# SEISMIC RESPONSE OF BRIDGES IN NEW ZEALAND

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#### **Abstract**

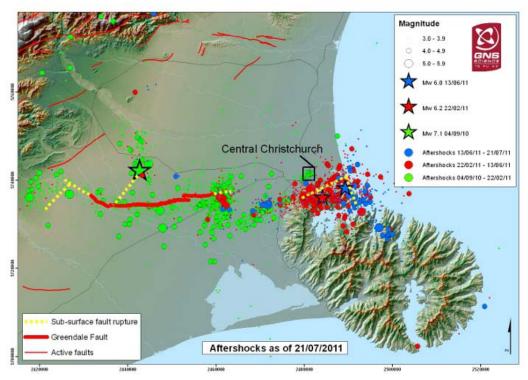
New Zealand has suffered a series of highly destructive earthquakes in recent times, and so it becomes increasingly important to better understand how a structure behaves under seismic loads. The main goal of this research is to form a database of important details that will aid in the modeling process of damaged bridges in the Christchurch area of New Zealand. In realizing this goal, two other purposes will arise. Firstly, the modeling will aid in the reconstruction process of Christchurch by determining which bridges will still be able to function; secondly, the modeling will also provide a better understanding of the seismic responses specific to the area, which helps form better design solutions for the future. It should be noted that this project does not actually involve the modeling process as that requires much time and skill that is better off in the hands of those who are more qualified. Instead, this research produces a detailed database containing all the relevant information necessary for others to conduct thorough modeling and computer analysis.

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#### **Project Overview**

On September 10, 2010, the city of Christchurch, New Zealand suffered significant structural damage from a M 7.1 earthquake located in the Darfield area (GeoNet, 2011). The seismic forces also caused the ground underneath many different bridges to move towards the riverbanks, resulting in further damage. On February 22, 2011, Christchurch experienced another large earthquake of magnitude M 6.3 which resulted in many casualties and exacerbated the damage. This was followed by powerful aftershocks on June 13, 2011 (GeoNet, 2011). Although the more recent two earthquakes were of lesser magnitude, they were located much closer to Christchurch than the first one as shown in Fig. 1 located below. Many crucial bridges were damaged by this series of earthquakes, so it is important to understand the seismic responses of bridges in order to develop better design methods in addition to aiding with reconstruction process.



**Figure 1** – A map showing major earthquakes and their aftershocks in the Christchurch area (NHRP 2011).

Currently, investigations are being conducted by the Natural Hazards Research Platform in order to establish which bridges are safe to use, which ones require retrofitting, and which ones will require demolition. Overall this will be achieved by modeling the bridges to determine the new load capacities. However, this entails a long process of data gathering in which the bridge's pertinent information (such as foundation details) must be determined. Once this is completed, the loads can be used to conduct moment-curvature analysis on the bridge piles, and the results can then be used as inputs in the actual 3D model of the bridge.

#### **Literature Review**

Earthquakes can be very both directly through forces from shaking and from effects of foundation conditions. Therefore, it is important to understand how different structures respond to earthquakes, and computer models paired with field investigations can be used to gain a better insight.

Even though bridges are designed to withstand a certain level of shaking, significant damage can still occur without the seismic forces actually reaching the design load (Palermo et al. 2010). An investigation revealed that although most of the bridges in the Canterbury region of New Zealand successfully withstood the seismic forces of the Darfield earthquake, the ones that did sustain damage tended to be located on riverbanks (Palermo et al. 2010). This damage is due to a mechanism of ground displacement known as lateral spreading, which is a result of soil liquefaction (Kramer 1996). It occurs when the shaking is significant enough to cause soil layers to lose stiffness and strength; as a result, there is no support for the foundation and significant displacement can occur in anything that has its foundation resting in or above the liquefied soil. This can damage the piles that support the abutments and cause the abutments to shift and rotate, resulting in displacement or other damage to the superstructure. Therefore, it is necessary to be able to properly design foundations and piles in areas where there is a high chance of soil liquefaction. Berill and Yasuda (2002) have delved into case studies surrounding this issue and have found that it is a complex matter requiring more field data than is currently available. For that reason, future work should be geared towards developing a general method of effectively designing foundation piles.

