The development of guidelines and continuing professional development in earthquake geotechnical engineering design practice in New Zealand

Développement de guides et de formations professionnelles dans le domaine de la conception parasismique en ingénierie géotechnique en Nouvelle-Zélande

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ABSTRACT: New Zealand suffers on average around one shallow magnitude 7+ and ten magnitude 6+ events each decade, some of which have caused significant loss of life and economic damage. Recognising that earthquake resistant design practice in New Zealand needed greater consistency the development of a series of national earthquake geotechnical engineering practice guidelines was first discussed at a New Zealand Geotechnical Society (NZGS) symposium in 2006. The initial module addressed liquefaction and was published in July 2010, just two months before the Canterbury Earthquake Sequence which caused NZ$40 Billion damage and was one of the most extensive liquefaction events known globally within an urban area, highlighting the importance of liquefaction resistant design. The Canterbury Earthquakes Royal Commission of inquiry (CERC) recommended that the Ministry of Business, Innovation & Employment (MBIE) work closely with professional societies to improve design practice. This paper describes the joint development between the NZGS and MBIE of Earthquake Geotechnical Engineering Practice Guidelines and training for practising engineers.

RÉSUMÉ : La Nouvelle-Zélande subit en moyenne, chaque décennie un séisme peu profond de magnitude supérieure à 7 et une dizaine d'autres de magnitude supérieure à 6. Certains ont coûté des vies et causé d'importants dégâts. S'étant avéré que les pratiques parasismiques nécessitaient plus de cohérence, la Société Néo-Zélandaise de Géotechnique a engagé le développement de guides nationaux sur le génie géotechnique parasismique lors du symposium national de la Société en 2006. Un premier module portant sur la liquéfaction des sols a été publié en juillet 2010, juste deux mois avant la série de séismes de Canterbury qui ont coûté 40 milliards de dollars NZ de dommages. Ces séismes ont causé la plus importante étendue de phénomènes de liquéfaction connue en milieu urbain, soulignant ainsi l'importance des pratiques de conception de fondations résistant à la liquéfaction. La Commission Royale d'investigations sismiques de Canterbury (CERC) a recommandé que le Ministère du Commerce, de l'Innovation et de l'Emploi (MBIE) travaille en étroite collaboration avec les sociétés professionnelles pour améliorer les pratiques de conceptions parasismiques. Cet article décrit le développement de guides techniques pour la conception parasismique en Géotechnique et des formations techniques correspondantes dispensées aux ingénieurs en exercice. Ces actions ont été entreprises par la NZGS et le MBIE.

KEYWORDS: Earthquake, Guidelines, Geotechnical, Engineering, Professional Development, New Zealand

1 INTRODUCTION

New Zealand straddles the junction of the Asia-Pacific and Australasian tectonic plates, with the plate boundary crossing the country obliquely from north-east to south-west. To the north-east the Asia-Pacific plate is being thrust beneath the north island, which sits on the Australasian plate, while to the south-west the reverse is true, with the Australasian plate being thrust beneath the Asia-Pacific plate. The two plates are moving together at the rate of about 40mm per year.

About half of the population of the country of 4.7 million is concentrated in the three largest cities, Auckland, Wellington and Christchurch. The country is fortunate that by far the largest of these, containing about one quarter of the country's entire population, lies in a zone of low seismicity and the likelihood of damaging effects from a seismic event there is low. However, the other side of the coin is that the capital, Wellington, with a population of 491,400 (Greater Wellington region, 2014, Statistics New Zealand) lies in one of the highest seismicity zones. The Wellington fault, estimated to have a return period of 840 years, and capable of producing a Magnitude 7.4 earthquake, runs directly through the capital.

Much publicity in recent years has gone towards Christchurch and Kaikoura, due to the two series of earthquakes in these places and the huge damage to infrastructure and loss of life in the former. However, the country's focus and concerns with respect to earthquakes are directed largely towards Wellington, due to the expectation of a major event in the area. A Magnitude 9 'megathrust' Earthquake event is now considered to be a possibility on the Hikurangi subduction zone interface in the Wellington region. The hypothesized megathrust rupture extends along the entire East Coast of the North Island from northern Marlborough in the South Island to north of East Cape in the North Island. A smaller magnitude 8.1 earthquake scenario has been estimated to have a recurrence interval of 550 years (Stirling et al, 2012), which is slightly longer than the predicted recurrence interval of 300 to 500 years for a magnitude 8.1 event on the Alpine fault (Stirling et al, 2007) which passes down the backbone of the South Island.

