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nehrp SeismicWaves

How the National Earthquake Hazards Reduction Program Is Advancing Earthquake Safety

Getting in GEER for New Zealand

Joint Reconnaissance of the 2011 Christchurch Earthquake

Soon after the deadly February 22, 2011 Christchurch earthquake in New Zealand, a team of engineers from that country and the United States surveyed the geotechnical effects of this event. Their focus was on the characteristics of affected soils, how the soils responded to earthquake shaking, and how these responses affected buildings and lifelines. Due to a confluence of factors, the geotechnical effects produced by this magnitude 6.2 earthquake were of immense significance.

U.S. participation in this joint reconnaissance was supported by grants from the National Science Foundation (NSF, a NEHRP member agency),[1] and coordinated by the Geotechnical Extreme Events Reconnaissance (GEER) Association, an NSF-supported association of geotechnical and geological experts from academia, industry, and government (www.geerassociation.org). As in other disasters, GEER's approach in New Zealand was to offer supplemental assistance to the local experts involved. By sharing the load, GEER helps to ensure that the geotechnical engineering community worldwide is able to learn as much as possible from disasters to improve practice and mitigate the impacts of future events.

Scope of the Reconnaissance

The reconnaissance team documented the occurrence and severity of liquefaction, lateral spreading, rockfalls, and landslides, and examined how these phenomena affected buildings, bridges, levees, buried pipelines, and other infrastructure. Loose, saturated granular sediments can behave like liquids when subjected to strong earthquake shaking. This process, termed liquefaction, can render the ground less able to support structures. It can also cause lateral spreading, where sloping ground that has liquefied or that sits atop a liquefied layer slides sideways. Such ground movements can damage structural foundations and underground lifelines. Further damage can occur to buildings, roads, and other surface infrastructure when liquefied soils reconsolidate following an earthquake, causing the ground to subside or settle unevenly.

A lateral spread crack running along the crest of a levee in Kaiapoi, just north of Christchurch. Courtesy of R. Green, Virginia Tech.

Team Findings

The GEER team found these and other geotechnical effects during their reconnaissance. What made this earthquake unique, however, was the severity and spatial extent of the liquefaction. Much of Christchurch, a city of more than 360,000 inhabitants, was built on alluvial deposits and coastal wetlands drained in the 1800s. The soils generally comprise loose silts, sands, and gravels that are highly susceptible to liquefaction. Ground such as this, however, will not liquefy unless it is saturated with ground water and subjected to strong ground shaking.

Both of these conditions were met during the earthquake of February 22, 2011. Christchurch has a high water table that extends, in the eastern part of the city, to within 1 meter of the ground surface. The epicenter of the earthquake was only about 5 miles from the center of Christchurch, with the fault rupturing directly under southern neighborhoods of the city. This generated intense ground shaking throughout the city.

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[1] NSF grant award numbers 0825734 and 1137977. Award abstracts are available at www.nsf.gov/awardsearch/.

The earthquake resulted in at least 185 deaths, approximately 1,500 injuries, and damage to about 100,000 structures in the affected region.[2] It also caused severe and widespread liquefaction in central and eastern Christchurch, worse than that experienced in the September 4, 2010 Darfield earthquake, which although larger in magnitude (7.0) occurred farther from Christchurch. According to the GEER reconnaissance report,[3] this extensive liquefaction severely damaged about 15,000 residential properties. The majority of these structures sustained only minor to moderate damage due to shaking, but were damaged beyond repair by liquefaction.

These severe impacts were typically associated with differential settlement or lateral spreading that damaged the foundations and structural systems of homes. Similar effects were found among many of the approximately 3,000 commercial, industrial, and multifamily-residential structures located within the central business district of Christchurch. Although the deadly building collapses in this area were caused by structural failures due to the intense ground shaking, liquefaction caused many buildings to subside and tilt.

The reconnaissance team inspected a number of area bridges, finding that although none collapsed, some sustained minor to major damage caused primarily by settlement and lateral spreading at the approaches. They found that liquefaction severely damaged many streets as well as underground utility pipes and power cables. Wastewater pipes were the worst-affected lifelines, with lateral spreading causing numerous breaks estimated to require several years to fully repair. In the hilly, less-populated suburbs south of Christchurch, the team found numerous rockfalls caused by ground shaking, which resulted in five fatalities and many damaged structures and roads.

Reconnaissance Outcomes

The work of the joint reconnaissance team is strengthening geotechnical earthquake engineering in several ways. The team's measurements, tests, and analyses are helping engineers further elucidate the relationships among soil properties, ground shaking, geotechnical effects, and damage to the built environment. Team members were able to compare observed liquefaction to that predicted by on-site soil testing and seismic monitoring, which will aid in refining analysis and design procedures. In addition, they were able to examine the effectiveness of several methods used to mitigate the effects of liquefaction and landslides.

The team's success in capturing perishable data has also enabled follow-on research that builds upon their findings. In one such study, U.S. researchers funded by NSF are collaborating with counterparts in New Zealand to investigate why a method commonly used to mitigate liquefaction (soil improvement through construction of underground stone columns) did not work as well as anticipated in Christchurch. NSF is also supporting a GEER-coordinated study that is gathering additional data on how liquefaction affected building foundations and lifelines in the Darfield and Christchurch earthquakes and their aftershocks.[4]

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[2] See the USGS Earthquake Summary for event ID #usb0001igm at http://earthquake.usgs.gov/earthquakes/eqinthenews/2011/usb0001igm/#summary.

[3] Cubrinovski, M., R. A. Green, and L. Wotherspoon, eds. 2011. *Geotechnical Reconnaissance of the 2011 Christchurch, New Zealand Earthquake.* GEER Association Report No. GEER–027. Version 1, November 8. Accessed at www.geerassociation.org/GEER_Post%20EQ%20Reports/Christchurch_2011/Index_Christchurch_2011.html.

[4] For more information about these follow-on studies, see the abstracts for NSF award numbers 1201026 and 1306261 at www.nsf.gov/awardsearch/.