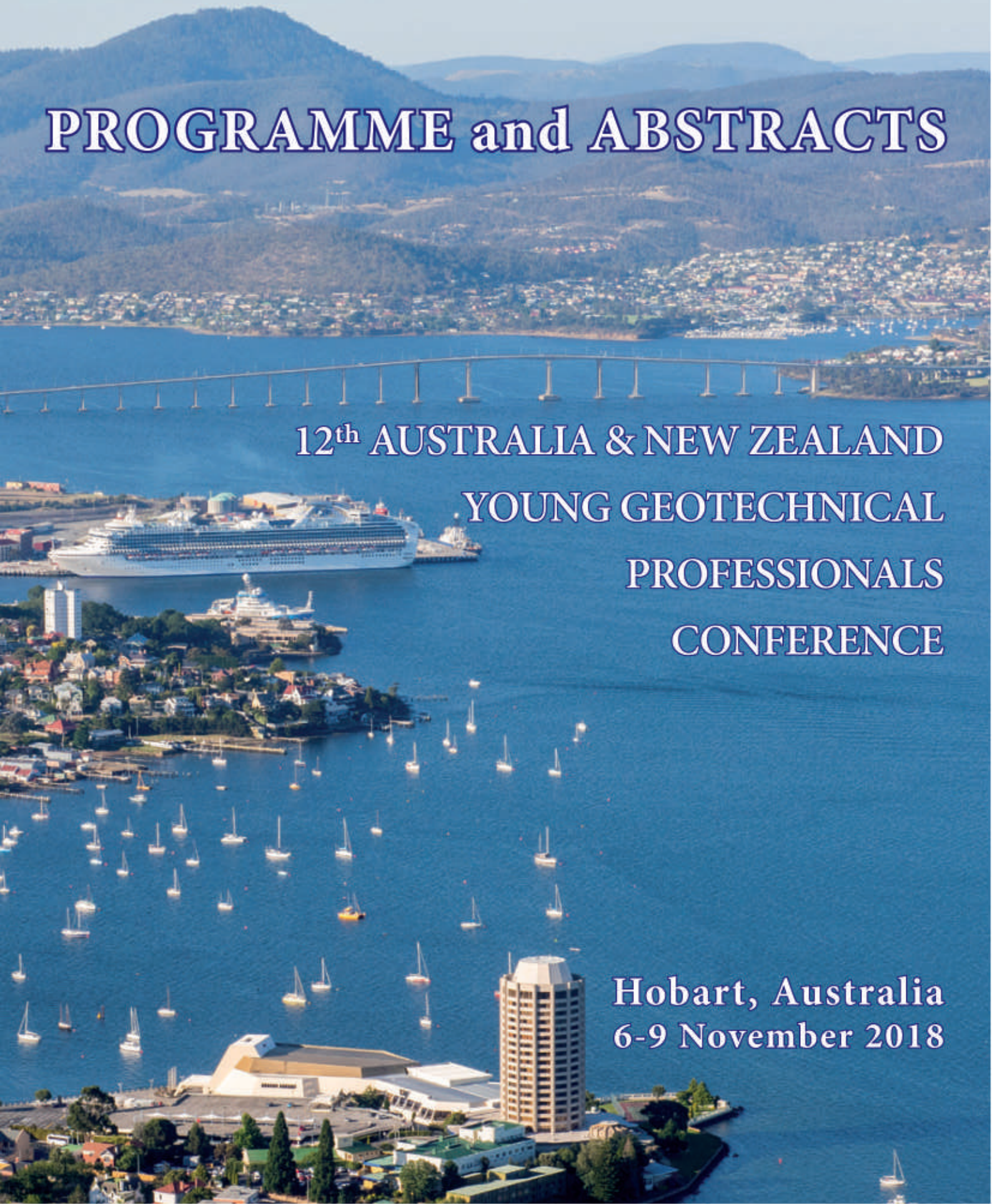
AUSTRALIAN GEOMECHANICS SOCIETY

NEW ZEALAND GEOTECHNICAL SOCIETY INC

# PROGRAMME and ABSTRACTS

## 12th AUSTRALIA & NEW ZEALAND YOUNG GEOTECHNICAL PROFESSIONALS CONFERENCE



**Hobart, Australia**
**6-9 November 2018**

A Joint initiative of the AUSTRALIAN GEOMECHANICS SOCIETY and
NEW ZEALAND GEOTECHNICAL SOCIETY

