Ground Improvement Trials
for Liquefaction Vulnerable Land

EQC
EARTHQUAKE COMMISSION
Kōmihana Rūwhenua

New Zealand Government

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Introduction

One of the features of the Canterbury earthquakes was the significant damage caused by liquefaction. We now have a better understanding of what land is vulnerable to liquefaction and the need to improve resilience if building on liquefaction vulnerable land, like in TC3 areas.

The design of a home's foundations is clearly an important part of achieving resilience in these areas. Improving the resilience to liquefaction of the land itself, or strengthening the land, also has the potential to play a key role. There are some known methods for doing this but they are not proving to be effective in Canterbury. As part of its research function, EQC is looking to identify new methods that are practical to apply on liquefaction vulnerable properties. The aim is to find a balance between improving the land and foundation design to contribute to cost effective, consentable construction solutions, and better outcomes for homeowners.

The Trials

EQC is funding a programme, run by leading experts from New Zealand and around the world, to trial a number of ground improvement methods that are tried and true in large scale civil construction projects, to see if they can be applied in residential construction in Canterbury.

There are four methods being trialled. Some of them are intended to strengthen soil on bare land prior to a rebuild. In other situations, land that is materially vulnerable to liquefaction lies beneath a lightly damaged house. In these cases a land improvement technique that avoids the need to move or demolish the house is needed and we are trialling a method for this.

The testing programme is world-leading, smart, and rigorously applied research. It is being run for EQC by leading experts from New Zealand and around the world. Geotechnical engineering firm Tonkin and Taylor is guiding the trials, supported by reviewers from the University of Canterbury, Cornell University, UC Berkeley, University of Texas and leading engineering consultancy firms.

The trials are being conducted on unoccupied cleared land in parts of the residential red zone, at three sites in Wainoni, Avonside, and Bexley. These areas have soil characteristics representative of almost all of TC3 residential properties. The sites were selected by an international academic panel, convened by Tonkin & Taylor and the University of Canterbury, and were based on extensive geotechnical and geophysical analysis of representative soil conditions in the different areas.

To assist in the investigations, we have helped bring the specialised truck-mounted geophysical test equipment, known as the T-Rex, over from the University of Texas.

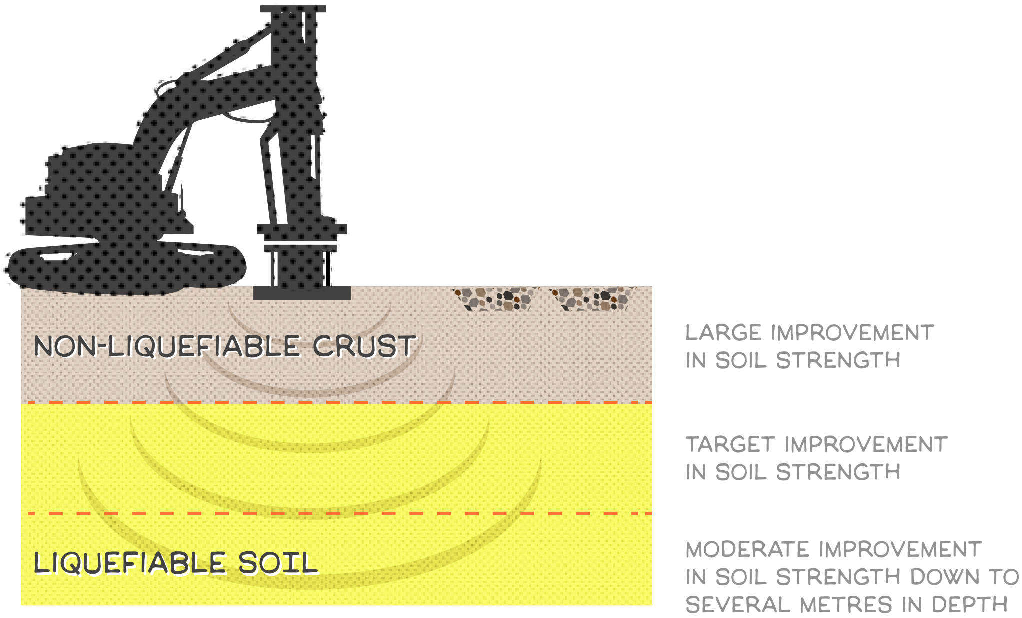
The T-Rex truck uses a large metal plate to create intense, but highly localised, shaking that diminishes rapidly with increasing distance from the truck. This shaking is applied to areas of test site land to assist in the evaluation of the strengthening methods being trialled.

