. 54

Engaging with End-users Towards an Earthquake Early Warning System for New Zealand

Earthquake early warning systems (EQEWS) should be part of an Earthquake Resilience toolkit as they can potentially save injuries and lives. The Sendai Framework of disaster risk reduction 2015-2030 has 7 global targets including "Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to

people by 2030". However New Zealand does not currently operate a national EQEWS. What strategy needs to be adopted to get there?
EQEWS relies on 3 pilars: earthquake science, sensor and communication technologies, and end-users. Scientists have made tremendous progress in earthquake science and related EQEWS algorithms. Sensor technology and communication engineering constantly evolve allowing to "save precious seconds" (Prasanna et al., 2022). Finally there is an appetite for EQEWS in New Zealand (Becker et al., 2020).
Funded by RNC2, we are currently developing a simulation toolbox to engage with national end-users with:

- *realistic input parameters (current state of the National network of instrumentation, investment required to upgrade/maintain for desired warning levels and uncertainties),*
- *realistic simulation models (EQEW algorithms tested on realistic earthquake catalogs)*
- *statistical outputs that can be converted into a dollar value. Benefits such as life safety can be quantified by the economic cost by mapping the cost to society from minor-major injuries. The benefit of a EQEWS on providing damage avoidance strategies for structures and infrastructure can also be directly valued economically.*

It's worth noting that any proposed strategy to support EQEWS implementation needs to take into account already existing community resilience. Any new response systems need to work in harmony or inform current practices rather than being disruptive and confusing for the public.

Horspool, N., Goded, T., Kaiser, A., Chadwick, M., Charlton, D., Houltham, J., Groom, J., Moratalla, J. 7

GeoNet's Shaking Layer Tool: Automatic generation of maps of near-real time ground shaking for post-earthquake response

Information on ground shaking following an earthquake is important for many applications from emergency response, engineering assessments, infrastructure management, insurance claim estimation and research applications. GeoNet, along with the RCET programme, is developing a tool, named Shaking Layers, that produces maps of ground shaking across New Zealand in the minutes after an earthquake. Shaking Layers uses the USGS ShakeMap software to create maps of PGA, PGV, MMI and Sa(T) for M4.0 and above earthquakes. The model combines observed ground motions from strong motion stations with ground motion models to produce spatial estimates of ground shaking for each intensity metric type. The first maps are available within 10-20 minutes of an earthquake. The maps are automatically generated in the first instance, and can be manually updated by GNS Science seismologists if new information is available, such as a fault rupture model, earthquake tectonic type, and moment tensor solutions. This poster will present an overview of GeoNet's Shaking Layer Tool and provide information to the QuakeCoRE community on the product and how they can access Shaking Layer information through the GeoNet website, the Shaking Layer data website, and an API.

Johnson, L. 46

Interventions to improve earthquake resilience: Surveying disaster researchers in Aotearoa New Zealand

Public policy plays a central role in earthquake resilience strategies in Aotearoa New Zealand. From public awareness campaigns to investment in scientific research, a range of policy interventions are used to help mitigate earthquake risks. Following academic surveys in other academic disciplines, such as the US Economic Experts Panel by The Initiative on Global Markets, this project will survey disaster researchers in New Zealand and aim to identify points of agreement and disagreement on a variety of earthquake policy issues. Do disaster researchers generally agree about which policies are most effective? Is there a consensus on

the least effective interventions? How do views on the effectiveness of different policies differ between academic disciplines? Do the economic and political views of researchers correlate with views on effective policies? A better understanding of the views of disaster researchers may help to provide policymakers with better information about the effectiveness of various earthquake risk mitigation policies.

Johnston, D., Horspool, N., Vinnell, L., Hogan, L., Stephens, M. 55

Meet EDDIE – QuakeCoRE's new earthquake test dummy

Until recently there has been limited understanding of the relationship between behaviour during earthquake shaking and risk of injury. Studying human behaviour during shaking is important, however, because with a better understanding of the actions that put people at risk, and the contexts within which these actions occur, we can explore how to enhance safety (including via engineering solutions, or the promotion of life safety actions such as Drop, Cover and Hold). A new research direction will be the introduction of a new partner: EDDIE (Earthquake Dummy for Debris Impact Experiment). 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. ATDs 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. 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 identifying improvements in seismic design of non-structural elements and demonstrating 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!

Tapuke, K., Johnston, D., Kaiser, L., Becker, J. 56

Enhancing earthquake and tsunami preparedness and response in Kura Kaupapa Māori/Schools Aotearoa New Zealand

Aotearoa New Zealand is exposed to numerous potentially damaging impacts from various hazard events. The east coast of the North Island, one of the most active seismic regions in New Zealand, faces significant earthquake and tsunami risk. Given the variety of hazards the regions face, how risks are managed within schools needs to be considered. This research aims to understand the challenges and opportunities for enhancing earthquake and tsunami preparedness and response in Te Tairāwhiti/Waiāriki Kura Kaupapa Māori/ Schools. Ten schools were visited from Gisborne to Matata in August 2021. Information was collected from a hui with school staff and invited members of the school Board of Trustees. Topics included tsunami zones, evacuation practice, resources for teachers, planning at home, school response plans, stakeholder involvement, and capability development. Their reflections on the 5 March 2021 earthquakes and tsunami warnings were also covered. Initial analysis of the interviews reveals long-standing knowledge of earthquakes and tsunami risk, experience from past events and various risk management strategies for future events, as well as insight on how isolated Māori communities collectively respond to disasters. There was a desire for further knowledge about what future events may look like and ways to prepare schools and the wider community. A return visit is planned for late 2022.

Kerby, C. 28

Staggered Lap Splices in Reinforced Concrete Structural Walls

Severe structural damage associated with lap splices located near the foundation of reinforced concrete (RC) structural walls has been recorded in the field after recent major earthquakes in Chile and Taiwan, and in multiple laboratory investigations completed in the last two decades. Strain concentrations occurring near lap splice ends can cause decreases in wall deformability and, as a result, compromise building resilience. RC standards in the USA, Taiwan, and Chile have banned all lap splices located within plastic deformation regions of structural walls in response. In contrast, the current New Zealand RC standard (NZ3101:2006A3) allows lap splices near ductile RC wall foundations when splices are staggered by 50% of the lap length and when no more than one of every three bars is spliced at a given section. To date, no systematic study of the details allowed by the New Zealand RC standard has been performed. Six full-scale RC walls with NZ3101:2006A3-compliant confining reinforcement and concrete clear cover will be cyclically tested to quantify the strength and deformation capacity of structural walls with staggered lap splices arranged near the foundation. The New Zealand seismic assessment guidelines consider lap splice strength, but amendments may be required based on staggered lap splice deformability. Experimental results will assist in assessing the seismic vulnerability of New Zealand's building stock.

Kim, J., Jeong, S. 8

Characterization of dynamic site properties in the Gimhae Plains using the Microtremor Array Method and the Horizontal-to-Vertical Spectral Ratio method

We determined the dynamic characteristics of the Gimhae Plains sediments located in the southeastern part of the Korean Peninsula. We estimated the fundamental mode vibration frequencies by microtremor horizontal-to-vertical spectral ratios (HVSR) at over 200 locations. Using the Microtremor Array Method (MAM), we also derived Rayleigh wave dispersion curves by applying the high frequency–fk (HFK) method and the modified spatial autocorrelation (MSPAC) method. We obtained shear wave velocity profiles by inverting the fundamental mode Rayleigh wave dispersion curves. Obtained velocity profiles show that shear wave velocities are around 200m/s in the shallow Holocene estuarine and deltaic sediments and nearly 400m/s for the late Pleistocene fluvial deposits overlying the bedrock. Based on the obtained profiles, we developed a simplified shear wave velocity model of Gimhae Plains sediments as a function of depth. Our results suggest that bedrock is likely encountered at the depths of 60~100m at most sites where we obtained HVSR. We also found that significant amplification of ground motion is expected in the vibration frequencies f≥1Hz in this region.

Kuncar, F., de la Torre, C., Bradley, B., Lee, R. 9

Evaluating the performance of 1D site-response analysis in physics-based earthquake ground-motion simulations: Insights from small-magnitude events

Physics-based ground-motion simulations enable the explicit modelling of earthquake rupture and region-specific seismic wave propagation effects, offering significant advantages for ground-motion prediction over conventional empirical models. However, due to computational and knowledge limitations, local site effects are usually not explicitly included in the regional-scale simulations, and instead, they are typically modelled through an empirical amplification factor based on the parameter Vs30. Recent validation studies conducted in New Zealand have suggested that the explicit modelling of local site effects using site-response analysis has the potential to significantly improve predictions, especially at complex sites. Using observations from small-magnitude earthquakes at 20 strong-motion station sites located in Christchurch, the aim of this study is to systematically evaluate the performance of 1D site-response analysis and compare it to that of the conventional Vs30-based approach. A previous validation study was conducted at the same sites considering 11 moderate-to-large magnitude events, mostly from the 2010-2011 Canterbury Earthquake

Sequence. However, modelling complexities associated with those events added significant uncertainty to the input motions used in the site-response analyses, which limited the inferences regarding the performance of this approach. The use of small-magnitude events in this study will reduce this uncertainty and substantially increase the validation data, which will help to draw more robust conclusions. In addition, the regional-scale simulations used will incorporate recently implemented improvements, which also will be beneficial for this purpose.