# 12th Australia and New Zealand Young Geotechnical Professionals Conference

## 12YGPC

## Hobart, Australia, November 2018

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# FOREWORD

It is with great pleasure and excitement that the organising committee welcome you to the 12th Australia and New Zealand (ANZ) Young Geotechnical Professionals Conference which is being held at the Old Woolstore Hotel, Hobart from 6th to 9th November 2018. Held every 2 years, the Young Geotechnical Professional Conference (YGPC) events are unique 3 day conferences facilitated by a joint initiative of Australian Geomechanics Society (AGS) and New Zealand Geotechnical Society.

The aim of the 12YGPC is to provide younger professionals both in industry and academia experience in technical paper preparation and conference presentation. Presenting at this conference is the culmination of many months of paper preparation and peer review by senior professionals. Uniquely conference attendance is limited to only presenting authors with what is likely to be their first technical paper to their peers and a panel of senior industry professionals. It is important to note that a record number of 104 abstracts are received. Unfortunately, only 44 of them are accepted due to the limitation of the single-session conferences. The acceptance ratio is 42% and many of the rejected abstracts are in very high quality. We believe our ANZ young geomechanics community has grown to the point of having multiple sessions in next YGPC.

We are delighted to have Stephen Fityus (University of Newcastle & AGS National Chair), Ross Roberts (Auckland Council & NZGS Vice Chair and Treasurer), and Darren Paul (Golder Associates & former AGS National Chair) as our senior industry mentoring panel. This panel not only has vast technical knowledge but also provides a direct link between the Young Professionals and both Trans-Tasman learned societies. We hope that delegates not only gain professional development but also learn more about the AGS and NZGS and the work they do to promote and advocate for our industry. NZGS provides 10 scholarships for attendees from New Zealand, which highlights her commitment to cultivate young geotechnical professionals. AGS has also a long standing of commitment to the geomechanics industry in a wider capacity than Australasia.

YGPC events also include a field trip into the surrounding Hobart region, and we are thrilled to have the assistance of Colin Mazengarb (Mineral Resources Tasmania) and his colleagues at Tasmanian Government to provide what will no doubt be an interesting, informative and entertaining commentary on the Mount Wellington, impressive outcrops and amazing geotechnical features. Moreover, field trip attendees will enjoy unbelievable views of Hobart and surrounding areas during a walk along hiking trails and at the summit of Mt Wellington. No conference is complete without a number of social events to encourage interaction between the delegates, and this conference is no exception. We look forward to showcasing Hobart during these events.

We wish to acknowledge the financial support provided by the Sponsors of this conference. Without their support and assistance this event could not occur and we thank each and every one of these organisations. We also thank the peer reviewers who gave their time and technical expertise to provide thorough and supportive reviews of the papers. Finally, I wish to acknowledge the hard work and commitment of the organising committee and guidance of both AGS and NZGS national steering committees. Without their efforts and the support of their respective home organisations this conference would not be possible.

I hope the 12YGPC provides an enjoyable and informative event aimed at the development of future leaders in the geotechnical profession.

**Dr Hong Y Liu**
12YGPC2018 Hobart Organising Committee Chair

AUSTRALIAN GEOMECHANICS SOCIETY

## WELCOME FROM THE AGS NATIONAL CHAIR

I am delighted to be given this opportunity to record a few words in recognition of this significant event in the business of the AGS. As chair of the AGS I welcome our AGS YGPs to the event, and on behalf of the AGS, I especially welcome our NZGS YGP colleagues to share the experience of this gathering in Hobart.

The AGS is a dynamic, professional society providing a wealth of opportunity for professional development for all of its members, but there is nothing more core to its purpose than to provide for its YGPs. This gathering of young professionals in Hobart marks the 12th such event, in a series of excellent meetings which have helped to springboard many of today's most influential geotechnical professionals in Australia and New Zealand into their outstanding geotechnical careers.