The scenario outlined above indicates that earthquake geotechnical engineering is a very important engineering discipline in New Zealand. Not only do New Zealanders live with a high seismic hazard, but they also have complex geology and variable soil conditions, requiring a deep understanding of earthquake geotechnical engineering in order to understand how the ground is likely to behave in an earthquake, and to build safe, robust but affordable structures and linear infrastructure.

2 HISTORICAL EARTHQUAKE EVENTS

New Zealand suffers major earthquakes on a regular basis, on average over the last century around one shallow magnitude 7+ and ten of magnitude 6+ events every decade, Figure 1. Earthquakes that have affected urban areas have caused significant loss of life and economic damage, most notably a magnitude 7.8 event in Hawkes Bay in 1931 in which 256 people died, and more recently in Christchurch in 2010 and

2011 when a sequence of events with magnitudes 7.1 to 6.0 caused damage valued at some NZ$40Billion, approximately 20% of New Zealand's GDP; one of the magnitude 6.3 events resulted in the deaths of 185 people. The fact that this was not the largest of the earthquakes shows that the location of an event is as important, or more so, than its magnitude.

A further four events in the last hundred years have caused extensive damage to the country's infrastructure: 1942 Wairarapa, 1968 Inangahua, 1987 Edgecumbe and most recently 2016 Kaikoura , Figure 2.

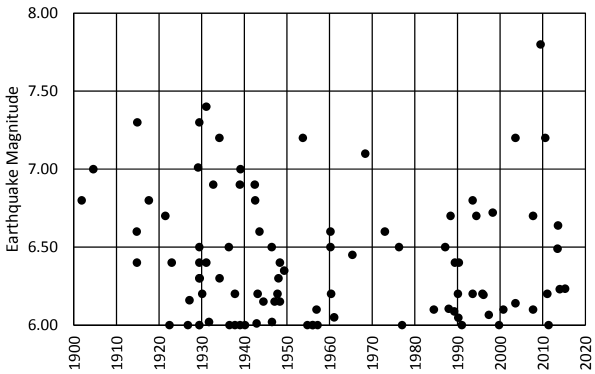

Figure 1. Magnitude 6+ Earthquake Events in New Zealand since 1900

Figure 2. Landslide Dam - Kaikoura Earthquake, 2016

An Earthquake and War Damage Commission for earthquake insurance was set up in 1944 in response to extensive damage from the 1942 Wairarapa earthquake, in which only one person died but at least 5,000 houses and 10,000 chimneys were damaged in Wellington by two major earthquakes (Te Ara, 2016). This organization became the Earthquake Commission, EQC, which provides insurance cover against natural hazards for all domestic properties covered by a buildings insurance policy with a private insurer. The EQC is funded by an additional premium levied on all domestic building insurance policy premiums. This provides the homeowner with damage insurance for all natural hazards, including earthquakes.

Instrumenting of earthquake events in New Zealand started in the 1930s, after which extensive records exist. These are held in the public domain by GeoNet, which is a collaboration between EQC and GNS Science, a limited liability company owned by the New Zealand government.

3 RECENT HISTORY

The New Zealand Government initiated a Canterbury Earthquakes Royal Commission of Inquiry after the February 2011 damaging event to report on the causes of building failure as a result of the earthquakes as well as the legal and best-practice requirements for buildings in New Zealand Central Business Districts. The inquiry began in April 2011 and was completed in November 2012. Their final report presented 189 recommendations, providing an important direction towards improving engineering capability and resilience of the New Zealand built environment.

Supporting the Canterbury rebuild and addressing the lessons and recommendations drawn from the Royal Commission inquiry have been a focus for government agencies and many other organisations during these past six years. There is a collective responsibility to those who have experienced loss, which is to learn, effect change and make improvements for the benefit of all New Zealand communities.

The Ministry of Business, Innovation & Employment, MBIE, responsible for regulating the New Zealand building sector, instigated a multi-year work programme with many streams of ongoing work (Stannard 2016).

Changes are being made to structural design standards where under-performance has been observed. Earthquake-prone building legislation has been changed, requiring retrofitting or removal of the most vulnerable buildings throughout New Zealand. Reviews of the Building Code requirements are also underway which may test the societal appetite for changes to code settings.