It is apparent that seismic phenomena are very complex and have numerous means of causing damage to structures. As the human populations grow, society demands larger structures with greater requirements for safety. This research will allow us to more thoroughly understand earthquake effects that weren't previously accounted for, and produce improved methods of design incorporating these issues.

#### **Contributions**

The first step in the data-gathering process was to use the engineering drawings of six damaged bridges (Anzac Dr, Avondale Rd, Bridge St, Fitzgerald Ave, Gayhurst Rd, and Pages Rd) in Christchurch to determine the volume of each bridge. This value was then used to calculate the mass of each bridge, which was then utilized to compute their respective dead loads. A small database was created to contain the summaries of each bridge's details. Once this was completed, it was then necessary to obtain information about the bridges' foundations; this includes pile details such as: length, dimensions, rake angle, reinforcement, etc.

The second step involved flying down to Christchurch in order to conduct field tests on the bridges. Each day, the team would visit one to two bridges and remove concrete cores from the abutments in order to test for the compressive strength of the concrete and the amount of corrosion in the steel reinforcement. Most of the equipment is used just for the operation of the concrete-coring drill. There is a cover meter to locate the reinforcement, a mount to place the drill on the abutment wall, tanks of water for cooling and lubricating the drill, a pump to supply the water to the drill, a large generator for powering the drill, and mortar for filling the holes after the cores have been removed. Refer to Fig. 2 and 3 to see the equipment used in the field tests.

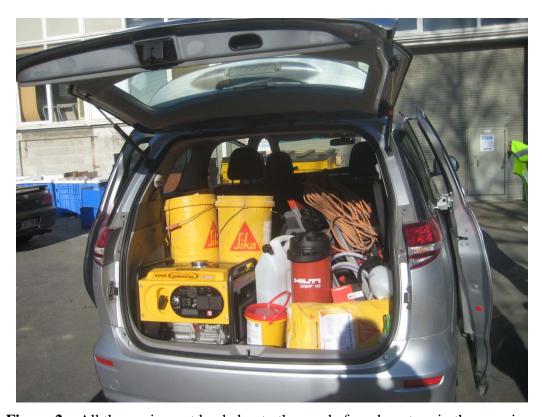


Figure 2 – All the equipment loaded onto the van before departure in the morning.



**Figure 3** – Setting up the concrete-coring drill to remove a core to expose the reinforcement.



Figure 4 – Concrete samples taken from a bridge abutment.

As shown in Fig. 4 above, several cores were taken out of each bridge for testing; one sample would be crushed to determine the strength, two others were sprayed with phenolphthalein and silver nitrate in order to observe the amount of carbonation and chloride in the concrete (this information can be used to estimate the level of corrosion in the steel reinforcement), and one more core would be removed to expose the reinforcement in the abutment to test for hardness.

There is also a large database of photos taken of bridge damage in various locations after each significant earthquake. After the field testing was done, each bridge was revisited in order to take more photos of damage to add to the database in addition to updating measurements of displacements and rotations of damaged bridge components. The photo database was sorted by damage location and date so that damage progression could be observed and help to understand the phenomena that have occurred due to the earthquakes. Fig. 5 shows the southwest abutment of the Bridge St bridge rotating further due to lateral spreading after each earthquake.



**Figure 5** – Image on top-left taken on 9/12/2010; image on top-right taken on 2/28/2011; image on bottom taken on 6/17/2011.

#### **Conclusions**

As previously stated, the data gathered from the engineering drawings will be used with information from the field tests by people with the experience and ability necessary to conduct complex computer analyses. All the information will be useful inputs at different stages of the modeling process. The models will provide a better understanding of the damage and will allow for a more accurate assessment for recovery process. In addition, these case studies will also help to better understand lateral spreading and how it affects the different types of bridge foundations and can be used to develop improved methods of damage mitigation in regions where soil liquefaction is common.

Further questions can be emailed to sdluong@ucsd.edu or l.wotherspoon@auckland.ac.nz.

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### Acknowledgments

I would like to thank the NEES REU program (EEC-1005054) and National Science Foundation for funding this project. I would also like to thank the UCSD PRIME program and all persons involved for providing me with this research opportunity and helping me with the logistics of this internship. Finally, I want to thank Dr. Lelli Van Den Einde for preparing me for this internship and Dr. Liam Wotherspoon for guiding me throughout the internship.