The Hobart YGP conference will give the assembled YGPs an ideal opportunity to stand up and stamp their authority on a specialist area of their choice, in an environment supported by some of the best mentors our profession can offer. There is no better way than this to develop confidence in our next generation. But even more importantly, this event provides a unique opportunity for some of our best and brightest young minds to be immersed in the company of their peers and contemporaries, where I am certain they will forge some enduring professional connections and personal friendships. I encourage all who attend to take what you learn and value from this experience forward, and to do your own part through ongoing membership and involvement with the AGS and NZGS, to nurture and support the professional development of YGPs into the future.

I am confident that this event will be a memorable experience for all who attend, and that like those YGP conferences which have gone before, it will be remembered for its resounding success.

To finish, I would like to thank, personally and on behalf of both the AGS and the NZGS, Hong, Philippa, Nigel and Colin, and their team of technical reviewers who have worked so diligently to deliver this quality event and these fine proceedings.

Regards

**Stephen Fityus**

National Chair, Australian Geomechanics Society

New Zealand
Geotechnical Society

## WELCOME FROM THE NZGS NATIONAL VICE CHAIR

Geotechnical engineering and engineering geology are often seen as highly technical, analytical disciplines. There is truth in this, but to succeed as a professional there are equally important non-technical skills that are essential for all practitioners. Of these skills two stand out as critical; communication and curiosity. This 12th Australia and New Zealand Young Geotechnical Professionals Conference has been carefully designed to promote these skills.

Curiosity is an under-rated skill, but implicit in the core value of lifelong learning required by our profession. Without curiosity we become technicians, recycling old solutions rather than learning, growing and improving. Hopefully you will find a lot of new information and ideas in the presentations you will see over the coming days, will take them back to your daily practice and implement them in new and innovative ways to make the world a better place.

Like curiosity, communication skills are at the core of almost everything that we do as professionals. Nothing that we assess, design or propose will be built if we cannot convince our peers, our clients, or the public that it's the right thing to do. Good technical writing can be particularly difficult. Too often technical papers and reports are convoluted and appear to exist only to show how clever the author is rather than to inform the reader. I encourage you to read each of the papers in these proceedings and learn not just from the technical content but consider also the strategies used to communicate complex technical topics. Is the paper easy to read? Do you understand every sentence? How are difficult concepts made easy to understand?

Presentation skills are nearly as important as written communications. Public speaking comes naturally to some people, but for most it is nerve-wracking. From personal experience I can confirm that practice, with helpful feedback, is a very effective way to improve and to overcome the fear of speaking in front of an audience. This event will give you a great opportunity to practice in a safe environment and I'm sure that you will learn a great deal if you ask for feedback from your peers.

I hope that you enjoy your time in Hobart, and that you feel so encouraged by this event that you will consider helping organise subsequent events. None of this could have happened without the efforts of the wonderful organising committee. I encourage you to take your turn in future years to volunteer on this committee. It can be hard work, but it is exceptionally rewarding and will further build your skills for the benefit of your own careers.

**Ross Roberts**
Vice Chair, New Zealand Geotechnical Society

## MENTORS

### **Stephen Fityus**, AGS Chair

Professor Stephen Fityus has a BE (civil) and a BSc (geology) from the University of Newcastle. After graduating, he worked with the Roads and Traffic Authority NSW and in geotechnical consulting with Coffey for 4 years before returning to do his PhD. His early research has focused mainly on the behaviour of residual clay soils, in the context of ground movements that affect foundations. He is now a Professor in the School of Engineering at the University of Newcastle, and Associate Dean for Research in the Faculty of Engineering and Built Environment.

His wider research interests include rock fall phenomena and rock fall risk mitigation, slope stability in dipping strata and the characterisation of soft soil behaviour. More recently, his research has focussed on the geomechanical behaviour of mudrocks and mine spoil. He has published 54 refereed journal papers, more than 100 papers in refereed proceedings, and he is a member of the Standards Australia committees for AS1726 and AS2870.

### **Ross Roberts**, NZGS Vice Chair and Treasurer

Ross has fifteen years' experience in the management, planning and supervision of geotechnical and civil engineering projects, including leading teams of up to 20 engineers and managing multi-year consulting projects. He has worked for consultants and contractors in the UK, Indonesia, Australia and NZ on projects including major highway construction, railway asset management, water pipeline scheme assessments, landslide assessment and remediation, micro-tunnelling and bridge foundation design and now works for Auckland Council as their in-house geotechnical specialist.