Kuwabara, R. 74

Effect of Cyclic Demands on Residual Capacity of Reinforcing Steel Bars

Following the Christchurch earthquakes in 2010-11, over 60% of multi-storey buildings in Christchurch CBD were demolished due to lack of specific guideline for assessing residual capacity and repairability of earthquake-damaged buildings. To prevent such significant demolition in future earthquakes, a methodology for assessing residual capacity and repairability of damaged buildings is needed. This study specifically focuses on low-cycle fatigue (LCF) failure of reinforcing steel bars during earthquakes, which can cause significant performance decay of a whole building. Probable cyclic demand was estimated using a single-degree-of-freedom (SDOF) model based on an existing building and 972 spectrum-matched strong-intensity ground motion records, of which half were long duration (LD) motion and half were short duration (SD) motions. Displacement response history of the SDOF model was subsequently converted to an equivalent uniform cyclic displacement history to identify the number of effective cycles applying a low-drift-cut-off of 0.5% so that any drifts below 0.5% was excluded as they were essentially elastic demands. The results shows that the maximum number of effective cycles is likely to be 15 cycles with combination of a long, short duration ground motions and one standard deviation. Comparing the probable cyclic demand to the low-cycle fatigue test database assuming the maximum strain demand of 0.05, it was found that LCF is a concern for some cases. Particularly for buildings that experienced inelastic demands (e.g. repaired buildings), detailed investigation should be undertaken to ensure LCF failure does not occur.

Lacrosse, V., McDougall, N., Saunders, W., van Ballegooy, S., Bird, E. 47

Loss Modelling of Lower Hutt to Inform Future Growth Planning

Loss modelling has been applied to compare various options for future growth in Lower Hutt. New fragility functions have been used which give an account of earthquake damage to houses from shaking and liquefaction under different-sized earthquakes, including a Wellington Fault rupture event.

For each earthquake scenario, the modelling gives credible estimates for damage costs, the number of houses needing to be rebuilt, and the number of displaced individuals. It can also provide a point of comparison between building design types and choices for areas of increased housing density.

The results from this work can directly inform land use planning, and allow us to give empirically justified answers to questions such as: how much benefit is associated with avoiding areas with a high shaking or liquefaction risk? Should we be building smaller buildings, or larger ones? Which foundation designs are most economic in the long run? What is the effect of sea level rise on these outcomes?

The approach we have taken is very general and will soon be applied to areas outside of Lower Hutt.

Li, L., Chang-Richards, A., Boston, M., Elwood, K. 75

Analysis of quantitative methods for assessing functional recovery in post-earthquake

While modern building design codes ensure buildings achieve the life safety performance objective, a 'better than code' building design, namely functional recovery, is needed. As evidenced by the Canterbury earthquakes and the Kaikōura earthquake, continued building functionality in post-earthquake with acceptable recovery times considered is important for community resilience. This research focuses on a critical analysis of quantitative functional recovery assessments. A number of functional recovery quantification methods are compared with their advantages and disadvantages discussed. It is suggested that future research could focus on measuring functional recovery probabilistically, capturing pervasive uncertainties towards different functionality levels with more advanced algorithms, such as neural network theory.

Li, Z. 29

Seismic strengthening of RC walls using FRP to prevent axial failure

Reinforced concrete (RC) wall buildings could collapse in an earthquake due to the collapse of the RC walls. RC walls with insufficient compressive strain capacity of boundary region concrete are unable to withstand the moments in the plastic regions caused by the seismic forces. As a result, the walls can experience premature crushing of the plastic regions and fall, which is named axial failure as a way of collapse. A solution of strengthening the RC walls was tested successful in preventing the axial failure of full-scale pre-1970s singly reinforced walls built in New Zealand. This solution applies fiber reinforced polymer (FRP) laminate and spike anchors forming confinement of the wall boundary region concrete to improve the compressive strain capacity. Moreover, a series of concrete prisms simulating the full-scale wall boundary regions with and without such FRP confinement were tested subjected to axial compression, to reveal the improvement in compressive strain capacity of the boundary region concrete individually. The experimental results of the pre-1970s singly reinforced walls and the concrete prisms are the focus of this poster.

Logan, T. 99

A holistic conceptualisation of risk and resilience

Why do we hear calls to separate and independently manage aspects of risk and resilience that are inherently related? These arguments are inconsistent with more holistic and integrated responses to wicked challenges – such as climate change – that are necessary if we are to find balances and synergies. The justification of such views is based on misconceptions of risk science that are no longer accurate. Rather than being irrelevant, the risk concept and related literature provide a wealth of resources for resilience analysis that may be being overlooked. In this Perspective, we introduce how the modern view of risk can provide an integrated framework for the key aspects of resilience.

London, W., L'Hermitte, C. 90

Maintaining the continuity of cruise ship supply chains in the aftermath of sudden disasters

The replenishment of cruise shipping supply chains (CSSCs) in the aftermath of natural hazards is a complex operation. This exercise is even more complex in remote destinations such as New Zealand. Cruise ships visit ports and explore shorelines where transport infrastructure and logistics networks may be severely damaged by a natural hazard or not exist at all. Onboard each of these ships may be hundreds or even thousands of passengers and crew whose needs must continue to be met in the aftermath of a natural hazard. Replenishment of a cruise ship's food and beverages as well as its hotel and technical supplies, fresh water and fuel involves

public and private sector actors. These actors represent diverse interests across the globe including the cruise lines, suppliers, transport and logistics operators, ports and governments. Efficient CSSCs require the cooperation of these actors; the integration of supply chain processes; the availability of transport and logistics services; the guidance of policy; and crucially, the elimination of constraints impeding fast replenishment. This qualitative research aims to understand the CSSC as a system using Systems Theory. Then, the Theory of Constraints Thinking Process will be applied to identify and eliminate or mitigate the constraints impeding ship replenishment. This research is expected to contribute to empirically-grounded policy and guide the shaping of national and destination-level resiliency strategies which address the replenishment of cruise ships in the aftermath of a natural hazard. A case study involving semi-structured interviews with actors involved in all aspects of the CSSC will be undertaken to gain a rich understanding about how CSSCs operate in NZ. This poster presents the conceptualisation of this doctoral research project.

Lotfi Rad, P., Clifton, G., Lim, J. 82

Seismic behaviour of cold-formed steel strap-braced stud walls as lateral force resisting systems for residential mid-rise buildings

The use of cold-formed steel (CFS) construction has increased significantly worldwide in the past few decades, especially in the construction of portal frames and low-rise to mid-rise residential buildings. Cold-formed steel construction, compared to more traditional hot rolled steel and timber framed construction, provides many advantages such as being lightweight, dimensionally stable, fast to build, rot and insect resistant, recyclable, sustainable, and having high potential for computer aided design and manufacture. Although much research has been done on CFS-related topics, there are still many gaps in our knowledge of system structural behavior, particularly in severe earthquakes. In this experimental research, a series of component tests along with full-scale wall tests are being undertaken to investigate the seismic behavior of the strap-braced stud-walls as lateral force resisting systems (LFRS) for residential medium-rise buildings. This testing is using a novel test rig which is capable of applying constant vertical load during lateral cyclic testing and which subjects the walls to the loading conditions encountered when these are part of the vertical load bearing system and the lateral load resisting system. The wall behaviour under combined actions can be different to that under lateral loading alone, as has been previously tested in the conventional P21 tests. The different configurations of strap-braced stud walls, along with currently used K-braced frames and plasterboard braced frames are all being tested in the current test series.

MacKenzie, J. 57

Stories of Glenorchy – Community Engagement and Resilience in Adapting to Cascading Natural Hazards

Many communities in Aotearoa sit within dynamic and multi-hazard environments. As such, it is important that local authorities plan for complex environmental change and empower communities to be prepared for hazard events, enhancing their resilience in an uncertain world. While local authorities are aware of the long-term challenges that cascading natural hazards and climate change impacts present, they are reluctant and fearful of engaging with communities in participatory processes. This research focuses on community engagement mechanisms undertaken by the Otago Regional Council (ORC) in developing a long-term, natural hazards adaptation strategy using the Dynamic Adaptive Pathways (DAPP) approach in the Whakatipu basin township of Glenorchy. The ORC is working in collaboration with local communities, Queenstown Lakes District Council, Kāi Tahu and the Department of Conservation. DAPP has been promoted by the Ministry for the Environment as a tool for local authorities in long-term strategic planning and decision-making processes. Community engagement is at the centre of the MfE's ten-step decision cycle of DAPP. This research uses

qualitative methods (interviews and participant observation) to explore how stories of place and science can provide the foundation for knowledge exchange, effective translation of complex information, and engage communities in hazard management planning. Local stories have enabled councils and scientists to understand the significance of place and local knowledge to iwi and hapū and local communities. Conversely, communities have learned about hazards and risk through science stories. Combined, these different stories of place can build relationships and trust between council, partners and communities. Additionally, this research aims to help local authorities engage with communities to empower them to take on disaster preparedness planning and action to become more resilient.

