September 4, 2010 Canterbury, NZ Earthquake

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8 September 2010

The field observations from Christchurch and the associated analyses discussed below have been jointly funded by Risk Frontiers (as sponsored by Aon Benfield, Guy Carpenter, ARPC, IAG, QBE, Suncorp and Swiss Re) with additional support from Aon Benfield.

Day 3 of investigation of the Christchurch earthquake (September 7)
(Matthew, Felipe)

Newsflash!! 0750 local time this morning. A shallow 5.0 aftershock about 14 km north of the city centre was felt quite strongly in our motel room resulting in loss of power and mirrors cracked and snapped from the wall. There are reports on the radio that this aftershock has caused further damage to already damaged buildings in the city centre and some parts of the city and the Lyttleton Tunnel have been shut down again for safety inspections.

The suburb of Bexley had hundreds of homes ruined as a consequence of soil liquefaction and made the local news headlines on Tuesday morning in Christchurch. The local newspaper “The Press” headline was that more than 100,000 homes would need some form of repair. As we had seen the catastrophic effects of soil liquefaction in Bexley yesterday, indeed we were visiting as the local channel 3 was shooting for the evening news, we set out to find were else liquefaction had caused distress to the community. We were told by locals on Sunday about widespread liquefaction and sand volcanoes near the motorway on-ramp, in the suburb of Marshland. We also had news of major damage on the banks of the Waimakariri river in Kaiapoi, and as a matter of fact, Kaiapoi bridge was in page 2 of the local newspaper because of its damaged condition.

We headed north through the suburbs of Bishopdale and Casebrook without seeing any apparent damage to buildings or streets, except for a few chimneys and old brick buildings (in our map, please see the red line for the path we took; legend further below).


In Redwood we saw extensive damage to roads and, and to a lesser extent residential homes. Not by coincidence, these sites were located in the vicinity of the water channels.
Massive Subsidence in Kaiapoi

We went further north to Kaiapoi, there we found massive subsidence around the fire station. Liquefaction there was so severe that Hilton St, north of the fire station, subsided uniformly by about half a metre (Figure 1). At the time of our visit about 200m of the approach to the main bridge that makes the North-South crossing of Waimakariri River is closed down to traffic and people, forcing the residents to take the motorway to cross the river.

Figure 1: Dr. Matthew Mason in what used to be an old car shed that sank by about one metre (Felipe Dimer, Risk Frontiers)

Surrounding these streets is the main business area of the city, which is obviously shut down and might result in extensive claims for business interruption as the situation there seemed critical.

The subsidence occurred at the expense of a considerable amount of silt being ejected from underground, and we witnessed and extensive cleanup activity. Many of the residences had their courtyards completely flooded with water and mud.

In the northern part of the city we could see more of the effects of liquefaction: the Trousselot Park lawn was flooded with silt while its pathway by the river banks shifted noticeably. The Mandeville Bridge, a small pedestrian wood bridge, apparently buckled as a consequence of its banks slipping towards the river.

The soil movement caused some structures by the river to fail as we could see that many buildings had bends and cracking induced by uneven settlement. A big commercial building collapsed near the main bridge.

Further north the traces of the earthquake damage were less apparent except for two semi-collapsed churches in Woodend.
**Dallington**

Heading south from Kaiapoi we drove through the suburb of Parklands. There we saw more of the same pattern of liquefaction damage in roads of cracks and holes. There was damage to the electric network and, again, the people were engaged in intensive cleanup work.

In New Brighton we saw a moderate amount of silt on the streets. In spite of its proximity to the river Avon we noticed only localized damage, and not the ubiquitous flooding of silt and cracks we would experience shortly.

