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Provision of liquefaction hazard information: Building resilient communities

La provision d'information de danger de liquéfaction: Construisant des communautés elastiques

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ABSTRACT
How effectively is knowledge of hazards disseminated throughout New Zealand in various communities? A brief introduction into New Zealand's regulatory planning and development for liquefaction risk evaluation and hazard mitigation is provided. The regulatory authorities have been surveyed on their perception of liquefaction and this showed that there is a wide variation in how liquefaction is perceived and dealt with. Finally, a discussion is provided on techniques that could be utilised to improve knowledge dispersion throughout our communities.

RÉSUMÉ
Combien efficacement la connaissance des risques est-elle disséminée dans l'ensemble de la Nouvelle Zélande dans diverses communautés? Une brève introduction dans la planification de normalisation de la Nouvelle Zélande et le développement pour la liquéfaction risquent l'évaluation et la réduction de risque est fournie. Les autorités de normalisation ont été examinées sur leur perception de la liquéfaction et ceci a prouvé qu'il y a une grande variation dans la façon dont la liquéfaction est perçue et traitée. En conclusion, une discussion est fournie sur les techniques qui pourraient être utilisées pour améliorer la dispersion de la connaissance dans toutes nos communautés.

1 INTRODUCTION

In the nineteenth and twentieth centuries we have put increasing pressure on coastal and riverside land as cities have built up and out around transportation hubs, none more so than in New Zealand where a new nation was in the process of being born. Furthermore, coastal properties have become more desirable and fashionable over the last 20 to 30 years. However, the soils in these areas are often prone to liquefaction. In these types of soils in New Zealand a number of earthquake induced liquefaction events have been recorded (Fairless and Berrill, 1984). Internationally prior to 1964 liquefaction was observed, but the understanding of its mechanisms was still developing (Housner, 1958; Florin & Ivanov, 1961). Following the 1964 Niigata (Kawasumi, 1968) and Alaskan Earthquakes (Scott & Zuckerman, 1973), where a significant amount of ground and infrastructure damage was caused by liquefaction, our understanding of the phenomena has grown dramatically. Nowadays, it is rare for a geotechnical conference, especially in a seismically active region, to pass without further knowledge being passed on in regards to liquefaction. But how well is that knowledge of liquefaction being passed from a knowledge centric technical community on to the wider community? Firstly in this paper we will briefly look at New Zealand's legislative framework, followed by a summary of liquefaction knowledge in New Zealand. Lastly, we will consider changes that could be made to present systems in order to create more resilient communities.

2 NEW ZEALAND'S LEGISLATIVE FRAMEWORK

2.1 *Resource Management Act 1991*

The Resource Management Act 1991 (RMA) is the principal Act for the management of land use, subdivision, the use of water and soil resources and several other functions. Its purpose is to promote the sustainable management of natural and physical resources. The RMA requires Regional Councils to collect information about natural hazards relevant to their communities.

2.2 *Civil Defence and Emergency Management Act 2002*

In 2002, the Civil Defence and Emergency Management Act 2002 (CDEM Act) was enacted, which requires a risk management based approach to the sustainable management of hazards, both natural and man-made. The Act's purpose includes: improving sustainable hazard management; improving safety of the public and property; encouraging communities to achieve acceptable levels of risk; requiring local authorities to co-ordinate CDEM planning and other activities; ensuring integration of national and local CDEM planning; and encouraging CDEM co-ordination across a range of agencies.

Of particular relevance to the consequence of liquefaction, engineering lifeline operators and local authorities are required to be able to function to the fullest possible extent during and after an emergency.

3 HISTORY OF LIQUEFACTION IN NEW ZEALAND

Liquefaction has been actively studied in New Zealand's Engineering Schools in the 1980's at an undergraduate and postgraduate level. Prior to this there were few 'champions of liquefaction' within academia. Lecturers at Canterbury University (NZ) published a liquefaction prediction methodology based on an energy dissipation approach in 1982 (Davis and Berrill, 1982). In addition, a few of the large national development projects (e.g. Motunui Gas to Gasoline Project) in the 1980's considered the hazard of liquefaction using 'state of the art' methods. But until the late 1980's and into the early 1990's the wider engineering community generally had a poor understanding of the hazard (and also the liquefaction process). From the 1980's, the main metropolitan Regional Councils commenced studies to identify the hazard of liquefaction in the more populous areas, resulting in the production of liquefaction hazard and

damage maps and supporting technical reports. But still the knowledge of the hazard was restricted to a select community, and there are members of the engineering community, albeit in decreasing numbers, who deny that liquefaction is a hazard that needs addressing. But in general, our civil and geotechnical engineering communities are becoming more aware of the concept of liquefaction, its implications and potential mitigation techniques. But what is the knowledge base in the wider community?

