Current Project Descriptions

16SUL - Seismic resilience of underground lifelines: Case study of the Christchurch City potable water network

Bellagamba - UC, Bradley - UC, Wotherspoon - UA, Hughes - UC

The recent 2016 Kaikoura earthquake and the 2010-2011 Canterbury Earthquake Sequence illustrated the devastating effects of earthquakes in terms of their impact on economic, social and personal life of the entire community. While significant efforts have already been devoted on the improvement of the building inventory, less attention has been devoted to spatially-distributed infrastructure providing crucial services like transportation, water, power, telecommunication or sewerage. The purpose of this thesis is to explore and improve the resilience of underground infrastructure, and to develop a framework of advanced concepts of seismic performance assessment for distributed infrastructure. The case study selected to illustrate the developed concepts and tools is the water distribution network of the city of Christchurch both in the context of the Canterbury earthquakes and also future seismic hazards in the Canterbury region.

This study can be decomposed into five different elements of research. First, fragility functions for buried pipelines in liquefaction-prone soils are developed using the Canterbury earthquake dataset. To make this model widely applicable, unknown parameters are replaced by random variables, increasing the uncertainty of the model. It should improve the accuracy of loss assessment studies for underground pipe network in liquefaction-prone soils.

Second, network resilience analyses are conducted. These analyses cover the seismic performance of the network as well as the recovery of its functionality. Results are given in terms of potential service reduction, as models are currently unable to accurately predict the amplitude of a single pipe failure. Three types of analyses are conducted: historical cases (e.g. 2011 February earthquake), scenario analyses (e.g. Alpine fault rupture, Porter Pass fault rupture) and probabilistic analyses. The results obtained will help communities improving their preparation to such events.

The third objective aims to quantify the probabilistic seismic hazard effect on the long-term maintenance costs. The realization of this objective will help network managers to provision their finances accordingly based on their accepted risk.

The penultimate objective is to estimate the benefits of pipe replacement given the applied maintenance strategy. The quantification of the potential benefits can help network operators and decision-makers to select the appropriate strategy given their available resources and goals.

Finally, the last objective is devoted to the development of a tool to estimate the most probable break locations following an earthquake. It can serve as a post-disaster decision-support tool to prioritize inspections and repairs, where they are most needed, and thus to reduce the global impact on the community.

In summary, the combination and application of the aforementioned research elements delivers new, efficient and intelligent tools to help decision-makers improve the seismic resilience of their social units (community, network operator company, insurance company or other). This should lead to a comprehensive mitigation and transfer of the seismic risks as well as a reduction of the earthquake impacts on their social units.

16RTN - Assessing the resilience of a rural transportation network

Aghababaei - UA, Costello - UA, Ranjitkar - UA

The performance of infrastructure in natural disasters, especially lifelines such as the transportation network, is critical to the resilience of communities and the economy at large. In addition, transportation networks play a major role in the recovery operation, both in terms of access for the emergency services and the repair of other infrastructure. This project will focus on the assessment of the resilience of the transportation network on the West Coast of the South Island in New Zealand. A network model will be built in AIMSUN, a specialist transportation simulation software. The performance of the network will then be modelled and assessed under the impact of a range of natural hazards. It is also planned to attempt calibration of the model using data from the 2016 Kaikoura earthquake. The model can then be used to help inform the relevant transport agencies on priorities for resilience improvements on their networks.

16UTM - Assessing the resilience of an urban transportation network

Afzal- UA, Ranjitkar - UA, Costello - UA

The performance of infrastructure in natural disasters, especially lifelines such as the transportation network, is critical to the resilience of communities and the economy at large. In addition, transportation networks play a major role in evacuation and in the recovery operation, both in terms of access for the emergency services and the repair of other infrastructure. This project will focus on the assessment of the resilience of Auckland's transportation network. Auckland city, with a population of almost 1.5 million, is situated on a volcanic field and, being a coastal city, is susceptible to Tsunamis. A network model will be built in Aimsun, a specialist transportation simulation software. The performance of the network will then be modelled and assessed under the impact of a range of natural hazards. For example, the performance of the network under a mass evacuation in the event of a volcanic eruption will be assessed. The model could then be used to help inform the relevant transport agencies on priorities for resilience improvements on their networks.

16SMS - Technical resilience of stormwater management systems to flooding

Valizideh - UA, Shamseldin - UA, Wotherspoon - UA

This study propose a novel methodology to evaluate the technical resilience of urban stormwater systems to flooding hazards. Three technical aspects in stormwater management; urban hydrological characteristics, hydraulic capacity of the system, and network structures properties are taken into account to evaluate resilience degree of the system. The outcome of this study will provide the framework to quantify the temporal nature of system robustness and functionality and evaluate the resilience degree of stormwater management systems in the conveyance of different extreme rainfall events and disaster scenarios.

17EPD - Electric power distribution system resilience modelling toolbox

Liu - UA, Nair - UA

This study will develop a resilience estimation methodology and associated tools for electricity distribution infrastructure factoring various natural hazard spatial temporal data, component fragility models, network connectivity and realistic cascaded outages. These tools will help to develop interdependency models with other distributed infrastructure networks to better understand overall infrastructure resilience to extreme natural hazards as a result of actions taken (pre-disaster mitigation or planning for post-disaster rapid recovery)

Output:
1. A natural hazard scenario based network outage simulation tool
2. Electric power system resilience metrics for case studies quantifying consequences of hazards to help assess network components, network interdependencies and future development of 'national report card' for resilience rating.