Magill, C., Horspool, N., Moratalla, J., Wang, X., Beale, T., Griffiths, N., Lin, S., Woods, R., Heron, D., Kelly, S., Lukovic, B. 48

RiskScape® for multi-hazard multi-impact risk assessment – Napier case study

RiskScape® is open-source risk modelling software created by GNS Science, NIWA and Toka Tū Ake EQC, with development largely undertaken by Catalyst IT. RiskScape® provides a platform for users to deploy deterministic, stochastic or probabilistic, single- or multi-hazard risk assessment models. A key feature of RiskScape® is its geospatial capabilities that allow geoprocessing and spatial sampling, and for hazard and exposure information to be geographically combined. Risk functions (fragility or vulnerability) are called within workflows or 'pipelines' to allow quantification of impact and risk.

Multiple hazard layers, with different metrics, intensities and temporal occurrences can be included to create coverage data of simultaneous or sequenced multi-hazard events for each exposure. Multi-hazard event impacts are then determined for each exposure using conditional or nested statements that apply functions in a logical sequence taking into account prior impacts.

We present a case study for Napier where two Hikurangi subduction scenarios (Mw 8.4 and 8.9) create both intense shaking and tsunami inundation. Impacts were calculated for these scenarios occurring now and with sea level rise and vertical land movement anticipated in 100 years. Likely impacts to both current and planned building exposure were modelled, as were potential casualties from the combined shaking/tsunami hazard. We will present building loss and casualty estimates for the two scenarios and show how risk modelling may be used to explore the benefits of mitigation options.

Mason, D., Brabhaharan, P., Fenton, C., Massey, C. 10

Performance of cut and fill slopes in the 2016 Kaikōura earthquake

The 2016 Kaikōura earthquake caused widespread damage to transport networks across the northeast part of the South Island, including fault rupture, landslides, debris flows, rock falls, slumping of embankments, and failure of retaining walls and bridges. Landslides and embankment failures caused the most damage and disruption, closing the Main North Line railway for 9 months and State Highway 1 for over a year. The extent of ground damage and the duration of outage of this nationally important corridor reinforce the need to improve earthquake design practices for slopes and enhance our understanding of hazard management of existing infrastructure.

A study of the mechanisms of slope failure and research into the performance of cut and fill slopes in the Kaikōura earthquake is underway, to document the impacts caused by the slope failures, analyse the failure mechanisms, and identify the key factors that contributed to the slopes' performance, which would underpin the development of resilience-based approaches to design of new slopes as well as management of the ubiquitous landslide hazards along infrastructure corridors throughout New Zealand. The findings from the investigation and analysis of key cut and fill slope failures in Kaikōura are presented in this poster.

Mayer, B., Boston, M., Chang-Richards, A. 76

Post-disaster functionality requirements of building occupancies: A literature review

Expectations for performance and functionality differ between building occupancy types after disasters. For example, some occupancy types, such as residential buildings, are designed to protect the lives of their occupants during a disaster but may require extensive repairs or demolition. Other critical structures, such as hospitals, are designed with the intent of continuous functionality, but may still experience disruptions due to structural and non-structural damage. However, there is still some uncertainty about what constitutes acceptable functionality levels for some building occupancies and what components are required to achieve these levels. This poster presents the findings of a literature review that investigated the role of the building occupancy type in determining the acceptable post-disaster building functionality. The findings were used to inform future research directions, including providing decision-makers with insights into societal expectations that should be accounted for when developing design standards.

McCombe, G. 58

A Lot on Our Plates - East Coast LAB and AF8 Social Media campaign

A Lot On Our Plates is a social media campaign, funded by Toka Tū Ake EQC, that aims to educate communities about plate boundary hazards through a collaboration between two plate boundary hazard projects – East Coast LAB and AF8. In 2022, the campaign ran for six weeks, with daily social media posts concluding in a live panel event in which seven scientists answered the public's questions. The first A Lot On Our Plates campaign ran in 2020 in order to engage communities virtually during COVID-19 restrictions, but the approach continues to be a valuable means of engagement.

Each week a different topic was explored, including tectonic plates, earthquakes, landscape changes, water movement, and cascading hazards and impacts. Information on each topic was communicated through bespoke graphics, quizzes, videos, and stories, each week includes a "call to action" post requesting people send in their questions for the live panel.

A Lot on Our Plates campaign is an example of how science communication can be delivered virtually and still achieve a two-way 'conversation', that is engaging and responsive to audiences' interests.

McDougall, N., Lacrosse, V., van Ballegooy, S., Bird, E. **30**

Loss Modelling of Shaking and Liquefaction damage to NZ Residential Buildings — New Fragility Functions

New earthquake fragility and vulnerability functions for New Zealand residential buildings have been developed. These functions are the basis for a probabilistic loss model. Damage due to shaking and liquefaction have been modelled separately.

We used data from the Canterbury Earthquake Sequence and the Kaikōura Earthquake. The data comprised comprehensive insurance claim data, PGA models, and historical liquefaction observations.

We considered the effect of various building attributes: construction year, floor area, number of storeys, foundation type, wall and roof cladding type, footprint irregularity.

The fragility and vulnerability functions apply to one and two storey buildings on flat land. They can be used to inform regulatory frameworks, future growth planning, insurance needs, and disaster response preparation.

The functions provide unprecedented insights into how houses respond over different levels of shaking intensity and liquefaction severity. They provide an empirically justified answer to questions such as: Has the introduction of NZS3604 improved housing resilience to shaking damage? Which building attributes most significantly impact the level of shaking or liquefaction damage on a house? Which combinations of attributes give rise to the best (or

the poorest) building performance? Which levels of shaking correspond to structural vs. cosmetic damage? What is the level of variability in performance between similar buildings?

McEwan, E., Stahl, T., Howell, A., Langridge, R., Wilson, M. 11

Modelling Fault-rupture Induced River Avulsions: A new method for examining coseismic river response to fault-surface displacement

Fault surface ruptures are capable of causing coseismic river avulsions, wherein streamflow is abruptly diverted from an established course. Notable examples of this phenomenon have been documented throughout history, yet the factors influencing instantaneous coseismic avulsions have not been examined in detail. Here, we examine the 2016 Kaikōura earthquake, where ~7 m of vertical and ~4 m of lateral offset upon the Papatea Fault partially avulsed the braided course of the Waiau Toa | Clarence River. Exceptional pre-and-post event imagery, lidar and river data allowed for a simple 2D hydrodynamic model to be developed, capable of replicating the salient characteristics of the river avulsion. Calibration models were compiled using post-event lidar, and 2012 'pre-event' lidar deformed with a synthetic fault-scarp reflective of Papatea Fault displacement vectors. Model results compared against classified satellite imagery taken on the day of the event, exhibited spatial accuracy scores ranging from 64% to 78%, and hydrodynamic predictions of avulsion flow paths closely matched those observed in nature. Our findings demonstrate that with some knowledge of fault location, kinematics, and river flow behaviour, the salient characteristics of the coseismic avulsion could have been forecast prior to the event. Active faults intersect rivers in >26,000 known locations worldwide, and this technique opens the door for probabilistic hazard models to be developed in localities where faults and rivers intersect. Many populations live in close proximity to such intersections, yet the impacts of earthquakes and flooding are typically considered in isolation despite not being mutually exclusive hazards. Flood models that disregard the presence of active faults may therefore ignore, or underestimate the extent, severity and spatial pattern of inundation following seismic events.

McMecking, J., Robinson, T., Wolter, A., Stahl, T. 12

Modelling the Hazard and Risk of Landslide Dam Outburst Flooding on the West Coast, New Zealand

Earthquakes can trigger a cascade of secondary hazards often more damaging than the initial shaking. One of these hazards is landslide dams, which form when debris from a landslide blocks a river. These natural dams are often unstable and can fail soon after formation, sending a large flood wave downstream. Here, we outline a model to predict landslide dam formation hazard on a regional scale by combining valley width with local relief, and apply it to observed landslide dam locations in North Canterbury following the 2016 Kaikōura earthquake. We show that in excess of 98% of observed landslide dams formed in locations where local relief exceeds local valley width, providing a threshold to evaluate hazard. In total, 1500 km (72.5%) of river in North Canterbury lie above this threshold, resulting in 228 observed landslide dams at a rate of 1 per 6.6 km. Applied to the West Coast Region, we show that >10,500 km (45.4%) of order 2 or greater streams sit above this threshold and therefore have potential for landslide dams in a future Alpine Fault earthquake. Using a conversion rate similar to that observed in North Canterbury, this could amount to >1500 landslide dams across the West Coast Region. This suggests landslide dam hazard following an Alpine Fault earthquake could exceed that witnessed in the 2016 earthquake, and may even exceed that witnessed in the 2008 Wenchuan earthquake. Future work will undertake a series of outburst flood inundation models at key sites to evaluate outburst flood hazard. This research demonstrates an approach for evaluating landslide dam potential regionally, and will allow greater understanding of the risk from landslide dams elsewhere in New Zealand.

Miranda, C., Toma, C., Elwood, K., Becker, J., Johnston, D., Stephens, M. 83

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 structural 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 to 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.