The T-Rex triggers localised liquefaction to particular areas of land – a couple of metres in diameter by a couple of metres deep directly beneath the truck. This allows the researchers to undertake the trials in a very controlled manner and increases the accuracy of the results.

The Methods

Rapid Impact Compaction (RIC)

1



RIC is a smaller-scale version of a method called Dynamic Compaction which has been widely used on projects in New Zealand and around the world. It was used in the foundation work of Te Papa Museum in Wellington, for example.

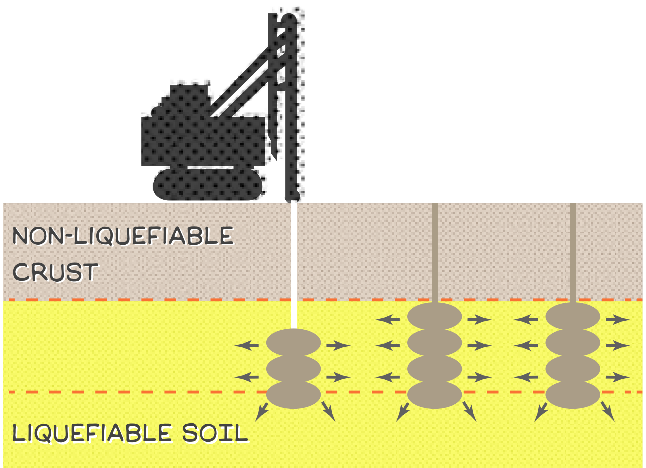
The RIC equipment is effectively a pile-driving hammer attached to a large steel end-plate, installed on the arm of an excavator. This end-plate is driven into the ground with rapid hammering. This improves the density of the ground in two ways – first, due to the physical compaction near the surface as the plate is hammered (with craters then filled in) and second, by vibro-compaction of the soils down to several metres depth.

The advantage of this improvement process is that it does not target a specific layer – all soils within several metres of the surface are treated.

This technique may offer advantages in cost and efficiency for well-suited sites, such as those with sandier soils. It requires sufficient working room and, due to vibrations, may be best applied on sites with vacant neighbouring properties or in cases where work can be sequenced across multiple properties.

Low Mobility Grout (LMG)

2



Also known as Compaction Grouting, this method works by injecting low-mobility (concrete consistency) grout to form a column of concrete “bulbs” within the soils. This squeezes out the existing soil sideways, providing densification and a positive increase in horizontal soil stresses, while the concrete columns also provides a stiffening of the soil.

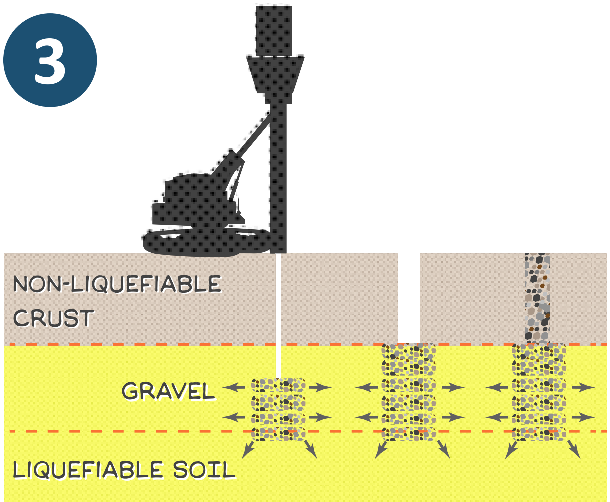
The grouting process usually starts at the bottom bulb and works upwards, so it generally improves only the target ‘new’ crust and provides only minor improvement for the liquefiable soil directly under the target layer.

The LMG technique offers advantages in cleared sites but where it’s still preferable not to disturb the soil or groundwater (e.g. on sites with historical ground contamination). It also offers the opportunity to provide moderate improvement of soils that are too silty to improve using the Rapid Impact Compaction and Rammed Aggregate Piers methods, but which are still susceptible to liquefaction.

