LIQUEFACTION

THE Q FILES

- WHAT IS IT?
- WHAT WILL HAPPEN WHEN THE GROUND LIQUEFIES?
- WHAT DOES THE LIQUEFACTION HAZARD RATING FOR MY PROPERTY MEAN?

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1. Liquefaction sand boil in ploughed paddock (1992 Gisborne Earthquake).
2. Collapse of rail embankment from liquefaction (1931 Napier Earthquake).

Produced by Rivers and Hazards Section Environment Canterbury

PORT ROYAL: A CARIBBEAN ATLANTIS

Terrified colonists huddle in prayer as an Earthquake destroys their town in June 1692. In this vivid contemporary depiction, the town lies ruined, but in fact a large part of it still remains buried under the sea.

The buccaneers who founded the British colony of Port Royal (Jamaica) built their city on a spit of land formed from 30 metre thick sediments. When the earthquake occurred the sediments slid seaward presumably as a result of liquefaction and lateral spreading. Within a short time parts of the town lay under 15 metres of water.

In 1959 archaeologists began to investigate the site and under 3 metres of silt what they found was astonishing. Though many buildings had been toppled, entire blocks of shops and homes had been carried virtually intact beneath the sea on sliding blocks of land.

In one kitchen, turtle bones lay in a copper kettle, remains of a meal begun but not finished. In a dining room, stacked pewter plates, glassware and crockery also told of meal time preparations. A carpenter's shop had a nearly finished bed and an apothecary was stocked with medicine bottles and ceramic jars of salve. Bottles of rose water and the booty of some buccaneering raid were also found.

WHAT IS LIQUEFACTION?

Liquefaction (pronounced “lick-wi-fack-shin”) happens during Earthquakes.

The ground shaking that occurs during an Earthquake can cause some soils to liquefy.

This means during an Earthquake these soils will behave more like a liquid than a solid...

WHAT TYPES OF SOILS ARE MOST LIKELY TO LIQUEFY?

Liquefaction does not occur at random, but is restricted to certain geologic and hydrologic environments. Young (less than 10,000 years old) marine sediments, estuary deposits, some river channel and floodplain deposits, and poorly compacted man-made fills are the most common soils to liquefy. The soils in these depositional environments are predominantly sandy and silty soils. For liquefaction to occur the soils must be loose (unconsolidated) and saturated (be below the water table).

HOW DOES LIQUEFACTION HAPPEN?

When the ground shakes during an Earthquake the soil particles are rearranged and the soil mass compacts and decreases in volume (Fig. 1). This decrease in volume causes water to be ejected to the ground surface.

Sand volcanoes or sand boils, water fountains and associated ground surface cracking are evidence that liquefaction has occurred (Fig. 2 and cover photograph).

DOES LIQUEFACTION HAPPEN IN ALL EARTHQUAKES?

No. Strong ground shaking is required for liquefaction to occur. Liquefaction may occur at Modified Mercalli intensity 7 (MM7). The MMI scale (1 to 10) is a measure of how strong ground shaking is at a specific location. At MM7 there is general alarm, it is difficult to remain standing, large bells will ring, furniture will move and un-reinforced masonry buildings will crack. Liquefaction is common in areas where there is MM8 and greater shaking. At MM8 alarm may approach panic, steering of vehicles is affected, substantial damage to buildings occurs, the ground cracks and road cuttings collapse.