Morris, N., Chandramohan, R., McGann, C. 31

Mitigating the occurrence of numerical non-convergence in nonlinear structural analysis

Structural analysts frequently encounter numerical non-convergence when conducting nonlinear structural analysis, and the source of non-convergence is not yet fully understood. The likelihood of encountering non-convergence typically increases with model complexity, level of nonlinear response, and duration of loading. Hence, non-convergence represents a significant obstacle impeding the advancement of structural analysis techniques. Although a number of heuristic strategies are available to overcome non-convergence, none of them are guaranteed to work. Recent studies have shown that persistent non-convergence is often misinterpreted to represent structural collapse due to dynamic instability, leading to the underestimation of structural collapse capacity. This study seeks to understand the mechanism behind the occurrence of numerical non-convergence in nonlinear structural analysis, and to develop strategies to mitigate its occurrence. Preliminary investigations into the dynamic response of nonlinear single-degree-of-freedom (SDOF) systems has helped identify the relationship between the convergence tolerance and the precision of computations as the primary source of numerical non-convergence. The dependence of the convergence behaviour on parameters such as natural period, damping ratio, strength reduction factor, and analysis time step was studied. Finally, guidelines are developed to select an appropriate convergence tolerance to avoid non-convergence in the analysis of SDOF systems. These results will serve a starting point for the investigation of the convergence behaviour of more complex multiple-degree-of-freedom (MDOF) systems.

Motha, J., Bradley, B., Paterson, J., Lee, R., Tarbali, K., Schill C. 13

Cybershake NZ v22.6: New Zealand simulation-based probabilistic seismic hazard analysis

This poster presents the computational components and results of the June 2022 version (v22.6) 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 v2.07) 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.

Mowll, R. 91

Infrastructure planning emergency 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 emergency 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 emergency levels of service across utilities for following an emergency event? Can this framework then be used to define any gaps of delivery of services?

Mueller, S., Orchiston, C., Bond, S. 59

Exploring Rural Communities' Resilience to Natural Hazards: a participatory disaster scenario simulation addressing secondary and cascading hazards

Participatory scenario-based approaches to resilience research can enable and support community resilience to earthquake hazard impacts by producing local place-based outcomes and strategies with community members. One challenge lies in transforming general conceptual ideas of resilience from guiding documents like the Sendai Framework for Disaster Risk Reduction, Sustainable Development Goals, and National Disaster Resilience Strategy into relevant, practical, and beneficial community scale actions to enhance resilience in local contexts. Currently, the academic literature contains very few examples of participatory studies involving collaborative scenarios to support local efforts to build resilience to impacts of earthquakes and the secondary and cascading hazards. This research aligns with QuakeCoRE Disciplinary Theme 4 with the aim to contribute to the literature by identifying steps and pathways to enhance community resilience through a participatory, scenario-based approach. Using a qualitative and geospatial methodology, community members and researchers constructed and workshopped a disaster simulation scenario based on the significant seismic risk presented by the Alpine Fault in New Zealand. In the scenario, co-created maps and sticky note brainstorms facilitated a sequence of group discussions on the community's current level of resilience, likely hazards and impacts, and long-term recovery. Finally, participants reflected on the scenario and identified practical actions to enhance resilience in their community. Findings show how participatory scenario-based approaches can support pathways to enhance community resilience that are specific to local hazardscapes, local contexts, and the communities' strengths, priorities, and values.

Naguit, M., Young, J., Salichon, J. 14

GeoNet's Strong Motion Network: 21 Years of Data Products & Services

Seismic strong motion data is a core component in fields of Seismology and Earthquake Engineering. Since GeoNet came into being in July 2001, this non-profit project improved the strong motion data as one of its base products and service for end-users including Engineers, Seismologists, Seismic Risk & Hazard Specialists and Urban Planners.

GeoNet operates under the Data Science & Geohazards Monitoring Department of GNS Science. It is primarily funded by the New Zealand Earthquake Commission (EQC). With highly integrated system, GeoNet offers data collection and processing, real-time monitoring, rapid response, and event analysis for various natural hazards –earthquake being the main item. GeoNet's network of over 315 strong motion stations situated strategically in New Zealand generates an ensemble of data products available within minutes of an earthquake – thanks to the real-time transmission of continuous data streams and near-real time data processing and accessibility.

Over the span of 21 years, the strong motion data grows dramatically along with denser networks, upgraded data transmission and better instrumentation. The advent of new technology makes large databases more dynamic and accessible, even supported by webservices to access seismic waveforms, metadata and catalogues in a robust and rapid fashion. The GeoNet strong motion network supports free-field and the NZ widespread locality, where strong motion instruments complement the weak motion instruments for rapid ground motion assessment and near-event source information. There are also 20 structural array sites in selected buildings and bridges that support earthquake engineering initiatives in improving NZ seismic design and in the upgrade of structural mitigation measures. GeoNet continuously caters to the requirements of its end-users to offer quality products and support services.

Nwadike, A., Aigwi, E., Wilkinson, S. 84

New Zealand Building consent activities in the COVID-19 pandemic era

Building consent activities provide a platform that thoroughly checks that all designs comply with the building code and other applicable requirements to ensure that only safe, healthy, durable, affordable homes and other related building projects are constructed in New Zealand. The study explores how the COVID-19 pandemic affects New Zealand building consent activities. A qualitative research method consisting of document analysis and integrative literature review was used to understand the New Zealand building consent activities during the COVID-19 pandemic from 2018 to 2021. The study findings show that the building consent activities were affected during the first sets of total lockdowns that led to several stop-work orders at different stages. However, the study outcome indicates an unexpected significant increase after the lockdowns across New Zealand due to changes in the building consent rules and proactive government measures to support the construction industry's recovery.

Pascua, C., Henry, R., Toma, C. 32

Experimental tests on concrete wall-steel beam connections

In recent years, buildings constructed with concrete walls and steel frames have started to emerge in New Zealand. Despite their growing numbers, the seismic performance of this building type has not been extensively investigated and there is little research on concrete wall-steel frame connections. Current design standards in New Zealand are compartmentalised according to material and therefore design procedures for concrete wall-steel beam connections are not explicitly addressed. Moreover, while engineers typically design such connections as pinned, this assumption still needs to be verified.

In this PhD research, experimental tests are currently being conducted to understand the rotational stiffness and capacity of typical concrete wall-steel beam connections, and to verify

the failure modes. Initial findings showed that even though these connections were designed to fail in a ductile manner, brittle failure still occurred by concrete breakout. The experimental data will serve as input for a whole building model. Ultimately, the results of the study will be useful to inform building design guidelines.

Paterson, J., Bradley, B., Wilson, P., Lee, R., Motha, J. 15

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.

Polwart, M., Robinson, T. 16

Risk from post-earthquake landslides: modelling potential remobilisation of coseismic landslides

Earthquakes can cause secondary hazards that can far outlast the initial shaking, resulting in long-lived and ongoing hazards. Following initial coseismic landsliding, post-seismic landslide hazard can continue and increase due to unstable failure surfaces. The 2016 Kaikōura earthquake resulted in over 20,000 landslides. Since the event many landslides have reactivated in storm events, impacting transport infrastructure. Previous studies have highlighted the initial impacts from coseismic landsliding during this event, however little research looks at the longevity of these hazards in Kaikōura.

This study reduces this gap by creating an understanding of the current and future risk from landslides following the earthquake. We map landslides along the coastal transport corridor (CTC) in Kaikōura and Mt Fyffe yearly between 2013 and 2021 to evaluate how landslides have evolved pre-, co- and post-seismically. A statistical analysis of mapped landslides shows a decrease of ~50% in the number and area of landslides since the earthquake in the CTC. This decrease is likely a result of engineering of unstable slopes. Comparatively, the number and area of landslides on Mt Fyffe, where no human modification has occurred, shows little change since the earthquake, with a decrease of just ~1%. A spatial analysis shows that landslides directly on the coast experienced more recovery compared to those further inland along the CTC, further supporting that slope mitigation works adjacent to the critical transport links are responsible for faster recovery rates and are effective. Future work will model potential runouts from selected landslides using RAMMS and Flow-R to help understand what future debris flows may look like, and identify high risk locations. This research will aid in more effective planning for a resilient CTC.

Prasanna, R., Chandrakumar, C., Nandana, R., Holden, C., Punchihewa, A., Becker, J., Jeong, S., Liyanage, N., Ravishan, D., Sampath, R., Tan, M. 100

Novel Earthquake Early Warning Sensor Architecture Driven by Low-Cost Ground Motion Sensors

Research led by the Crisis Response and Integrated Simulation Science Laboratory (CRISiSLab) of the Joint Centre for Disaster Research (JCDR), Massey University has implemented an experimental earthquake early warning network (EEWN) using Micro Electromechanical

System (MEMS)-based low-cost ground motion sensors. The study proposes a unique EEWN architecture driven by a Software-Defined Wide Area Network (SD-WAN)-based hole-punching technology consisting of MEMS-based, low-cost accelerometers hosted by the general public. In contrast to centralised cloud-based approaches, a node-level decentralised data-processing is used to generate warnings with the support of the modified Propagation of Local Undamped Motion (PLUM)-based earthquake early warning (EEW) algorithm. With several hypothetical earthquake scenarios, experiments are conducted to evaluate the system latency, and packet loss of the proposed EEWN architecture and its results are compared with more conventional centralised EEWN architectures. The results provide clear evidence to show that the decentralised EEWN architecture can outperform centralised EEWN architectures and can save valuable seconds when generating EEW, leading to a longer warning time for the end-user. Further, the number of packet losses of data in the proposed network is negligible compared to the conventional centralised EEWN architectures. In addition to the warning time and packet loss comparison, in this study, experiments are also conducted toward identifying an appropriate communication protocol for peer-peer communication between sensors.