### **Darren Paul**, AGS Past Chair

Darren is a Principal Engineering Geologist at Golder Associates in Melbourne. He holds a Bachelor of Civil Engineering and Bachelor of Science in Geology, a combination which took him into the fields of geotechnical engineering and engineering geology. He also has an MSc in Engineering Geology from Imperial College London.

Darren's professional interests are in ground model development, the identification, assessment and management of geological uncertainty, landslide risk assessment and terrain evaluation. He has worked on many notable projects in Melbourne including the Burnley Tunnel, Eureka Tower, and is currently on the Melbourne Metro Project. He has also worked on large projects in Africa, the Middle East and PNG. In 2008 Darren was awarded the Young Professional Engineer Award for Victoria and in 2010 was awarded The Richard Wolters Prize from the IAEG.

Outside of engineering geology, Darren was in the army reserve for 12 years and is currently an officer of army cadets. He enjoys travelling and getting outdoors with his wife and three young boys.

AUSTRALIAN GEOMECHANICS SOCIETY

NEW ZEALAND GEOTECHNICAL SOCIETY INC

# 12TH AUSTRALIA & NEW ZEALAND YOUNG GEOTECHNICAL PROFESSIONALS CONFERENCE

**7-9 NOVEMBER 2018** HOBART

## CALL FOR ABSTRACTS AND NOMINATIONS

The Australian Geomechanics Society and the New Zealand Geotechnical Society invite you to attend the 12th Young Geotechnical Professionals Conference (12YGPC Hobart)

The 12YGPC is for geotechnical professionals from Australia and New Zealand 35 years old and younger. It is designed for all attendees to present a technical paper on any topic of interest / experience relating to the field of geomechanics or geotechnical engineering.

### Call for abstracts and nominations

Please complete the nomination form attached to this call for abstracts. Nominations of delegates must also be supported by a senior mentor and include an abstract of 200 words on a topic that is related to geotechnical practice or research.

Successful nominations will be selected based on the quality and relevance of the abstract. Positions are limited to 50 attendees and all successful nominations will be expected to present their technical paper at the conference. The Don Douglas Youth Fellowship Award and the Young Geotechnical Professional Fellowship will be awarded to the best Australian paper and the best New Zealand paper, respectively during the conference. Top papers are to be published in a special issue of *Australian Geomechanics*.

### Registration Cost

Registration cost is AU$ 1,250 (incl. GST) and includes three nights' accommodation and breakfasts at the Woolstore Hotel near the waterfront in Hobart, lunches and refreshments, one conference banquet, one conference dinner, an arrival drinks reception, conference venue and a field trip to discover the engineering geology of the Hobart region.

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Sponsorship opportunities still available. Details available at the AGS website

### IMPORTANT DATES

**30 MAR 2018**
Nominations and abstracts due

**16 APR 2018**
Notice of acceptance

**30 JUN 2018**
Full papers due

**15 AUG 2018**
Notice of full paper acceptance

**14 SEP 2018**
Registrations close

**6 NOV 2018**
Welcome reception

**7-8 NOV 2018**
Conference presentations

**9 NOV 2018**
Field trip

### FURTHER INFORMATION

Further information will be available on the AGS website at https://australiangeomechanics.org/
For any urgent queries or return of nomination forms / abstracts, please contact the organizing committee through 12YGPC@gmail.com

### ORGANISING COMMITTEE

Hong Y Liu (University of Tasmania), Nigel Ruxton (Golder Associates), Philippa Mills (Coffey, New Zealand), and Colin Mazengarb (Tasmanian Government)

### STEERING COMMITTEE

AGS National Committee

AUSTRALIAN GEOMECHANICS SOCIETY

NEW ZEALAND GEOTECHNICAL SOCIETY INC

## Key Conference Details

**Location**
Hobart, Australia

**Venue**
Old Woolstore Hotel

## Conference Committee contact details:


**Hong Y Liu**
Email: Hong.Liu@utas.edu.au
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**Philippa Mills**
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**Colin Mazengarb**
Email: Colin.Mazengarb@stategrowth.tas.gov.au
Phone: +61 3 6165 4731

Alternative email for contact: 12YGPC@gmail.com


## Conference Programme Overview

| 2018 | Tuesday 6th November | Wednesday 7th November | Thursday 8th November | Friday 9th November |
|---|---|---|---|---|
| Morning | | Session | Session | Fieldtrip |
| Afternoon | | Session | Session | Fieldtrip |
| Evening | Welcome Drinks | Conference Dinner | Conference Banquet | |

## Attendance

The conference is limited to 50 delegates who are chosen based on abstract submission. Mentors and the organising committee are additional to this number.