The Methods

Rammed Aggregate Piers (RAP)

3



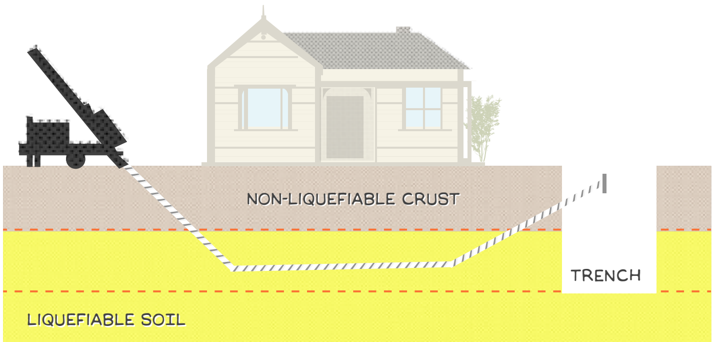
Working on a similar principle as the LMG method, this technique uses gravel, instead of concrete, to create columns that help stiffen the soil. A mandrel is pushed into the ground with a very powerful hydraulic ram, down to the target improvement depth. Gravel is fed down the hollow stem of the mandrel and released into the ground at depth.

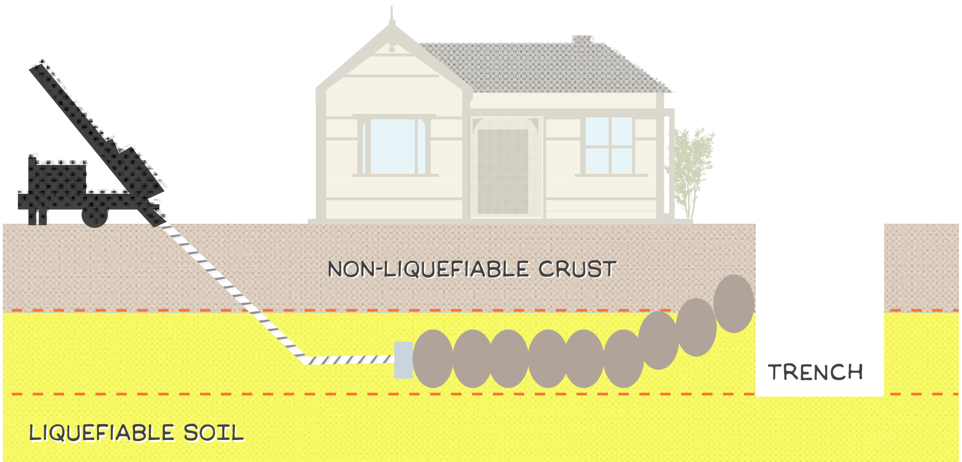
The mandrel then pushes back into the released gravel, compacting it and forcing the gravel to push outwards into the surrounding soil. This process is repeated as the mandrel is raised, forming a column of compacted gravel. This provides densification and increases positive horizontal soil stresses in the surrounding soil.

The RAP method is a proprietary ground improvement technique that offers advantages in sites with suitable ground conditions (sand through to sandy silt) and requires sufficient working room.

Horizontal Soil Mixing (HSM)

4





This technique offers advantages in situations where an existing building is to remain in place or where vibration and space constraints exist due to close proximity to neighbouring properties.

HSM works by drilling horizontally under an existing property, through the target layer out to a trench where it is then fitted with a horizontal axis rotary mixing tool. The tool is withdrawn back through the drilled hole, as cement mix is pumped through the drill steel and mixed with the soil by the rotary mixing tool.

This creates horizontal cemented columns in the target layer, which stiffens the soil and suppresses soil deformation, supressing the triggering of liquefaction.

Timing and impact on rebuild

The first phase of the ground improvement trials were completed in mid-July 2013.

A final round of geotechnical testing is being planned for September 2013. In the mean-time the team is undertaking an extensive programme of data analysis. This analysis will help inform a pilot programme where successful techniques will be deployed in actual residential settings. This will help us understand whether the methods are cost effective, commercially viable and will help the Christchurch City Council and Ministry of Business innovation and Employment understand if they are consentable.

We are hopeful that the trials will provide a greater range of ground improvement methods to landowners for the rebuilding programme in Christchurch, and lead to the development of cost-effective, verifiable and practical methods for use on residential properties.

This work may also inform land claim settlement for properties that have experienced a material increase in the risk of damage from liquefaction as a result of the Canterbury Earthquakes. However, at this stage the research is insufficiently advanced to determine this.

For more information go to: www.eqc.govt.nz
or freephone 0800 DAMAGE (0800 326 243)

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