4 CURRENT STATE OF KNOWLEDGE

The authors conducted a telephone survey in 2004 of the Regional and District Councils within New Zealand to assess the level of awareness and understanding of liquefaction and the extent and use of liquefaction hazard information.

District Councils, also grouped with city councils and unitary authorities, are local government bodies used to administer the affairs of local communities in New Zealand, of which there are 74. Regional councils, of which there are 12, serve a collective of district councils and have a greater focus on environmental issues. Collectively the councils make land use planning and development decisions, including consenting, but also create and maintain statutory plans. Councils are responsible for issuing consents to allow development and therefore are an important check-point for an issue such as liquefaction.

Generally, the survey attempted to ask questions of the chief building officer, but often that person was unavailable and other officers within the council were able to respond to the questions posed. It is possible that the informal survey technique may have resulted in erroneous or incomplete answers in some instances as the responses often relied upon an officer's personal knowledge, rather than the council's collective knowledge. Notwithstanding this, these officers were responsible on a regular basis for providing advice on building consents. The survey had a 98% response rate. Some of the questions asked in the survey are provided in Table 1 (other more detailed questions on the specifics of liquefaction knowledge were also asked). A graphic representation of the perception of liquefaction as a hazard in New Zealand is shown in Figure 1.

The results demonstrated in Table 1 imply that the regional councils appear to have collectively a greater knowledge on liquefaction as a hazard in their region. This is not surprising given their functions, roles and responsibilities. However, the results recorded for the district councils in all likelihood do not accurately depict the liquefaction hazard present in New Zealand. It is probable that there are soils in every district of New Zealand that would be susceptible to liquefaction, albeit their percentage coverage of a region would vary greatly. Consequently the liquefaction risk, or perceived risk, to districts is under-recognized, and it is likely that this is reflected in the results. Surprisingly there were some regions that have suffered from the affects of liquefaction over the past century, which have responded during the survey that liquefaction is not perceived as a hazard in their region. Therefore, at least on an individual basis, the collective knowledge of these councils is not being adequately communicated within the council and to the community.

If we are to build resilient communities, then the knowledge that is possessed needs to be passed onto the community. Furthermore, that knowledge needs to be passed in a manner suitable to the recipients. The survey undertaken shows that for large parts of the country, liquefaction is identified as a hazard. Yet steps of quantifying the hazard and presenting hazard information to the community is not occurring on a systematic basis. Only one third of the district councils are presenting information that it holds on liquefaction to landowners (via Land Information Memoranda, or LIM's, which are available from council and provide information on land parcels). Moreover, only 26% have maps that depict liquefaction hazard zones. A small number of councils, typically the larger and better-funded councils (on a population basis), do have a considered programme of identifying liquefaction hazards and educating the community on the risk.

Table 1: Liquefaction Survey Summary for New Zealand Council's

	Regional Council	District Council
Is liquefaction considered a hazard in your region?	83 %	46%
Are liquefaction hazards noted on Land Information Memoranda (LIM's)?	n/a	32%
Are maps available showing liquefaction hazards?	75%	26%
Does the region have a liquefaction public hazard education programme?	25%	8%

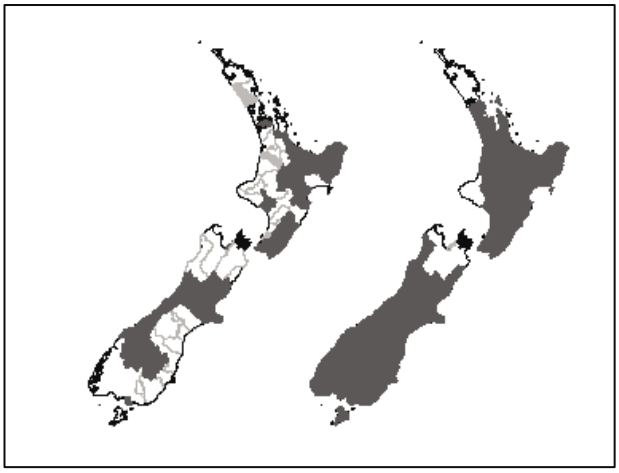

Figure 1: Distribution of Regional Council's (shown on the right) and District Council's (shown on the left), which have identified liquefaction as a hazard within their region. Dark areas show regions that identify liquefaction as a risk (light shading is for areas of no response in the survey).

In November 2004 the Auckland City Council released information to the community on pesticide hazards, through a press release and notification on LIM's. Where market gardens were known to exist historically, the property files were tagged with the possibility that the land was contaminated from pesticide residue in the soil. A significant press and public backlash resulted, causing the council to back-step and remove the possibility of contamination from the property files (primarily due to peoples concerns over reduction in property values). This demonstrates that caution needs to be exercised when relaying technical risks to the community. However, where liquefaction has been listed as a potential risk item on a LIM, it has proved comparatively inert as a risk item to the community compared to this pesticide case.