FIG. 1 THE LIQUEFACTION PROCESS

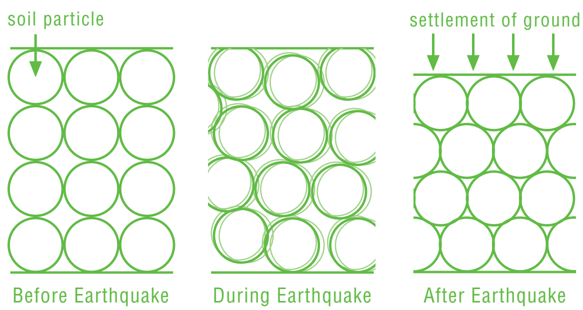
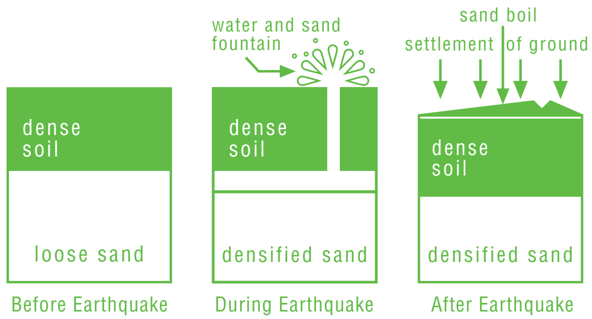


FIG. 2 FORMATION OF WATER FOUNTAINS AND SAND BOILS



WHAT ARE THE EFFECTS OF LIQUEFACTION?

Liquefaction causes damage to the ground. Because the soil mass decreases in volume as a result of liquefaction, the ground surface may subside. Uniform subsidence over large areas may go unnoticed. Differential subsidence, particularly where there are buildings and other infrastructure, can be very obvious because of the variation in damage to those structures (Fig. 3).

Lateral spread of the ground can also occur. Lateral spread is when blocks of land move sideways. This is most common near rivers, streams, lakes and coastal areas (Fig. 4 and Fig. 5).

Flow failures (displacement of large masses of soil laterally for tens of metres and sometimes kilometres) and loss of soil strength are two other significant effects of liquefaction.

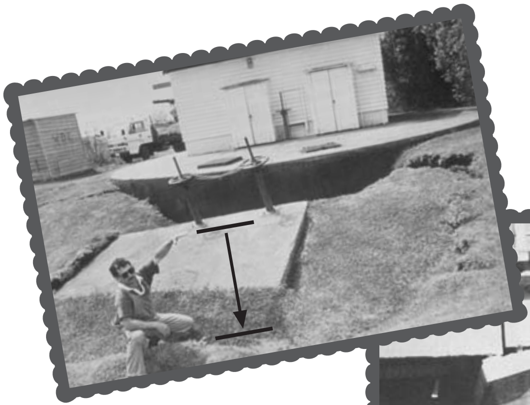
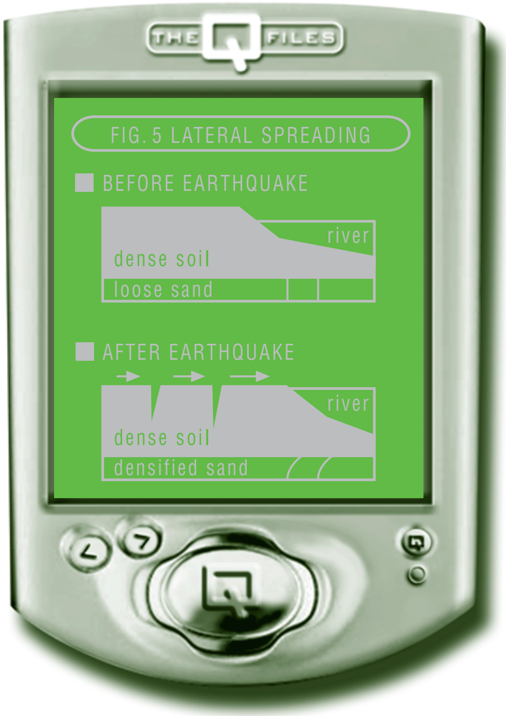


Fig. 3 – Ground surface settlement at sewage pump station (1987 Edgecumbe Earthquake).

Fig. 4 – Lateral spreading near river (1975 Liaoning Earthquake, China).



WHAT SORT OF DAMAGE MAY OCCUR TO STRUCTURES IN AREAS THAT LIQUEFY?