In the suburb of Dallington, however, we saw the consequences of liquefaction to a similar extent as in Bexley, however, without, apparently, the same amount of damage to homes. Streets were crowded with locals shoveling their way through the black silt. Army personnel, utility companies, and tractors were a common sight. Many branches of the road were closed down on account of the level difference the road. As in Kaiapoi, a pedestrian bridge buckled as the banks of the Avon River slipped towards each other. There we signs warning of the danger of contamination of the Avon River by broken sewage pipes.

At this point, it becomes difficult to make an estimate of the impact of liquefaction without a more detailed survey. The consequences for those affected by this particular aspect of the Christchurch event seem to unfold in many ways: damage to streets, cleaning up, power failure, damage to water, and contamination of river and wetlands by sewage. In Dallington we saw water trucks distributing clean water to the population, and retirement villages using chemical toilets. All this becomes more significant when we realize that, as in Bexley, many of the houses affected by liquefaction were built to code and withstood the ground shaking reasonably well. From the point of view of loss modeling, soil types and proximity to the river seem to be reliable indicators of sites with the potential for liquefaction, but damage models will have to include many more variables in order to be realistic. It will not be a trivial exercise to account for heavy damage as in, for example, new homes build to code.

**Damage to buildings in the city of Christchurch**

With the gradual opening of more of the city’s main streets, this afternoon we began our (somewhat) systematic survey of the damage to structures (follow our to-date assessment route through the link at the end of this briefing). Although reports have been coming in that damage is widespread, we perhaps did not appreciate the full extent of this. In most cases, as with our residential shaking damage observations, failures were largely of non-structural features such as parapets and chimneys, but cracking in brick or rendered concrete facades was also common (Figure 2). As would be expected, when masonry falls from significant heights, as is the case for many parapets on commercial or industrial buildings, it can cause major damage. At least one Christchurch resident wishes they had not left their car at work on Friday night (Figure 3). There were several cases where catastrophic structural failure was observed. Figure 4 shows two such cases; the first a building on Barbados Street and the second an old structure on Manchester street where failure appears to have begun at the parapets but progressed to much of the facade and the awnings below.

Observations in the city so far suggest that the commercial or industrial shaking damage has been mainly to unreinforced masonry or auxiliary fixings. Damage has
been mostly to older buildings with newer ones appearing to come through unscathed. This result is as would be expected given the relatively stringent earthquake codes used in New Zealand.

**Figure 2.** Failure of a parapet in a building on Madras St. (Matthew Mason, Risk Frontiers)

**Figure 3.** Car damaged by falling masonry. (Felipe Dimer, Risk Frontiers)

(applied only to newer buildings). The relatively large number of old and heritage buildings in Christchurch did however increase the damage over that which would have occurred in a comparably sized but newer city. Local council regulations in force throughout New Zealand aimed at improving earthquake resilience of existing structures have gone some way to minimise the potential damage to these buildings.
Unfortunately however, these regulations were not in place early enough for some of Christchurch’s many heritage buildings.

Figure 4. Severely damaged buildings in Christchurch. (Felipe Dimer, Risk Frontiers)
**Damage to the Bridge Street Bridge (New Brighton)**

The Bridge Street Bridge in New Brighton spans the marshland that caused so much of the trouble for the houses of Bexley discussed in yesterday’s briefing. Unfortunately the bridge fared no better. Significant lateral slumping was evident on both the east and west approaches to the bridge (Figure 5). Road cracking was prevalent along significant lengths of the approaches, with crack widths up to about 20 cm in locations with settlement of a similar magnitude. There was a larger extent of cracking and settlement of the ground beside the approaches. Inspecting the two bridge abutments, it was concluded that the force of the earthquake’s impact loaded the bridge at an angle to the span direction. This scenario resulted in an offset of the western abutment of approximately 10 cm to the south with the eastern abutment offset a comparable distance to the north (Figure 6). Both abutments showed signs of having moved towards the centre span (i.e. into the swamp, Figure 8), and had settled (Figure 7); this movement gives the impression that the deck had been lifted at both ends. Figure 9 shows the vertical displacement at the eastern abutment. As was the case in Bexley, the earthquake caused large scale liquefaction of the soil in the area and was probably the causative factor in this failure. Several sand volcanoes were sighted near the bridge and the bridge has been closed since Saturday.

