Christchurch Earthquake - an overview

THE EARTHQUAKE

GNS Science believe that the earthquake arose from the rupture of an 8 x 8 km fault running east-northeast at a depth of 1-2 km depth beneath the southern edge of the Avon-Heathcote Estuary and dipping southwards at an angle of about 65 degrees from the horizontal beneath the Port Hills. The amount of slip between the two sides of the fault was up to 1.5 m. The Port Hills have risen by about 40 cm, the mouth of the estuary has moved westward by a few tens of cm, and the land just north of the estuary by tens of cm to the east. Land west of the estuary, and the estuary itself, will have sunk by roughly 10 cm as a direct result of the fault rupture. However, there may be additional subsidence on top of this as a result of ground compaction during the strong shaking.

Earthquake records show that some buildings may have experienced shaking more than two times more intense than a new building would be currently designed for, but perhaps for a lesser duration than envisaged by the loadings code (NZS 1170.5). The intensity of shaking appears to have died out rapidly as it travelled westwards from the fault.

DESIGN OF BUILDINGS FOR EARTHQUAKES

Non-residential buildings designed before 1976 were not explicitly required to have ductility incorporated in them. In the early 1980s, the design standard for reinforced concrete was revised significantly to ensure non-brittle behaviour under design-level earthquake loadings, and the strong-columns/weak beams philosophy was introduced so that life safety could be achieved under design-level earthquake shaking.

During the 1990s, the understanding of the faults and historic earthquakes came together as the NZ Seismicity Model developed by GNS Science, and this is the basis for the current seismic zoning of New Zealand. This is considered internationally as a state-of-the-art model. The September and February earthquakes are thought to be consistent with this model.

Buildings are not designed to be earthquake-proof. Two design levels are considered. A building of ordinary importance is designed for a level of shaking that has a 10 % probability of being exceeded in its design life of 50 years. The design standards are formulated to ensure that life safety is achieved during that shaking, but the building might be an economic write-off because of the damage. It must not collapse at this level. The designer is also required to check that the building does not have damage at a level about 1/6th of this design level. This Serviceability Level is set to correspond with shaking that has a 10% probability of being exceeded in one year. To put it another way, The Life Safety design level can be expected to be exceeded on average (over a very long period of time) once every 500 years, and the Serviceability Level once every 20 years.

Note that no mention has been made of earthquake (Richter) Magnitude, as the building responds the same way to shaking that comes from a small close earthquake or a large distant one.

OBSERVED PERFORMANCE OF COMMERCIAL BUILDINGS IN THE CBD

The buildings designed to the current standards have, with few exceptions, performed well and as intended, with little damage. Notable exceptions are the failures of stairs in the Forsyth Barr building, and the tilting of a 10-storey building on Oxford Terrace near the river. The two buildings which have catastrophically collapsed (the Pyne Gould Corproration and CTV buildings), while described by the press as modern, are understood to have been constructed in about 1963 and 1986 respectively. Many buildings designed before the early 1980s may have experienced earthquake loads significantly above that for which they were designed. Nevertheless, many of them have experienced no or minimal structural damage. A number of experienced structural engineers have observed that buildings with well-conceived and simple structural systems with minimal irregularities have exhibited superior performance to those which may have only nominally or theoretically met codified requirements.

In buildings of all ages, ceiling systems, and in-ceiling services such as light fittings and air conditioning/supply systems, have been damaged to various degrees. While significant non-life-threatening damage is acceptable in the levels of shaking probably experienced, it is clear that lessons can be learnt in how to minimise this damage. The relevant Standard has recently been revised so as to address many of these known issues.

DAMAGE TO INFRASTRUCTURE AND GROUND

Most of the infrastructure damage is directly attributable to liquefaction. The likelihood of liquefaction in the wider Christchurch area in this level of earthquake has been known for more than 15 years, and was documented in great detail in studies commissioned and publically disseminated by Environment Canterbury and the Christchurch City Council more than eight years ago. The propensity for buried services to be disrupted and uplifted by the buoyancy of the liquefied material is well-known from the experiences of other earthquakes around the world, but the scale of the damage experienced in Christchurch may be the greatest ever recorded anywhere in a modern city.

POST-EARTHQUAKE BUILDING EVALUATION

Voluntary committees of the NZ Society of Earthquake Engineering have worked for more than 20 years to develop and refine guidelines for the rapid evaluation of building safety after a damaging earthquake. The Society's guidelines have been implemented by the Civil Defence in both the Christchurch earthquakes, and this is likely to be seen as an exemplary model by the international community. Similarly, the rapid development of Urban Search and Rescue teams with internationally-consistent training and methods over the last ten years has been heavily supported by professional engineers, and is attracting huge praise from all those who have observed them in action. IPENZ has planned for the provision of voluntary support from the profession for such a disaster as this earthquake, and has implemented those plans.