17123 - Tsunami loading characteristics on power poles

Whittaker - UA, Melville - UA

Electricity networks are vital for a functioning society, and their loss due to large-scale natural disasters such as tsunamis can have devastating consequences. This project will investigate the hydrodynamic loading characteristics of power poles, a vital component of the electricity network, under tsunami attack. A series of scaled physical experiments will quantify the relationship between the tsunami bore characteristics and the force exerted on different power pole structures with and without debris. Results from the physical experiments will be compared to available field data from the Chile 2010 tsunami. The hydrodynamic forces measured during tests of representative New Zealand power poles will be input into a structural model todetermine the relationship between the tsunami characteristics and the damage/failure states of the power poles. The resulting fragility curves will be imported into RiskScape, and will form the basis of the analysis of the electricity network resilience to tsunamis.

17143 - Characterising long-term ground deformation impacts on Christchurch City's buried high voltage electricity network since the start of the Canterbury Earthquake Sequence

Hughes, UC, van Ballegooy T&T, Wotherspoon - UA

Through the 2010-2011 Canterbury Earthquake Sequence (CES), liquefaction-induced permanent ground deformations caused severe damage to infrastructure lifelines such as roads, potable water, waste water and storm water systems. In contrast to the performance of these systems, Christchurch's electricity network, managed by Orion, sustained comparatively less damage due to investment in seismic design and retrofit of its assets. However, much of Orion's current network lies within urban landscapes that experienced significant horizontal and vertical ground movements through the CES, which raises questions on whether ground strains stretched the buried cabling and influenced long-term damage rates. We propose here a spatiotemporal correlation between cable repairs and measured CES horizontal movements and lateral strains. Pre-, syn- and post-CES Orion repair data will be spatially correlated with remotely sensed datasets of horizontal ground deformations derived from LiDAR surveys and satellite imagery, with vertical movements and angular distortions derived from LiDAR surveys, and with CPT-based liquefaction vulnerability parameters. The study will elucidate the seismic performance of Orion's network in liquefiable through the CES, and inform electricity lifeline providers elsewhere on future of seismic impacts. In addition, the study will characterise any potential long-term system repair rates resulting from the extensive seismically-induced ground deformation.

17145 - Characterisation and screening of New Zealand stopbank networks

Crawford-Flett - QC, Shamseldin - UA, Wotherspoon - UA

Stopbank networks are a critical distributed infrastructure network, providing the primary means of flood protection for people and properties in many New Zealand communities. Damage to this network may have significant economic and social impacts; therefore, a clear understanding of the attributes of this system is needed to be able to assess the expected performance and impacts. The aim of this project to develop a database of the New Zealand stopbank networks, with a specific focus on earth stopbank structures. This project will characterise the stopbanks using a range of hydrologic and geotechnical attributes to allow for the assessment of performance across a number of hazards.

The database developed in this project will form the basis for future research in this area. Without a centralised stopbank information repository, any detailed analysis on the performance of the system, both in terms of flood hazard and the cascading effect of other natural hazard events, would not be possible. The project will provide an initial spatial analysis framework that can be extended to assess the impact of potential stopbank failure on other infrastructure.

17104 - Framework for integrated 'end to end' impact assessment of infrastructure networks under natural hazards

Uma - GNS, Prasanna - Mas, McDonald - ME, Horspool - GNS

Infrastructure network is likely to suffer damage under natural hazards resulting in disruption to the levels of services (LOS) that can be available for the end-users. In order to quantify the extent disruption and assess the economic and societal impact, several models and tools are developed or being developed in the research and commercial arena (e.g. Riskscape, EPANET, MERIT etc.). The impact assessment process requires various models representing: (i) natural hazard; (ii) network assets / components; (iii) vulnerability/fragility of components; (iv) integrated performance of network components considering intradependencies within the network; and (v) interdependencies among the networks.

It is acknowledged that a number of research programmes are underway with funding from the Resilience to Nature's Challenges, QuakeCoRE, NHRP and other sources, contributing towards infrastructure network performance at different capacities in terms of scope and features. Even though these models are developed for their own specific purposes, at present there is no structured framework to link different models together, in terms of what is needed in the flow from one model to the next so that integrated impact assessment can be performed. For this purpose we are going to develop a detailed linkage structure framework to link the models and identify potential modifications to software modules to refine inflows into successive models.

Assessing wastewater pipe performance through the 2010-2011 Canterbury Earthquake Sequence

Tang - UC, Scott - UC, Hughes - UC

The 2010-2011 Canterbury Earthquake Sequence (CES) caused widespread damage to Christchurch City's wastewater network, resulting from permanent liquefaction-induced ground deformation and transient seismic shaking. Network damage led to significant loss of services and community disruption, in addition to environmental contamination. Although most of the Christchurch network has been repaired, questions remain on exact pipe damage mechanisms, structural performance and how earthquake impacts affected the service lifetimes of pipes. This study will use a dataset of concrete and reinforced concrete (rubber ring-jointed) pipes, with pre-and post-CES Closed Circuit Television (CCTV) observations, to assess earthquake-induced changes to structural condition related to pipe material and age, ground conditions and seismic parameters. Results will provide Christchurch asset managers with better information for their ongoing pipe renewals programmes, and provide asset managers in New Zealand and internationally information with which they can plan for anticipated earthquake impacts on their own pipe networks. To date a subset of pipes has been selected, and a review of pre-CES CCTV footage to improve and standardise structural performance observations is under way.