Prattley, L., Beaven, S., Wilson, T., Leonard, G., Williams, J. 60

Tsunami Evacuation Behaviour: A review of survey findings across Aotearoa New Zealand

Approximately 70% of the people in Aotearoa New Zealand reside in coastal areas, and almost 10% of the national population live within tsunami evacuation zones. Tsunami are a low frequency, high impact hazard event, with the potential to cause widespread damage and loss of life. Evacuation from exposed areas is the only effective emergency response to imminent tsunami hazard. A recent international review has indicated that most tsunami research has focused on particular aspects of evacuation operations (from initial warnings to return to home), finding that more research is required to understand evacuation behaviours across the wider evacuation process, from initial warnings to the return home.

A literature review of research conducted with Aotearoa New Zealand coastal communities has compiled and synthesised 11 publications reporting on tsunami evacuation survey findings. Of these, 4 are prospective, using questionnaires that invite participants to share tsunami awareness and evacuation expectations. The other 7 have gathered data after recent tsunami evacuation events. Nine report on small, localized case studies, with another 2 that are much broader in scope. The data is unusually comparable, reflecting the tightly linked tsunami research community in Aotearoa New Zealand. Each study acknowledges and builds on preceding work, ensuring that key questions continue to be asked over the last decade. Key themes include hazard perceptions, awareness, preparedness, response activity and sources of tsunami and warning information. Since 2018, survey questionnaires have widened the focus to include behaviours across the end to end evacuation process, helping to address this gap in the global literature.

Qin, Y., L'Hermitte, C. 92

Identifying and mitigating post-disaster transport disruptions: a study of perishable food deliveries in New Zealand

The perishable food sector plays a critical role in New Zealand's economy. However, New Zealand being prone to natural hazards, disruptions in the movement of perishable food products are common. Infrastructure damage and traffic disruptions trigger cascading effects across transport operations (congestion, insufficient trucking capacity, shortage of drivers, late deliveries, etc.). Academic research capturing this complexity and the interconnections between multiple transport disruptions in the perishable food sector is limited. Therefore, this research will address the following questions: 1) How do major disasters disrupt the transport of perishable food products? 2) How can the disruptions in the transport of perishable food

products in the wake of a major disaster be mitigated? Semi-structured interviews with key informants involved in the transport and distribution of perishable food products will be conducted to collect primary data. Topics will include the transport constraints experienced in the aftermath of a major disaster and the mitigation strategies used to reduce the impact of freight disruptions. Data will be analysed thematically and a set of analytical tools provided by the Theory of Constraints' Thinking Process will be used to capture the complexity of the New Zealand freight transport system when a disaster strikes. More specifically, this research will establish the cause-and-effect relationships between multiple transport problems, identify the root causes of these problems, and investigate possible mitigation strategies supporting the timely delivery of perishable food products. By comprehending the complex reality of the freight issues experienced in the perishable food sector in the wake of a disaster, this research is expected to support the development of effective freight resilience strategies. The poster outlines the objectives, scope, and approach of this research.

Rahayani, R., Nair, N. 101

GIS-AHP Analysis of Optimal Solar Site Locations based on Disaster Risk Assessment

As part of the commitment to reduce GHG emissions in electricity production, New Zealand has planned to achieve the target of 100% renewable energy by 2035. One renewable energy resource that is abundant in nature and has a high potential to be developed in New Zealand is solar energy. In addition, global solar generation technology improvement and declining capital costs also impact solar power development. Site selection for solar power plants is a critical stage. Proper planning aims to produce more solar power with low investment and operation cost and harmless to the environment. Even though solar irradiance became the primary consideration in site selection, the disaster risk assessment should be included in site selection considerations since New Zealand is a disaster-prone country. This research will propose a reliable tool for site location selection for large-scale solar power plants in New Zealand. Using the Analytic Hierarchy Process (AHP), disaster risk will be analyzed and integrated into a Geographical Information System (GIS) package. GIS layer will define local constraints based on required descriptive data such as settlement location, power grid, road network, forestry area, endangered habitat, cultural land, water bodies, plantation & farming.

Rangwani, K., Rodgers, G., MacRae, G., Ramhormozian, S., Clifton, C., Yan, Z. 33

Frictional GripNGrab Component Test

The large scale component experimental testing of the newly developed friction tension-only device, known as the "GripNGrab (GNG)", is described. The 2.2m long device tested, consists of (i) a ratcheting part, which carries force in tension but not in compression as it ratchets, and (ii) a sliding dissipation part, that dissipates energy in friction. Frictional dissipators, in a symmetric friction configuration, uses plates and shims clamped together using high strength bolts. These bolts provide the normal force for the connection, and required force is obtained using partially post-tensioned conical spring washers (PPCSWs). Slotted holes in the central plate allow large sliding displacements. The device is subjected to various cyclic "extension and return to initial displacement" test regimes to represent the behaviour expected of such a device attached to a rocking frame where full post-earthquake recentring is required. During the cyclic extension, where it carries force and then dissipates energy due to sliding, then the displacement is returned to the original position, where ratchetting occurs and the device carries very little compressive force thereby avoiding buckling. Other parameters varied were the device initial axial tension force, the GNG ratchet pitch, and the dissipator bolting.

Rincon Gil, J., Pujol, S., Dhakal, R. 34

Active Confinement of Reinforced Concrete Columns

Existing older reinforced concrete (RC) columns designed and constructed before the 1970s may be vulnerable in an earthquake due to insufficient shear strength and inadequate drift capacity. Past earthquakes have demonstrated the vulnerability of such columns and the need for their retrofit. Popular retrofit techniques such as steel and fibre-reinforced-polymer jackets 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. An alternative that is reliable and easy to apply is needed especially for developing countries and mass retrofit of large inventory of structures. Ease of installation is also key when it comes to emergency repairs after strong ground motion. After a strong earthquake, the repair of a building often needs to be done quickly to ensure rapid restoration of the safety of its occupants and neighbours.

A new retrofit technique consisting of post-tensioned external clamps fastened around the column is proposed. The post-tensioned clamps consist of four steel brackets, bearing against the corners of the square in cross-section column, and high-strength threaded rods connecting the brackets. The confining lateral pressure provided by the clamps is expected to help delay the spalling and crushing of concrete as well as the formation of inclined shear cracks. The proposed technique is easy to design and implement and does not require specialised workmanship. Its effectiveness is tested against experimental data from large-scale RC columns subjected to shear reversals at increasing drift ratios and constant axial load. Initial tests results have proven the efficacy of the proposed technique on improving the shear strength and the drift capacity of RC columns.

Sadashiva, V., Wang, X., Lukovic, B., Lin, S., Heron, D., Suppasri, A. 85

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 residential building portfolio in Napier area will be presented in this poster.

Sauvage, E., Latif, F., Nair, N. 102

Evaluating the seismic resilience of the fixed communication systems

Telecommunications network infrastructure is vital for services which ensure safety and develop economic activities during everyday life. When a natural disaster occurs at a large scale, the proper functionality of the systems appears critical to share information and start organizing the response. This research project aims at defining and quantifying the resilience of the fixed communication network, considering the scenario of a magnitude 8 earthquake on the Alpine Fault. Physical damage on the fixed communication system infrastructure owned by Chorus in the West Coast is first investigated. The analysis focuses then on the service

degradation which is correlated to the abnormally high usage demands that usually follow large seismic events. Outcomes are likely to provide guidelines to design future networks and directions for contingency plans.

Scheele, F., Wilson, T., Becker, J., Horspool, N., Campbell, M. 86

Estimating population displacement following natural hazard events

To plan and prepare for future events we need to have a good understanding of the impacts to communities. This means going beyond physical damage assessments to examine the impacts to individuals and households, such as population displacement, temporary accommodation needs and the resources required to assist households to shelter-in-place. This project will develop agent-based models to assess household impacts for various natural hazard events, utilising an updated residential building inventory and a synthetic population model containing demographic information at the household level. These data sources at the microscale allow for modelling of habitability and resident decision-making for any natural hazard. The models will be demonstrated through case studies such as AF8 and Taranaki Maunga volcanic scenarios.

Shrestha, S., Orchiston, C., Elwood, K., Becker, J., Johnston, D., Tomassi, I. 49

Post-Earthquake Cordons in Practice

Post-earthquake cordons have been used following major seismic events around the world. However, whenever used, it has been a reactive approach to control a chaotic situation created by respective seismic events leading to numerous practical issues during its implementation, especially when maintained for a long period. To this end, this research aims to provide a detailed understanding of cordons and their management, and also shed light on various aspects relevant to practical considerations for cordon use. Qualitative case study approach was used to investigate cordons through two cities where cordons were used for extended periods: Christchurch (Mw 6.3) and L'Aquila (Mw 6.3) earthquakes. Data was collected through 23 key informant interviews obtained through purposive and snowball sampling of participants who were directly or indirectly involved in a decision-making role and/or had influence in relation to the cordoning process. The participants were from varying backgrounds and roles i.e. emergency managers, council members, business representatives, insurance representatives, police, and communication managers. We find that cordons are used primarily as a tool to control access for the purpose of life safety and security, but cordons can also be adapted to support recovery. Broadly, our analysis suggests two key aspects, 'decision-making' and 'operations and management', which overlap and interact as part of a complex system driven by communication and governance structures and processes which is illustrated through the CODE framework. The underlying complexity arises in large part due to the multitude of sectors affected by cordons: economics, law, politics, governance, evacuation, civil liberties, available resources etc. Furthermore, contextual factors such as insurance, demolitions and heritage were significant. The complexity further increases as the duration of cordons are extended.