Despite the tragic losses of life, professional engineers should be extremely proud of the efforts made over many decades that have minimised the effects of this extreme event.

Prepared with the assistance of Members of the New Zealand Society for Earthquake Engineering · 4 March 2011

Building Safety Evaluation

The rapid evaluation placarding of buildings is a useful and pragmatic way to quickly ‘triage’ the structural condition of buildings in the aftermath of an earthquake, in much the same way that accident victims are triaged in emergency care wards.

- Red carded buildings are considered unsafe to enter.
- Yellow carded are considered suitable only for restricted use or access until repairs are completed.
- Green carded buildings are considered safe to enter and appear to be in much the same structural condition as prior to the earthquake.
- Green placards state that building owners are “encouraged to obtain a detailed structural assessment of the building as soon as possible” and “report any unsafe conditions” to the Territorial Authority”.

Detailed structural evaluations of damage, and strengthening of buildings up to current standards once the state of emergency is over, remains the responsibility of the building owner.

- All building owners are recommended to contact a structural engineer for a thorough assessment after an earthquake if they suspect some damage has occurred whether it is placarded or not.
- Some damage may not be obvious until linings are removed in critical areas to allow detailed inspection.
- The placards are a ‘snapshot’ of the condition of the building after a particular event and do not indicate compliance with the building regulations or whether the building can sustain another event of similar or greater intensity.

The placarding system was first used in New Zealand after the Gisborne earthquake and is an adaptation of the system used in the USA.

- It was developed by the New Zealand Society of Earthquake Engineering in conjunction with the Department of Building and Housing.
- It was further refined by a team of New Zealand engineers who used it to evaluate buildings damaged in Padang, Indonesia, after the earthquake there in September 2009.
- It was implemented to assist the building safety evaluation work of the Christchurch City Council after the Darfield Earthquake in September 2010 and allowed swift communication of damage information to local and national agencies.
- Further improvements of the system have been made by Christchurch City Council since then, to cope with the effects of aftershocks on the placarding process.

The rapid evaluations are done and placards are placed during the period in which a state of emergency has been declared after an earthquake has occurred.

- Placards assist emergency managers identify buildings that may cause danger to the community.
- They identify buildings the public may reasonably return to, that have much the same ability to resist future earthquakes as before.
- In their aggregate they allow emergency managers and relevant agencies to make decisions around moving safety cordons, opening roads to traffic and estimating the economic impact of the earthquake.

The rapid evaluations are done in two stages; Level 1 and Level 2, by teams of qualified structural engineers and building control officers.

- Level 1 evaluations are usually based on observations made from the outside of the building.
- Level 2 evaluations take longer and require the assessors to enter the building if it is greater than two storeys high. They are only undertaken once the Level 1 evaluation has shown the building to be sufficiently stable for a team to enter.
- A Level 2 evaluation supersedes an earlier Level 1 evaluation.

The rapid evaluations and placards posted during a state of emergency are recorded in the building control database of the relevant local authority.

- As aftershocks occur these assessments may be updated.
- Once a state of emergency is lifted the yellow and red placard records are converted to 'dangerous' or 'restricted use' building notices, which are changed once the local authority is advised that repairs have been effected to bring the building back to a condition comparable to that prior to the earthquake.

The building safety evaluation system has become an increasingly valuable tool in managing both the initial management of earthquake damaged buildings, and also as a means for managing the recovery process in the months and years following a quake.

- It is hoped that all territorial authorities around New Zealand take up the same system in preparedness for a similar event that may occur in their locality, recognising that it is an international best practice system.
- The system allows people to make informed decisions about reoccupying buildings after an earthquake.
- The ability of a yellow or red carded building to safely resist a future earthquake of similar intensity is reduced,
- The ability of a green carded building to resist a future earthquake remains largely unchanged from prior to the event, but does not indicate that it will survive a larger earthquake in the future.

There is a mandatory requirement that old buildings be strengthened to provide resistance to earthquake loads to a minimum of 33% of the current design level. The New Zealand Society of Earthquake Engineering recommends a minimum of 67% of current design level.

- Building owners must recognise the need for them to undertake further work, even for green-labelled buildings to ensure the minimum legal obligations are met, but are recommended to consider strengthening to 67% of current design levels.
- The strengthening process should also increase the ability of the structure to sustain damage without collapsing and causing loss of life.

Prepared with the assistance of Members of the New Zealand Society for Earthquake Engineering · 4 March 2010

Liquefaction

The recent sequence of earthquakes and aftershocks in the Christchurch area has highlighted a phenomenon that previously has had a very low public profile. Now, 'liquefaction' is visible. Its effects in Christchurch are extensive and have resulted in significant damage to property, buildings and infrastructure, not to mention creating a widespread mess. Silt, sand and water bubbled up in people's backyards, in streets and parks and even through the concrete floors of buildings. Some refer to the sand and silt as liquefaction, but that is not correct. The soil at the surface is a result of liquefaction.