Guidance has been developed to address repair strategies and rebuilding on liquefaction-prone land. It has also included improvement to response capability for managing the building assessment and placarding process following a damaging event. Field guides have been produced and the Geotechnical Field Guide was trialed during the Kaikoura Mw7.8 2016 earthquake. An increase in geotechnical and structural research activity is occurring with close international collaboration. Better access to geotechnical data to understand probable ground performance during earthquakes has been facilitated by the development of a national Geotechnical Database (Scott 2015).

Importantly, the Canterbury sequence has provided the opportunity for a much higher level of collaboration between all parties involved in building decision making.

As land damage was a defining feature of the Canterbury earthquake sequence, MBIE and NZGS agreed to a collaborative Memorandum of Understanding to address specific Royal Commission recommendations relating to earthquake geotechnical engineering and improve the level and consistency of practice. The focus has been to develop guidance and implement a sustained education programme for geotechnical professionals.

4 THE NEED FOR EARTHQUAKE GEOTECHNICAL ENGINEERING GUIDELINES

The New Zealand Geotechnical Society (NZGS) first identified the need for guidelines on Earthquake Geotechnical Engineering in 2006, when the release of a new loading standard specifically excluded design of soil retaining structures, slope instability and soil liquefaction. Even with very limited guidance given in the previous standard there was perceived to be a significant and undesirable variability within geotechnical earthquake engineering practice in New Zealand (NZGS, 2010). A working party was therefore formed by the NZGS to interpret the new loading standard for application to geotechnical engineering, and with a view to developing more specific guidelines for different geotechnical engineering aspects of earthquake engineering, each of which would be published in a separate 'module'.

The first module, on liquefaction, was released in July 2010, shortly before the Darfield earthquake in September 2010, which was the first event in the devastating Canterbury Earthquake Sequence. Widespread liquefaction occurred from at least six of the earthquakes, with Christchurch being subjected to by far the most extensive liquefaction experienced by any urban area globally in modern times. The release of the module was timely and extremely useful for the geotechnical engineering profession in assessing future vulnerability both in the affected areas and nationally. What is perhaps most significant is that these guidelines have enabled a consistent approach to be taken by different practitioners, resulting in more consistent outcomes for use in design during this most difficult of periods. One of the beneficial outcomes of this is that other guidelines developed by the then Department of Building and Housing (now MBIE) for the repair of residential buildings have been able to define performance limits for foundations with the knowledge that these could be sensibly and consistently evaluated across the profession. Without the consistency that these guidelines have brought to geotechnical practice the application of these repair guidelines is likely to have been less successful.

The series of Earthquake Geotechnical Engineering Guidelines is being produced as a collaborative partnership between the New Zealand Geotechnical Society and MBIE. It is being developed for practising geotechnical professionals who have a sound background in soil mechanics and earthquake engineering in New Zealand.

5 THE DEVELOPMENT OF EARTHQUAKE GEOTECHNICAL ENGINEERING GUIDELINES

The intention for the Earthquake Geotechnical Engineering Guidelines is to improve overall New Zealand practice and to promote a consistent approach. These guidelines provide 'high level' principles rather than being design handbooks. Worked examples are also being developed to provide more detail, helping to demonstrate the practical application of each module.

Some modules in the series have already been published and others will be developed and released progressively, each focusing on different aspects of earthquake geotechnical engineering. It is intended that each one will continue to be developed and be kept up to date as new research results are produced and new design methods are advanced, as has already been done with the liquefaction module initially published in 2010.

Module 1 gives an overview of the guidelines. There is also some technical detail related to estimating ground motion parameters, which is common to all the modules. Further work is currently being undertaken on estimation of ground motion parameters in New Zealand and changes may be made to the recommended methods in the future, but practitioners require guidance based on current knowledge and the guidelines provides this.

Module 2 covers ground investigation for seismic design. It includes discussion on the type and level of investigation required, which depends on the site, the scale and importance of the proposed structures and on the level of risk arising from a failure. It explains the importance of creating a geotechnical site model, and includes planning of the investigations, investigation techniques, and recommendations for subsurface exploration and sampling. There is also a section on the preparation of geotechnical reports.

Module 3 addresses liquefaction hazards and their effect, including lateral spreading, and is an update to the original module 1 released in 2010. Detailed guidance is given on the use of the simplified procedure for assessing liquefaction risk, including clear recommendations on which of the many methods available is considered to be most appropriate for use in New Zealand. Sources of liquefaction-induced ground deformation are described and procedures for assessing ground deformation are outlined. Inclusion of Canterbury earthquakes learnings

Module 4 deals with the seismic design of foundations. It includes discussion on the different types of foundations in common use together with a strategy for selecting the most suitable for each site. Both shallow and deep foundations are covered.