*Figure 5. Damage to Bridge Street bridge, New Brighton. (Matthew Mason, Risk Frontiers)*
Figure 6. Lateral offset between the western abutment and bridge deck of the Bridge Street bridge. (Matthew Mason, Risk Frontiers)

Figure 7. Settlement of the western abutment of the Bridge Street bridge support into the marsh. (Matthew Mason, Risk Frontiers)
Figure 8. Dr Felipe Dimer of Risk Frontiers inspects settlement of the bridge approach and sand boils in the swamp near the Bridge Street bridge. (Matthew Mason, Risk Frontiers)

Figure 9. Dr Felipe Dimer of Risk Frontiers inspects apparent uplift of the Bridge Street bridge deck at the eastern abutment. (Matthew Mason, Risk Frontiers)
Go on Your Own Reconnaissance Tour using this Site:


This site shows the places we visited and pictures and words describing what we saw.

Key for the Map:

Day 3

- Highlights of the day
- Places where we visited and took photos
- General observation

Days 1&2

- Places where we took photos
- Highlights

Recorded Strong Ground Motions

(Paul)

The fault rupture zone has been added to the maps showing the locations of the recording stations and their peak accelerations (Figure 10). These maps were provided by Brendon Bradley of University of Canterbury.

The recorded ground motions at Glendale, located almost on the fault rupture at its western end (Figure 10), are shown in Figure 11. The peak horizontal acceleration was about 0.75g, and the peak horizontal velocity was about 100 cm/sec. The spikes in the acceleration records indicate strain hardening as the water is progressively squeezed out of the soil with each cycle of motion, indicating non-linear hysteretic behaviour of the soil. The large pulses in the velocity records indicate forward rupture directivity effects. The duration of strong motion is about 10 seconds, much shorter than that in Christchurch, due to forward rupture directivity effects. The presence of two pulses in the Horizontal 1 velocity recording may represent the motions due to the two major sub-events of the earthquake rupture process.
Figure 10. Recorded peak acceleration values in %g in the Canterbury Plains (top), showing the surface faulting rupture zone (red line), and Christchurch (bottom). (GeoNet; Brendon Bradley).
Figure 11. Recorded ground motions Glendale, located at the western end of the fault rupture (Figure 10). The top three traces show the three components of acceleration, and the bottom three components show the three components of velocity. (GeoNet; Brendon Bradley, University of Canterbury).

The variation of peak ground acceleration and response spectral acceleration at a period of 1 second are shown in Figure 12, including a much larger set of data than in our first report. The closest distances are measured to the fault shown in Figure 10. As expected, the values are generally larger the softer the soil. The median value of the predictions for site category D using the Chiou and Youngs (2008) model are shown by the solid lines, and the dashed lines show one standard deviation about the median. Many of the recorded ground motions are generally consistent with the predictions of the Chiou and Youngs (2008) ground motion model, but there are many other values that lie more than one standard deviation above the median value. This is true to a greater extent for spectral acceleration at a period of 1 second than it is for peak acceleration.
Figure 12. Recorded peak acceleration (top; equal to spectral acceleration at a period of 0.05 sec) and response spectral acceleration at a period of 1 second (bottom) shown as a function of closest distance to the fault, whose location is shown in Figure 10. Site classes A, B, C, D, and E are in increasing order of softness; in approximate terms A is hard rock, B is soft rock, C is stiff shallow soil, D is deep soil, and E is soft (potentially liquefiable) soil. The median value of the predictions for site category D using the Chiou and Youngs (2008) model are shown by the solid lines, and the dashed lines show one logarithmic standard deviation about the median. Source: Brendon Bradley, University of Canterbury.