WHAT IS LIQUEFACTION AND WHY DOES IT OCCUR?

Liquefaction is the process that leads to a soil suddenly losing strength, most commonly as a result of ground shaking during a large earthquake. Not all soils however, will liquefy in an earthquake. The following are particular features of soils that potentially can liquefy:

- They are sands and silts and quite loose in the ground. Such soils do not stick together the way clay soils do.
- They are below the watertable, so all the space between the grains of sand and silt are filled with water. Dry soils above the watertable won't liquefy.

When an earthquake occurs the shaking is so rapid and violent that the sand and silt grains try to compress the spaces filled with water, but the water pushes back and pressure builds up until the grains 'float' in the water. Once that happens the soil loses its strength – it has liquefied. Soil that was once solid now behaves like a fluid.

WHAT HAPPENS NEXT?

Liquefied soil, like water, cannot support the weight of whatever is lying above it – be it the surface layers of dry soil or the concrete floors of buildings. The liquefied soil under that weight is forced into any cracks and crevasses it can find, including those in the dry soil above, or the cracks between concrete slabs. It flows out onto the surface as boils, sand volcanoes and rivers of silt. In some cases the liquefied soil flowing up a crack can erode and widen the crack to a size big enough to accommodate a car.

Some other consequences of the soil liquefying are:

- Settlement of the ground surface due to the loss of soil from underground.
- Loss of support to building foundations.
- Floating of manholes, buried tanks and pipes in the liquefied soil - but only if the tanks and pipes are mostly empty.
- Near streams and rivers, the dry surface soil layers can slide sideways on the liquefied soil towards the streams. This is called lateral spreading and can severly damage a building. It typically results in long tears and rips in the ground surface that look like a classic fault line.

Not all of a building's foundations might be affected by liquefaction. The affected part may subside (settle) or be pulled sideways by lateral spreading, which can severely damage the building. Buried services such as sewer pipes can be damaged as they are warped by lateral spreading, ground settlement or floatation.

AFTER THE EARTHQUAKE

After the earthquake shaking has ceased, and liquefaction effects have diminished (which may take several hours), the permanent effects include:

- Lowering of ground levels where liquefaction and soil ejection has occurred. Ground lowering may be sufficient to make the surface close to or below the watertable, creating ponds.
- Disruption of ground due to lateral spreading.

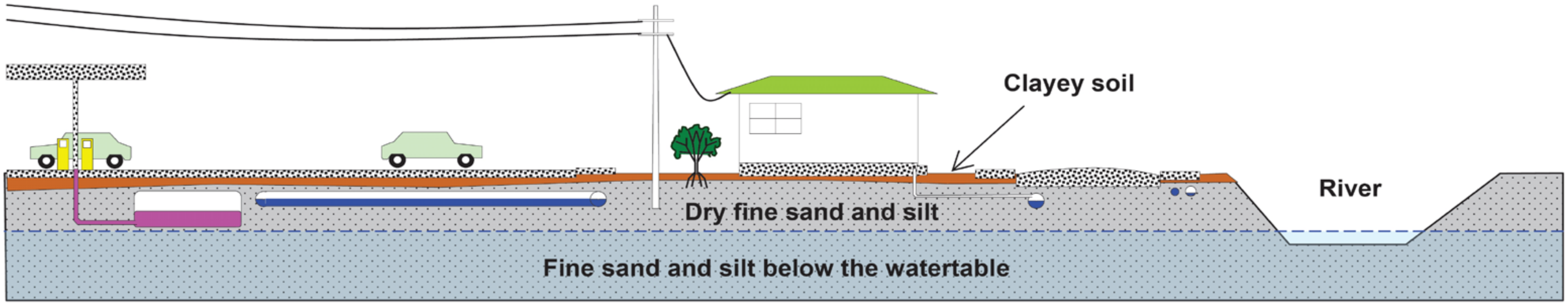
The liquefied soil that is not ejected onto the ground surface re-densifies and regains strength, in some cases re-densified soil is stronger than before the earthquake. Careful engineering evaluation is required to determine whether ground that has suffered liquefaction can be redeveloped.

Prepared with the assistance of Members of the New Zealand Geotechnical Society · 4 March 2011

Liquefaction and its Effects

Before the Earthquake

Areas of flat, low lying land with groundwater only a few metres below the surface, can support buildings and roads, buried pipes, cables and tanks under normal conditions.



During and after the Earthquake

During the earthquake fine sand, silt and water moves up under pressure through cracks and other weak areas to erupt onto the ground surface. Near rivers the pressure is relieved to the side as the ground moves sideways into the river channels.