With time, a greater range of projects in New Zealand are addressing liquefaction, not just those that have a major infrastructure or engineering lifeline utility function. Provided below are three examples of how liquefaction hazard has been addressed in New Zealand, including two regional studies to determine the risk and a case of liquefaction mitigation that has been completed.

4.1.1 *A Mapping Example – Christchurch Liquefaction Study*

A geotechnical study was undertaken in 2002 (and updated in 2004) to evaluate the liquefaction hazard for Christchurch City (Beca, 2004). Liquefaction was recognised as a potential hazard for around one-third of Christchurch City (Brown & Weeber, 1992, and CAE, 1997). These published liquefaction maps showed the hazard as a function of distribution of soil types across the City, but did not take into account the soil strength

data. A new study was completed which took into account the available soil strength and water table data.

The new desk-top study included: the collation of soil information from various organisations (both public and private); analysis of historical monitored bore water levels held by the regional and district councils; creation of geotechnical database with around 10,000 data points including bores, cone penetrometers, hand augers and test pits; creation of an algorithm to analyse liquefaction hazard based on actual soil strengths; estimation of liquefaction ground damage; and presentation of liquefaction hazard and ground damage on maps compiled at a scale of 1:25,000. The analysis was undertaken using three ground-shaking scenarios and two ground water elevation scenarios. This methodology provided a more robust and detailed means of identifying liquefaction trends across the city (it does not however eliminate the need for site specific studies to be undertaken).

The resultant study forms part of a greater earthquake hazard education package. The package includes a poster detailing the results of the liquefaction study and information booklets on liquefaction, earthquake hazards, and general natural hazards throughout the region. The liquefaction hazards are presented to the residents of Christchurch through information on LIM's available at Christchurch City Council.

4.1.2 *A Mapping Example – Wellington Liquefaction Study*

A study of the liquefaction hazard, in addition to other hazards, was completed in 1993 (Works, 1993) for the Wellington Regional Council. The study published six different maps of the more populous localities within the Region at scales varying between 1:50,000 and 1:75,000.

The maps were compiled based on geological maps, ground water conditions, a small number of 'representative' boreholes and CPT's, and a few particle size distribution tests. The limited field-testing was used to establish typical profiles for select geological units, which in turn were used to describe the regional hazard. Sensitivity to liquefaction was demonstrated using two different earthquake scenarios. As with the Christchurch Study, the maps distinguished areas of liquefaction potential and liquefaction ground damage. This information has been presented to the local community through newspaper reports, available maps, and on LIM's.

4.1.3 *A Mitigation Example – Christchurch Wastewater Treatment Plant*

The eastern side of Christchurch City is a low lying coastal margin that sits atop of Holocene sand deposits, i.e. a prime liquefaction candidate. The city's wastewater treatment plant is located beside a large estuary on these deposits. The plant services a community of around 330,000 people.

Aware that Christchurch was in a zone of potential liquefaction (CAE, 1997), the council decided that when constructing the new facilities in 1998 (required to improve effluent quality and expand plant capacity) that they would be designed especially to resist liquefaction. The major components of the upgrade included four 50m diameter, 5m deep in-ground concrete clarifier tanks. Specific seismic and field investigations were undertaken to determine the extent of the liquefiable soils. It was found that a layer of around 5m thickness located directly beneath the clarifiers had the potential to liquefy in a major earthquake (Beca, 1998). The design solution utilized vibrocompaction beneath the clarifier to densify the subgrade and make the treatment plant more resilient to damage from liquefaction.

5 EDUCATION AND KNOWLEDGE DISPERSION

Fisher et al. (1991) conducted a survey of risks that most concerned people. Respondent's most frequent nominations for risks were for threat to life from accident, disease and crime, while only 10 per cent of respondents listed environmental, natural or technological risks as a concern. As expected we are primarily concerned about risks that have a high frequency, but typically low consequence (such as theft), as compared to those risks that have low frequency and high consequence (such as earthquakes). Furthermore risks are contextual, for example, most will perceive the risk of earthquake damage in Kobe (Japan) to be significantly greater than in Alice Springs (interior of Australia). Earthquake risks (including liquefaction) interest only a select group of professionals or those that have been recently affected by that risk. How then do we bring a suitable level of understanding and hazard mitigation to the community when peoples risk portfolio is probably already full with higher likelihood risks?