Singeisen, C., Massey, C., Wolter, A., Bloom, C., Kellett, R., Bruce, Z., Stahl, T. 17

Fault zone contributions to the evolution of a landslide complex – insights from Half Moon Bay, Kaikōura

Tectonic deformation in fault damage zones can influence slope stability and landslide failure mechanisms through structural control and rock mass damage. Here, we use a detailed site investigation to evaluate controls on deformation within the Half Moon Bay landslide complex located above State Highway 1 north of Kaikōura. The landslide, located at a distance of c. 1 km from the Hope fault, likely occurs within the fault damage zone. During the 2016 Mw 7.8 Kaikōura earthquake, it experienced significant ground deformation and partial failure as a

rock avalanche. Morphology, however, suggests that deformation predates the 2016 earthquake. Based on geomorphological analysis, coseismic landslide displacements, geophysical surveys and a 60 m deep borehole in the incipient portion of the landslide, we infer the structure and mechanism of this landslide complex. Our results indicate the presence of sub-vertical structures, appearing in survey as resistivity contrasts, and the drill core shows intense fracturing and weathering of the rock mass gradually decreasing with depth. Specifically, the rock mass is highly fractured in areas with large coseismic landslide displacement, close to the head scarp of the 2016 rock avalanche. Landslide movement mechanisms are thought to comprise a combination of flexural toppling facilitated by the sub-vertical features – assumed to be tectonic structures in the Half Moon Bay area – and 'step-path' sliding along pre-existing, closely-spaced discontinuities within the rock mass. Inherited tectonic structures, cumulative rock mass damage, weathering and amplification of seismic ground motion all contribute to the evolution of this landslide complex and in future events, increasing landslide displacements will likely cause largely intact blocks to transition from sliding to avalanching, with potentially hazardous consequences for the transport corridor.

Sistla, S., Chandramohan, R., Sullivan, T. 35

Benchmarking the seismic performance of a code compliant BRBF building

Benchmarking the seismic performance of a code compliant BRBF is the first step of a larger study aimed at developing a risk-targeted seismic design framework for BRBFs in New Zealand. In this sub study, we assess the seismic performance of a code-compliant buckling-restrained braced frame (BRBF) building in New Zealand using realistic nonlinear structural models. A number of recent studies have highlighted the possibility of gusset plates and brace end-zones buckling out-of-plane before the buckling-restrained braces themselves yield. Very few studies have, however, attempted to incorporate this failure mode in nonlinear models of BRBFs used to estimate their global seismic performance. Hence, the focus of this study is to benchmark the seismic performance of a code-conforming BRBF building, using a novel modelling approach capable of capturing this out-of-plane buckling failure mode. A four storeyed BRBF building was first designed based on the NZS1170.5 standard and the NHERP design guidelines. A nonlinear BRBF model incorporating the out-of-plane buckling mechanism was then developed in OpenSees and analyzed using hazard-consistent ground motions at a series of different intensity levels. The seismic losses were then estimated using the performance-based-earthquake-engineering (PBEE) framework.

Sit, J. 18

Energy-based Liquefaction Assessment Method for Pumiceous Materials

Pumice sands are commonly found in river valleys and flood plains in the Central North Island of New Zealand concentrated at Bay of Plenty and Waikato regions.

The pumice particles are lightweight and in angular shape with vesicular structure. The internal voids are either connected or occluded. The surface voids are opened to the particle surface. The pumiceous particles are therefore highly crushable under significant seismic loadings.

Field energy released from an earthquake will be dissipated in a soil deposit in some forms of seismic response. For hard-grained sands with liquefaction potential, the energy will be dissipated to develop excess porewater pressure and deformation. In addition to that seismic response, the crushing of pumice particles results in greater cyclic resistance. The extensive research done by the University of Auckland using natural undisturbed pumiceous rich and reconstituted soil samples elucidated the seismic response differences between pumiceous materials and hard-grained materials. Carrying out liquefaction assessment for pumiceous materials using the stress-based method could potentially lead to over-conservative and unrealistic results.

Many of the energy-based liquefaction assessment methods have been developed based on the seismic response of the hard-grained materials. To predict the liquefaction potential of the pumiceous-rich materials, strain energy dissipated in the crushing of the pumice particles should be considered in the energy-based method. The research done by the University of Auckland indicated that dissipated strain energy caused by pumice crushing is corresponding to the content of the pumice particles and the intensity of the earthquake. The research will be looking into the development of a new energy-based liquefaction method for pumiceous rich and hard hard-grained soil deposits.

Sivakumar, V., Hogan, L., Henry, R. 36

Seismic behaviour of low-rise precast wall to foundation connection

Slender precast concrete walls are extensively used in the low-rise buildings such as warehouse buildings. Many slender panels in New Zealand utilize a dowel-type wall to foundation connection with starter bars extending from the side of the panel to the foundation to transfer the lateral load demand on the wall to the foundation. Following the Christchurch earthquake, concerns were raised about the robustness of the load path in these connections when shallowly embedded inserts were used (SESOC, 2013). A series of out-of-plane testing on different existing connections confirmed the lack of a reliable load path. These panels are designed as cladding in the out-of-plane direction and are used to hold the building in the in-plane direction. If there is out-of-plane damage to the panel, what happens to the in-plane carrying capacity is studied under bi-directional testing. To determine the overall seismic performance of the panels with the dowel type connections, in-plane and bi-directional testing was performed on two types of threaded insert connections, shallow and deep embedment with 50mm and 0mm cover.

(Hogan et al., 2017) investigated the two inserts and concluded that the panel's performance was similar when subjected to in-plane or bi-directional loading. There was no change in the drift but a difference in the failure modes. In-plane walls had failed with a single crack at the foundation level. The bi-directional test of shallow insert resulted in the formation of a crack, dive down behind the insert, and the panel suffered rapid damage rather than a buckling of bars with a brittle failure. Detailed investigation of these four walls concerning percentage drift and the damage progression will be studied and discussed.

Smith, J., Beaven, S., Wilson, T., Leonard, G. 61

The 5th March 2021 Earthquake and Tsunami Response Survey: collaborative approaches to designing and implementing a national research project.

Tsunami are low frequency, high impact hazard events in which a large volume of displaced seawater washes onto coastal areas. With the potential to cause widespread devastation, tsunami are one of the most life-threatening sudden onset natural hazards. Aotearoa New Zealand's coastline is exposed to local and distal sources of tsunami hazards, posing a significant national risk. Evacuation is the primary strategy for saving lives during a tsunami response, but to date there have been few opportunities to gather data after tsunami evacuation operations to understand responses to tsunami warnings and behaviour during evacuations.

On the 5th March 2021 a sequence of earthquakes off the east coast of the North Island triggered three complex tsunami evacuation responses. Involving multiple agencies and diverse evacuation orders and warning methods, this sequence provided the opportunity to gather data across a wide range of coastal communities. The geographic range and the number of agencies and levels involved required a collaborative, integrated research design, to maximise both the research quality of findings and their value to agencies and communities. Supported by the wider national Tsunami Research Group (TsuRGe), a Working Group was formed to lead design and implementation decisions and activities, made up of research leads

from UC & GNS science and representatives from nine CDEM Groups. CDEM Group representatives also served as key links to local and community networks in coastal areas, leading engagement with local iwi. Meetings led by Māori researchers including local (Canterbury) kaiārahi, focused on ensuring the survey was as inclusive of Māori participants as possible, and informed the use of the survey in aligned science engagement with Māori communities.

Stahl, T., Walsh, E., Howell, A., Robinson, T. 19

Multi-fault earthquakes in an empirical rupture simulator

Multi-fault earthquakes present significant challenges to seismic hazard analysis. Here, we develop a data-driven simulation that uses relationships derived from databases of surface rupturing earthquakes to quantify the relative likelihoods of different rupture pathways initiating on a seed fault. This empirical rupture simulator uses five parameters to compute passing probabilities for all fault section connections in proximity to the seed fault and subsequent 'active ends' of the propagating rupture. We applied the ERS to two seed faults in the region of the 2016 Kaikōura (New Zealand) earthquake and compared the results to independent constraints on paleoseismic magnitude, segmentation, and global estimates of rupture complexity. Rupture set characteristics change based on seed fault location and indicate that kilometer-scale structural discontinuities serve as persistent barriers. Length-based magnitudes generally agree with those estimated from paleoseismic single-event displacements. Our preferred model reproduces total trace complexity of historical earthquake catalogues and rarely generates events involving the specific faults which moved in the Kaikōura earthquake. This approach may be useful for weighting on-fault maximum magnitudes in earthquake rupture forecasts.