Module 5 covers the general topic of ground improvement. The various techniques and design methods are considered, and guidance is provided on assessing both the need for ground improvement and the extent of improvement required. The advantages and disadvantages of each method are indicated.

Module 5A provides a specification for designing and constructing ground improvement and includes the four main ground improvement techniques. It is specifically directed at ground improvement for liquefaction mitigation in residential properties in Canterbury. However, it also applies to other areas of New Zealand prone to liquefaction.

Module 6 will address the design of retaining walls and will build on material already produced during the Canterbury rebuild for residential retaining walls situated in the Christchurch Port Hills, extending it into more complex situations. Attempts have already been made to develop this module, but this has proved particularly elusive to date.

Module 7 will address earthquake slope stability.

All documents can be obtained in pdf format, at no cost, from the Geotechnical Society and MBIE Building Performance websites (www.NZGS.org and www.building.govt.nz/building-code-compliance/b-stability/b1-structure/geotechnical-guidance/). All the modules are being released with a six month period for user feedback before being finalised. Comments are requested, specifically from NZGS members but also from geotechnical practitioners at large. This is particularly important, as the intention is to ensure that the modules are not only technically correct but are also useful for geotechnical practice and therefore inclusion of learnings from practitioners who have actually made use of them are considered important.

6 CONTINUING PROFESSIONAL DEVELOPMENT IN EARTHQUAKE GEOTECHNICAL ENGINEERING

It was recognised that geotechnical education needed a more co-ordinated national approach, involving all the key groups. As a result, a five year Geotechnical Education programme was initiated, originally as a joint venture between NZGS, MBIE and the Institution of Professional Engineers New Zealand Inc. (IPENZ), with the Earthquake Commission and the New Zealand Transport Agency joining later. The first step was education to support the release of the Earthquake Geotechnical Engineering modules to a target audience of geo professionals, as well as structural engineers, architects, developers, land planners and building officials. The programme includes other education, beyond the modules, on associated topics such as rock fall protection structures.

Representatives from the key groups are included in a Working Group that creates the resources and a Reference Group that provides governance to the programme. The programme aims to:

- develop a long-term strategy for increasing geotechnical skills
- create a collaborative working relationship with geotechnical stakeholders
- increase awareness of available geotechnical resources, such as the Module series, and
- increase decision maker understanding of the importance of appropriate geotechnical involvement in building

projects.

The educational resources are created in a variety of formats to suit the different audiences, including:

- face to face short courses – usually one day workshops delivered by subject matter experts and including case studies
- short sessions – 1 to 1.5 hours, incorporated into regular meetings NZGS regional meetings
- conference sessions – dedicated to key topics. One such workshop is planned to be appended to the biennial NZGS symposium, next scheduled to take place in 2017
- online learning modules – housed on the IPENZ Learning Management System
- video clips to give context which will sit on the MBIE educational webpage
- online fact sheets
- newsletter articles.

The first short course activity supported Module 3, Liquefaction. It included a series of one day face-to-face workshops in key centres, targeting experienced geotechnical engineers and experienced engineering geologists who have some experience in liquefaction assessment and a good understanding of the principles. It was not for those requiring advanced training. An online presentation highlights key aspects for highly advanced geo professionals.

The programme has a webpage on the MBIE building.govt.nz website, with links through to the IPENZ Learning Management System where many of the educational resources sit.

7 CONCLUSION

The past six years has been a very intense period for the New Zealand engineering community, rebuilding Christchurch, strengthening buildings elsewhere as a result of the increased public perception of risk, and making sure the lessons from Canterbury are captured and implemented for the benefit of communities elsewhere.

New Zealand is a seismically active country and understanding the likely performance of land during earthquake is critically important for the design of a resilient build environment. The 14 November 2016 Mw7.8 Kaikoura earthquake further highlighted the importance of appropriate investigation and sound geotechnical design. Slips and rock falls have cut off main road and rail corridors, leaving towns and rural areas without access. Large areas of land have been affected. There have been in the order of 80,000 landslides and approximately 50 earth dams formed, potentially endangering lives.

The development of the earthquake geotechnical earthquake guidance series and the accompanying education programme is an important part of the goal to improve the resilience of New Zealand communities.

8 ACKNOWLEDGEMENTS

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