Firstly we need to understand the logic of people. Nathe (2000) suggests that people do not think in terms of probabilities, they are more likely to make decisions in a binary fashion. An example of such a logic process for an earthquake would be:

1. Earthquake: what is it?
2. What damage can it do?
3. Is it likely to happen?
4. What losses would there be?
5. Can I reduce the losses?
6. How complicated is the mitigation?
7. What is the cost?
8. Has anyone done it before?
9. Who can help me?
10. When shall I begin?

At any stage in the above process, if credible information is not available then we are unlikely to move to the next step, and a fatalistic attitude may prevail in relation to the risk. To create a successful education campaign we must firstly generate interest or a questioning attitude of our audiences. We then need to be available to provide credible answers to the questions in a simple manner and also reinforce a consistent message over time.

The first task in improving liquefaction awareness is to identify the target audience of our message. In New Zealand there is an ongoing campaign at national level to reinforce earthquake preparedness through the use of television advertisements using celebrities, the use of print media, and every telephone book in the country sets out useful information on emergencies and 'B-Ready Kits'. Furthermore, New Zealand is using a 4 R's concept – reduction, readiness, response and recovery. Reduction being the avoidance of liquefaction prone areas and designing structures to reduce damage and then lessening the need for readiness, response and recovery. And still after decades of earthquake preparedness campaigning, most individuals do not take a personal responsibility. How then are we to address more specific and technical aspects of liquefaction hazard awareness and mitigation to the wider community? The short answer is that we should not attempt to. We do not want to dilute a basic earthquake awareness campaign with technical issues, at least not until a minimum level of understanding is achieved for general earthquake concepts. We should instead focus our attentions on our building professionals (developers, owners, certifiers, engineers, planners), who at this stage appear to be receiving mixed messages. Nonetheless, we still need a consistent message to provide to the general public, when an interest is generated, so that we reinforce our message at multiple levels.

We need some simple and yet effective tools in order to further increase the awareness of our building professionals, developers, owners, certifiers, engineers, planners. These tools when used in conjunction with legislative requirements should help provide a consistent approach (this is the key – but it needs to be attacked from as many fronts as possible). Such tools should include:

1. Provision of a nationwide information pack which sets out in simple terms what liquefaction is, how it occurs, what damage may be caused, how to mitigate the effects, and where to find more detailed information (something not

too dissimilar to Environment Canterbury's information booklets referred to in Section 4.1.1). Tying the information pack back to New Zealand's liquefaction history will help to reinforce the risk as a reality.

2. Provision of standardized procedures for dealing with liquefaction investigations to ensure that minimum standards are met.
3. Provision of a video showing the differences between a building that has liquefaction resilient features incorporated and a similar house that has not (this could be a simple as a video of shake table scale models). For many people visual media are a more powerful tool, as we tend to think in pictures.
4. Reinforcing the existing statutory requirements to address liquefaction at the regulatory level through increased awareness of building compliance officers.
5. Educate a wider range of professionals at university, not just civil engineers but also other disciplines, about risks that affect our communities and how those risks can be mitigated within different disciplines.
6. Conduct a nationwide road-show presenting tools to practitioners to make their jobs easier.
7. Reinforce the above on a regular basis.

6 SUMMARY AND CONCLUSIONS

Historical evidence suggests that New Zealand has had well in excess of 20 earthquakes that have generated liquefaction in the last 150 years. However, New Zealand's state of knowledge on liquefaction is highly variable. In some instances a few leading experts have furthered the technical knowledge of the international liquefaction community. The task now is to get those responsible for our built community reading from the same book when it comes to liquefaction. Without a common approach to education, but not necessarily the same solution, we as a nation will have a fragmented and less resilient community.

An investigation of district and regional councils in New Zealand has found that the depth of knowledge on liquefaction varies widely amongst our building compliance officers and regulators (in reality there is also likely to be a spectrum of understanding amongst politicians, planners, and developers). Moreover, where knowledge on liquefaction exists in a region or district, often that knowledge is not passed on to the wider community to allow people to make informed judgments on the risk that may affect them.

For too long we have allowed liquefaction hazard to be addressed in a random manner and a more structured education programme is overdue. It would be unthinkable in New Zealand to allow development on an active landslide or to allow a modern building to be built over an active fault line. Then why in some instances are developments allowed in areas that are liquefaction prone without mitigation? Liquefaction may not create dramatic failures that immediately endanger life, but they can have significant consequences, for example, on lifelines, potentially leading to uncontrollable fire spread in the urban environment. To date we have not given the right people sufficient information/education in liquefaction, nor the tools they require to address liquefaction. We need to provide our compliance officers with maps of liquefaction hazard at a district scale so that they can understand what areas are most at risk. Next we need to provide information on what damage can be caused, when is it likely to happen, what mitigation can be incorporated in designs, how much it might cost, and who can help with the technical questions? Only when these tools are provided to our planners and compliance officers can expect them to adopt a consistent and reasoned approach.

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