Stolte, A., Wotherspoon, L., Jeong, S., Munro, J. 20

The influence of multiple impedance contrasts on mHVSR site period estimates in the Canterbury Plains of New Zealand

An experimental study of the fundamental period of vibration of geologic strata above multiple impedance contrasts is presented for the Canterbury Plains, a deep, complex sedimentary basin on the South Island of New Zealand. Microtremor Horizontal-to-Vertical Spectral Ratio (mHVSR) analysis was used at 152 locations to investigate the fundamental period of the strata above three significant impedance contrasts in the region: the Riccarton Gravel, the Banks Peninsula volcanic (BPV) rock, and the deep greywacke basement bedrock. Up to three mHVSR peaks were observed in many of the mHVSR curves, with the long period (2-7 s) peaks controlled by the BPV and/or the underlying basement bedrock. As thickness of the BPV increases, the response of the geologic strata above basement bedrock was masked by the shallower BPV, effectively changing the definition of what constitutes the reference condition (i.e., engineering bedrock) for site response analyses. The mHVSR peaks matched the long period amplification peaks observed in the response spectra calculated from ground motions recorded during the Canterbury Earthquake Sequence events, underscoring the importance of the identification and consideration of deep impedance contrasts in site classification.

Syed, Y., Uma, S., Sadashiva, V. **93**

Identification of significant factors for the recovery of distributed infrastructure networks through knowledge elicitation processes

Critical infrastructure networks such as electricity, potable water, natural gas, transportation, and telecommunications provide the services that are essential for continuous societal functions. These infrastructure networks rely on each other to be functional and therefore disruption of services for one infrastructure network can directly or indirectly affect the

services of other infrastructure networks. Hence, they are highly vulnerable to any disruptive event which makes their recovery a more challenging task for asset managers and investment decision-makers. In this paper, we study the recovery issues of infrastructure networks following a disruption event. We review the existing guidelines for infrastructure recovery and propose a list of significant recovery factors that should be considered while dealing with any infrastructure network recovery model. The objective behind considering these recovery factors is to minimize the total cost and time associated with the recovery process of the interdependent infrastructure networks and making them more resilient. We did knowledge elicitation with stakeholders who are responsible for the recovery of their networks and what matters to them. This elicitation process is designed to identify significant recovery factors to be considered in planning for their resilience against the hazard in question.

Tan, M., Vinnell, L., Prasanna, R., Becker, J. 62

The public's initial insights on the Android Earthquake Alerts in Aotearoa New Zealand

The Android Earthquake Alert system was launched in Aotearoa New Zealand on 28 April 2021. Since then, some of the New Zealand public who use Android phones have received earthquake early warning (EEW) alerts, informing them in advance of incoming ground shaking from earthquakes. The technical performance of the alerts is still a work-in-progress since some estimation of the predicted location and magnitude of the earthquake has not been accurate. Moreover, some Android users have missed the alert (i.e. felt shaking but did not receive an alert). Receiving EEW alerts is a relatively new experience for most New Zealanders, so people may not have been aware of such technology when they received the initial Android alerts. Understanding how people perceive and respond to a new earthquake alerting system is important as it will provide insights on communicating better for EEW and alerting in general. This poster presents some of the results from a study investigating the public's perception of the Android alerts sent out in 2021, using data gathered from Twitter and two online surveys. The results show that the Android alert recipients generally view the alert positively. However, there is some confusion regarding who the alert is from. Both the Twitter data and survey results show that people anticipate that the alert will be useful in the future. However, the survey found that people did not necessarily know what to do upon receiving the alert. The poster also presents future research opportunities to improve people's response to EEW alerts and to manage people's expectations of EEW.

Till, H., Stephens, M., Toma, C. 37

A Structural Approach to Tsunami Loading on Buildings

Hydrodynamic tsunami forces acting on a building introduce a potentially controlling load case that - as shown following the 2004 Sumatra and 2011 Tohoku tsunamis - can be designed for. Subsequent work has improved the knowledge base on the topic leading to the development of new guidance documents for the design of buildings. Despite the increase in literature and guidance, the state-of-the-art understanding of structural performance for tsunami loading continues to trail that of other design loads. Continued analysis of parameters relevant to the loading scenario will improve the understanding of performance capabilities in the existing building stock. The current study focuses on the impacts of parameters such as flexibility and asymmetric structural openings on tsunami loading profiles. Physical modelling will generate load values for the validation of a numerical fluids model and behavior characteristics for the validation of a numerical structural model. Future work will include numerical modelling to provide insight into the performance of a larger set of structural archetypes, allow for sequential earthquake and tsunami loading analyses, and allow for probabilistic analyses.

Tsai, R., Henry, R., Elwood, K. 38

System response of reinforced concrete coupled walls

Reinforced concrete (RC) wall systems are commonly adopted as lateral-load resisting systems for mid-to high-rise buildings. To meet the architectural requirements, such as door or window openings, RC walls are often divided into two wall piers with coupling beams that form a coupled wall system. Post-earthquake reconnaissance reports and past experimental research has indicated that coupling beams could exhibit higher strength than expected due to axial restraint from the adjacent floor diaphragm and wall piers, altering the seismic actions that develop in the wall piers and overall system. The modified actions could cause an undesirable failure mode if the wall piers if not considered in the design. Therefore, the main objectives of this research are to quantify the impact of axial restraint on the seismic response of coupling beams and the wall piers, investigate the system response of the coupled wall, and provide improved design guidelines for the coupled wall system.

This research has collected a database of coupling beam tests and established a numerical model for simulating the seismic responses from the coupling beams incorporating axial restraint. Furthermore, a series of coupling beam tests will be conducted as part of an international collaboration to quantify the influence of axial restraint on seismic performance of the coupling beams. Following this, the component model will be extended to the coupled wall model to study axial restraint from the adjacent structural members and the force distribution among the components. Lastly, a large-scale test is planned to investigate the seismic response from the coupled wall system. Based on the experimental and numerical study results, robust design guidelines and suggestions will be provided for the coupled wall design.

Vercoe, H. 66

Natural Hazard Recognition & Vulnerability of Marae Infrastructure

Despite the complexity of hosting the multitudes with limited resources, Māori have demonstrated effective emergency management, response and relief. Without adequate infrastructure, marae would not have the capacity to cater for the masses. In many cases, marae are under-resourced, with many having infrastructure, services, and buildings in need of repair or upgrade. As flooding is the most common natural hazard in New Zealand and earthquakes are potentially the most damaging and disruptive, it calls into question the adequacy of marae infrastructure in a natural hazard event. Given the barriers faced by many marae, it is of interest to investigate the infrastructure aspects of marae that could experience disruption in a natural hazard event. The critical services explored in this nationwide marae study include three waters, transport and energy infrastructure.

There is a definite need to develop appropriate solutions for marae, which can experience sharp demand peaks due to the sporadic nature of events and their magnitude. Moreover, there is a need to enhance the natural hazard response of marae to alleviate the strain impacts on infrastructure and whānau. This research seeks to strengthen the resilience of marae infrastructure in combating natural hazard events, with additional consideration to the effects of climate change. Underpinning the research includes exploration of the role of Māori knowledge or 'ways of knowing' in the natural hazard context. Moreover, learnings we can employ from indigenous knowledge systems to inform the future of disaster risk reduction in Aotearoa and clues that may lie within our origin stories and local narratives regarding natural disasters.

Vinnell, L., Inch, P., Johnston, D., Horspool, N. 63

Social Influences on Behavioural Response to Earthquake Shaking

Many earthquake injuries in Aotearoa New Zealand occur because people either do not act quickly to protect themselves or act in a way which can lead to harm. Earthquakes are an uncertain context in which to make behavioural decisions. Previous research has

demonstrated that people's initial response to earthquake shaking is to wait and see if the shaking continues or increases in intensity. Evidence also suggests that people frequently look to those around them for behavioural cues. We discuss this evidence, in the context of underlying psychological phenomena which might explain these behavioural tendencies in response to the uncertainty of earthquake shaking, in particular social norm theory. As part of our discussion, we present evidence from Closed Circuit Television (CCTV) footage of the 2016 Kaikōura earthquake at Wellington International Airport, Aotearoa New Zealand. We make suggestions for future work exploring the role of social influences on behavioural responses to earthquake shaking including the benefit of varies study methods and data types

Vishnu, P., Rodgers, G. **77**

Low-cycle fatigue testing of sacrificial energy dissipating fuses to better understand residual capacity.

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 and strain-ageing effects 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 a low-cycle fatigue assessment of sacrificial steel fuses made from Grade 300E reinforcing steels. It will provide the evidence base for design recommendations on allowable strain limits and will quantify relative low-cycle fatigue performance. Displacement-controlled low-cycle fatigue testing was undertaken at a range of design strain targets, from 1% through to 5%, using both unipolar and bipolar (fully-reversed) cyclic testing. The results indicate a logarithmic relationship between input loading amplitude and a number of cycles to fracture and specific curves are fitted to results for different loading amplitudes.

Walakulu Arachchige, R., Francois-Holden, C., Savage, M., Andreae, P. 64

Testing Earthquake Early Warning Systems for Aotearoa New Zealand

Aotearoa New Zealand is located on the boundary of two major tectonic plates and therefore is vulnerable to earthquakes as well as local and regional tsunamis. Although earthquakes are not predictable, it is possible to issue a warning for areas distant from the epicentre by rapidly analysing seismic waveforms. Currently, earthquake early warning (EEW) systems are implemented in several countries including Japan, Taiwan, South Korea, and Mexico. However, still there is no public earthquake early warning system in New Zealand. The aim of this research is to test earthquake early warning algorithms for Aotearoa New Zealand considering the current seismic and geodetic networks. The key objectives of this research are: develop an understanding of the requirements for a New Zealand EEW system; quantify the effectiveness of the existing EEW algorithms in the New Zealand context; improve or adapt the algorithms to be effective in issuing earthquake early warnings for the New Zealand context while proposing improvements to the current sensor network.