Fig. 7 – Tilting and toppling of buildings (1964 Niigata Earthquake, Japan).

Loss of soil strength can cause large buildings and other structures to sink into the ground, tilt, topple over or partly collapse (Fig. 6 and Fig. 7). Where there is differential subsidence, foundations of small buildings may crack and settle, causing deformation of the structure and cracking of walls.

Buried structures such as large pipes, tanks and manholes can become buoyant and float to the ground surface (see Fig. 8). Pipes are likely to be damaged. Other buried services are often damaged at the transition from a liquefied soil into a non-liquefied soil.

Deep foundations (such as bridge piers) can break where there are alternating layers of liquefied and non-liquefied soils. Approaches to bridges and stopbanks are particularly vulnerable (Fig. 9). Roads and railway tracks, and other structures built on fill can be damaged (Fig. 10).

FIG. 6 SINKING AND TILTING OF BUILDING

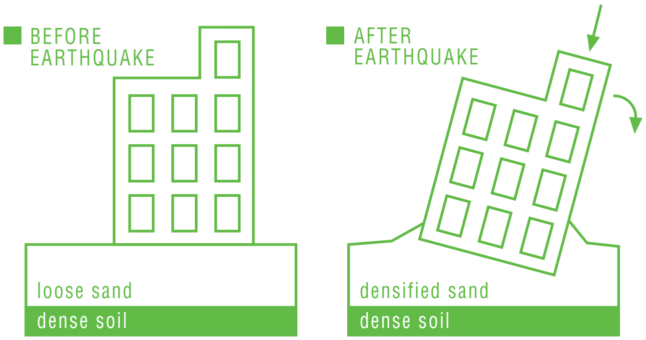


Fig. 9 – Collapse of rail embankment (1931 Napier Earthquake).

WHAT CAN BE DONE TO REDUCE THE IMPACT OF LIQUEFACTION?

There are three main ways to reduce the effects of liquefaction – by stabilising the ground, by specific foundation design or by strengthening structures to resist predicted ground movements (if small).

There are various methods available to stabilise a soil. These methods generally increase the density of the soil thereby increasing the resistance of the soil to liquefaction. Most of the methods are expensive and would be uneconomic for residential structures.

FIG. 10 COLLAPSE OF ROAD OR RAIL EMBANKMENT

Lower cost compaction methods such as repetitive dropping of a heavy weight or using a heavy roller may be economic for residential developments.

Removal of liquefiable material and replacement with coarser material, de-watering (drainage) and buttressing of lateral spread zones are other ground stabilisation techniques.

Specific foundation designs reduce the likelihood of damage to the foundation and deformation of the structure. Stronger foundations, deep piles and piling to non-liquefiable soil layers are the more common methods used to reduce the effect of liquefaction on structures.

HOW DO WE ASSESS THE CHANCE OF LIQUEFACTION HAPPENING?

There are five main factors used to assess the likelihood for soils to liquefy. These are the strength of ground shaking, duration of shaking, depth to the water table, soil properties (grain size and density), and confining pressures.

Your Christchurch City Council Land Information Memorandum (LIM) or Environment Canterbury Land Information Request (LIR) gives a “liquefaction potential” rating and a “liquefaction ground damage” rating. The liquefaction ratings are derived from a database of borehole and other subsurface information.

The liquefaction potential rating is based on soil type and strength, groundwater level, and the location and strength of Earthquakes. There are four classes of liquefaction potential – High, Moderate, Low and No or Unknown liquefaction potential.

Areas of Christchurch rated as having “high liquefaction potential” have soil types and strengths that are the most prone to liquefaction. Three types of Earthquakes could cause liquefaction in these areas. These are a local Earthquake, a foothills Earthquake and an Alpine fault Earthquake.

A local Earthquake (magnitude 6) is likely to have a return period (the average time between events) of about 200 years. A foothills Earthquake (magnitude 7.2) and an Alpine fault Earthquake (magnitude 8) have return periods of about 2000 years and 400 years respectively.