This poster presents an overview of the research project, preliminary work regarding data latency of the current seismic network, and initial simulation results for an EEW algorithm using New Zealand sensor data for recent large earthquakes. Future work will include simulating potential future earthquakes of interest using synthetic earthquake catalogue data

and quantifying the effectiveness of the EEW algorithms for possible future earthquakes in New Zealand.

Wang, K. 103

Realising interdisciplinary machine learning research in QuakeCoRE

Artificial Intelligence (AI), since its invention, has demonstrated the nature of interdisciplinary research that requires and integrates multiple disciplinary knowledge and approaches. From the early days expert systems to modern days data-driven machine learning (ML) systems. Disciplinary knowledge, computing technology, data science, and innovative ways of data sensing and collection are all cornerstones to achieve successful AI and ML solutions in solving real-world challenges. It is without doubt one of the technology megatrends that is impacting the QuakeCoRE and its fields of research, including but not limited to earthquake science, infrastructure resilience, intelligent transportation, smart cities, etc. In this poster, we will present some of the application domains, visions of ML for the QuakeCoRE community, and potential synergies in QuakeCoRE based on the findings of the first survey conducted by the AI & ML establishment group, and to share and to further explore the different views of our community.

Wight, J., Logan, T., Mollenkopf, D., Brown, C. 94

Improving Urban Food Supply Chain Resilience using Hybrid Agent-Based Modelling and Discrete-Event Simulations of Local Supply Chains

Following a disaster, local supply chains are essential to food resilience. Strengthening these supply chains requires the ability to evaluate alternative interventions. However, we must improve our ability to compare different interventions to enable local supply chains to deliver sufficient food to retail stores after a disaster. A hybrid Agent-Based Model (ABM) and Discrete-Event Simulation (DES) will be developed and used to address this. This model will explore different local supply chain interventions that strengthen local food distribution following a disaster. The quantitative output provides decisions makers with the ability to understand better the risks, resources, uncertainty, and trade-offs of the different intervention options.

Wolter, A., Upton, P., Uma, S., Kaiser, A. 21

Site-City Interaction effect on seismic waves – preliminary 2D modelling in the Wellington CBD

How do urban landscapes interact with seismic waves? And do we need to worry? We present preliminary 2D dynamic numerical simulation results to answer these questions. The models were run in Itasca's UDEC (Universal Distinct Element Code, v. 7) using a 1:10 000-year earthquake scenario. Average rock mass, sediment, and building properties were derived and upscaled from laboratory and field testing, and literature. Thirteen simulations were completed, eight along a NNW-SSE cross-section and five along a WSW-ENE cross-section through Wellington CBD.

Preliminary results indicate that the "city effect", or site-city interaction, is significant in Wellington. Maximum shear strain, an indication of deformation, is two orders of magnitude higher in models with buildings than models without. Modelled displacements in specific buildings and within the sedimentary basin suggest that seismic waves are influenced by building configuration and density, not just the sedimentary basin. Duration of shaking is also slightly longer in models with buildings than those without. The initial modelling presented contributes to understanding the city effect, ultimately promoting a safer, more resilient Wellington.

Wotherspoon, L., Lin, A., Zorn, C. 95

How has land movement from the 1931 Hawke's Bay earthquake affected regional exposure?

The 1931 Hawke's Bay earthquake resulted in significant damage to buildings and infrastructure and over 250 fatalities. Tectonic displacements led to uplift greater than 2 metres in some areas, with over 40 square kilometres of land shifted above sea level. This changing landscape altered the way that the region developed following this earthquake, with these new areas of land now supporting residential, commercial and industrial facilities, along with the infrastructure that supports them. Had the 1931 earthquake not occurred, these locations may have not been developed and the exposure of the region to natural hazards would have looked quite different. To explore this further, geospatial analyses were undertaken to assess the level of exposure of buildings and infrastructure to natural hazards at present and the built environment assuming that no uplift or development had occurred. As there is the potential for tectonic subsidence in future earthquakes, the exposure of the built environment to future land movement was also explored. This provides an interesting case study of the potential for long term cascading impacts from past earthquakes.

Yan, Z., Xie, J., Rangwani, K., Ramhormozian, S., Xiang, P., Jia, L., Quenneville, P., Dhakal, R., Clifton, C., MacRae, G., Zhao, X. 39

Three-storey Configurable Steel Framed Building Incorporating Friction Based Energy Dissipaters: Overview of Component Test Results

A 9 m high, full-scale three-storey configurable steel frame composite floor building incorporating friction-based connections is going to be 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. To have a better understanding of the expected system behaviour, as well as the effects of other structural and non-structural elements on the overall system response, experimental testing at the component level has been conducted prior to the shake table testing. The component test specimens were designed and detailed to reprint the connections adopted in the shake table testing. A total of 4 concepts were tested namely, the sliding hinge joint (SHJ), the optimised sliding hinge joint (OSHJ), the brace to gusset plate connection using symmetric friction connection (SFC) with Belleville Springs (BeSs), and the column base strong axis aligned asymmetric friction connection with BeSs. An overview of the test results of the above-mentioned connections is reported. Despite the overall satisfying results from all cases, it is found that the use of BeSs significantly improves predictability and stability.

Ying, F., Mireku, S., Filippova, O. 78

Building user expectations of repaired buildings and restoration timeframes

Globally, seismic disruptions have devastating effects such as loss of lives and economic loss to individuals, communities and nations at large. While building codes and standards focus on life safety, ensuring the structural design of buildings reduces the risk of collapse, a building's uninterrupted (albeit reduced) functional capacity may be limited. In addition to life safety, researchers and experts in the built environment stress the need to shift our building codes from the life safety focus to elevating standards where buildings are designed for higher performance such that building systems and components remain functional after an earthquake.

In addition to structural safety, a building's non-structural elements (e.g. mechanical systems, plumbing) are also critical in maintaining functionality. Significantly, non-structural components contribute up to 75% of the building's economic value. In this research, we will be conducting key informant interviews to investigate building user expectations of functionality

and what drives these perceptions. We will also interview occupants and owners of repaired buildings to collect their views on the quality of repairs and their expectations about building performance. In the second part of this research, we will investigate expectations for restoring building functionality (from re-occupancy to functional and full recovery). Specifically, which services are essential during the different stages of achieving full recovery for different building types (e.g. office, retail, residential).

Zaidi, F., Elwood, K., Stephens, M., Horspool, N. 40

Fatality Risk Calculation Tool to Facilitate Post-Assessment Decision Making

In the detailed seismic assessment per NZ seismic assessment guidelines, the capacity of any of the building's components, failure of which can lead to a "significant life safety hazard" is calculated and compared with the ULS (Ultimate Limit State) seismic demand, which is defined as the minimum demand for the design of a similar new building. This ratio of capacity to demand is defined as %NBS (New Building Standard) score and specified as a percentage. The lowest score amongst all components becomes the rating. The rating is a comparison of capacity with respect to demand for design of a similar new building but does not directly provide information on the degree of risk to life safety posed by the assessed building. When a building is assessed to have a low score (including rated as earthquake prone), building owners are faced with a challenge of deciding on the future of the building may even decide to shut the building down. However, considering that there may be high consequences of building closure, the decision must be made by weighing the risk and consequences. A web-based application is being prepared with the intent of facilitating building owners in calculating fatality risk. It makes use of the seismic hazard at the site, building fragility information and the consequences in terms of expected fatality rates. The application user will be able to visualize impact on the fatality risk by modifying occupancy and exposure time (time to retrofit). This will help the user in deciding the future course of action which may be a planned retrofit of the building or closure over a period of time.

Zhan, S., Chang-Richards, A., Boston, M., Elwood, K. 79

A critical review of measuring building functionality post-disaster

Following a major disaster such as an earthquake, determining building functionality is crucial to enhance stakeholders' understanding of the restoration works required and the expected recovery state of the building. There are a number of quantitative and qualitative methods for building functionality assessments. This research aims to delve deep into qualitative building functionality assessments to identify the research gaps and challenges facing by engineers, government agencies, researchers, and communities. Qualitative approaches to building functionality assessment have advantages in understanding the original and expected functionality of the building from the perspectives of stakeholders and users compared to quantitative methods. The results of this study can aid with decision-making when selecting suitable functionality assessment methods.

Zhou, H., Wotherspoon, L., Stolte, A., Hayden, C., McGann, C. 22

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.

Zorn, C., Lin, A., Wotherspoon, L. 96

Liquefaction and landslide hazards across New Zealand State Highways

Events such as the 2010 – 2011 Canterbury Earthquake Sequence and the 2016 Kaikōura earthquake demonstrated the impacts of liquefaction and landslides on the New Zealand State Highway network. To better estimate co-seismic hazards of future events, the liquefaction and landslide probability of 478 potential earthquakes are calculated using geospatial models. The outcome is presented as national-scale hazards maps highlighting State Highway sections that could be affected during multiple earthquake scenarios and provide an alternative exposure assessment in comparison to other methods that are based on a single event or a return period. The results can be further evaluated regarding the impact on the network services (e.g. traffic volume) in order to support decision-making processes for emergency preparation and response planning.