Areas of Christchurch rated as having “moderate liquefaction potential” have soil types and strengths in between the High and Low classes. Two Earthquake types could cause liquefaction in these areas – a foothills Earthquake and an Alpine fault Earthquake.

A foothills Earthquake (magnitude 7.2) and an Alpine fault Earthquake (magnitude 8) have return periods (the average time between events) of about 2000 years and 400 years respectively.

Areas of Christchurch rated as having “low liquefaction potential” have soil types and strengths that are the least prone to liquefaction. Only an Alpine fault Earthquake could cause liquefaction in these areas.

An Alpine fault Earthquake (magnitude 8) has a return period (the average time between events) of about 400 years.

Areas of Christchurch rated as having “no or unknown liquefaction potential” generally do not have soils prone to liquefaction, or there is currently not enough soil information to determine the potential for liquefaction.

Five classes of liquefaction ground damage have been defined for Christchurch – Very High, High, Moderate, Low and No liquefaction ground damage potential.

Areas of Christchurch rated as having "very high liquefaction ground damage potential" may be affected by lateral spreading and significant ground subsidence. Subsidence is likely to be greater than 300mm.

Areas of Christchurch rated as having "high liquefaction ground damage potential" may be affected by significant ground subsidence. Subsidence is likely to be greater than 300mm.

Areas of Christchurch rated as having "moderate liquefaction ground damage potential" may be affected by 100-300mm of subsidence.

Areas of Christchurch rated as having "low liquefaction ground damage potential" may be affected by up to 100mm of ground subsidence.

Areas of Christchurch rated as having "no liquefaction ground damage potential" are those areas where liquefaction is not expected to occur.

IMPORTANT NOTES ABOUT LIQUEFACTION

- Liquefaction itself may not be particularly damaging or hazardous. When accompanied by significant ground damage it is potentially damaging or destructive to the built environment.
- Liquefaction is only one effect of an Earthquake that may threaten life and property. Other effects of Earthquakes such as ground shaking strength must be considered to obtain a complete picture of Earthquake hazard.
- While the liquefaction potential and liquefaction ground damage potential assessments are based on mapped hazard zones, there is no certainty that liquefaction will occur at a particular site due to an Earthquake of any magnitude.
- There is limited soils information for parts of Christchurch. Therefore the potential for liquefaction and associated ground damage may be under or over estimated.
- The boundaries between the mapped liquefaction potential and damage zones are approximate and indicative only.
- The liquefaction potential and ground damage potential classifications are indicative only, and do not imply any level of damage to any particular structures, services or other infrastructure.
- The liquefaction hazard information is regional in scope and cannot be substituted for a site-specific investigation. Further advice on the liquefaction hazard at a specific site, the effects on existing or proposed development, and options for mitigating any risk may be sought from specialist geotechnical engineers.

REMARKABLE FISSURES IN THE EARTH

"At Kaiapoi, when the shock had passed…his land was apparently flooding from springs having been opened. It was then discovered that across his land…fissures from 1inch to 3inches [25 to 75mm] in width, and several chains [40m] in length had opened. From these earthquake openings the water was freely issuing…a liberal supply of sand from a grey quicksand layer below the level of the river, and this was deposited…in the shape of round and oval porridge pots and little hills.

The fissures remained open, and could be probed to a depth of six feet [2m].

On the opposite side of the Waimakariri…a crack is traceable out of the river 2ft [600mm] in width on to the river bed…where one of the fissures is 9inches [230mm] wide, and has, like many smaller cracks of the earth, been filled with quicksand blowing up. A rod several feet long was inserted in the sand, but was not long enough to test the exact depth of the ooze, though it is surmised to have come up from 20ft to 25ft [6 to 7.5m]."

Evidence that liquefaction occurred in Kaiapoi during the Cheviot Earthquake in 1901.

("The Press" 18 November 1901).