## Cancellation Policy

The Organising Committee reserves the right to cancel the Conference not later than 30 July 2018 in case of circumstances beyond its control. In such a case all monies paid to date will be refunded in full. The liability of the organisers will be limited to that amount.

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Tasmanian Government

## MINERAL RESOURCES TASMANIA

Mineral Resources Tasmania (Department of State Growth) is pleased to be able to support the 2018 YGP Conference as a Bronze Sponsor. We welcome you to our state and hope you will enjoy your stay. As the only State Geological Survey in Australia currently undertaking engineering-geology and natural hazards research, the presence of this geotechnical conference in Tasmania is particularly relevant. We have enclosed complimentary wafer cards containing publicly available information including geoscientific products and links to our online datasets in your conference satchels. Be sure to speak to our representative during the conference if you want to learn more about our work.

# PREVIOUS ANZ YOUNG GEOTECHNICAL PROFESSIONALS CONFERENCES

- 1st ANZ Young Geotechnical Professionals Conference, Sydney, Australia, 1994.
- 2nd ANZ Young Geotechnical Professionals Conference, Auckland, New Zealand, 1995.
- 3rd ANZ Young Geotechnical Professionals Conference, Melbourne, Australia, 1998
- 4th ANZ Young Geotechnical Professionals Conference, Perth, Australia, 2000
- 5th ANZ Young Geotechnical Professionals Conference, Rotorua, New Zealand, 2002.
- 6th ANZ Young Geotechnical Professionals Conference, Gold Coast, Australia, 2004.
- 7th ANZ Young Geotechnical Professionals Conference, Adelaide, Australia, 2006.
- 8th ANZ Young Geotechnical Professionals Conference, Wellington, New Zealand, 2008.
- 9th ANZ Young Geotechnical Professionals Conference, Melbourne, Australia, June 2012.
- 10th ANZ Young Geotechnical Professionals Conference, Noosa, Australia, September 2014.
- 11th ANZ Young Geotechnical Professionals Conference, Queenstown, New Zealand, 2016.
- **12th ANZ Young Geotechnical Professionals Conference, Hobart, Australia, November, 2018**

## Conference Programme

### *Tuesday 6 November: Welcome Function and Registration*

| | |
|---|---|
| 16:00 – | Registration desk opens |
| 17:00 – | Welcome function with refreshments |
| | Welcome on behalf of the organising committee, Dr Hong Liu |
| | Welcome from the AGS Chair Professor Stephen Fityus |
| | Welcome by NZGS Vice Chair Ross Roberts |
| | Acknowledgement of sponsors |
| | Presentations loaded onto computer |
| 19:00 | Registration desk closes |
| 19:15 | Committee and Mentors informal dinner |

### *Wednesday 7 November: Presentations*

| | |
|---|---|
| 8:15 | Last chance for papers to be loaded onto computer |
| 8:30 | Session 1 |
| | Opening announcements |
| | Presentation of papers 1-6, 15 minutes each |
| | Mentor Summary |
| | Sponsor messages |
| 10:17 | Keller sponsored morning break and refreshments 30 minutes |
| 10:47 | Session 2 |
| | Presentation of papers 7-12, 15 minutes each |
| | Mentor Summary |
| 12:22 | Lunch 1 hour |
| 13:22 | Session 3 |
| | Presentation of papers 13-18, 15 minutes each |
| | Mentor Summary |
| 14:57 | Keller sponsored afternoon break and refreshments 30 minutes |
| 15:29 | Session 4 |
| | Presentation of papers 19-24, 15 minutes each |
| | Mentor Summary |
| | Announcements |
| 17:10 | Session concludes |
| 19:00 | Dinner at Saffron Restaurant |
| | After dinner speeches on behalf of AGS and NZGS |

Programme continues on next page

## Conference Programme continued

### *Thursday 8 November: Presentations*

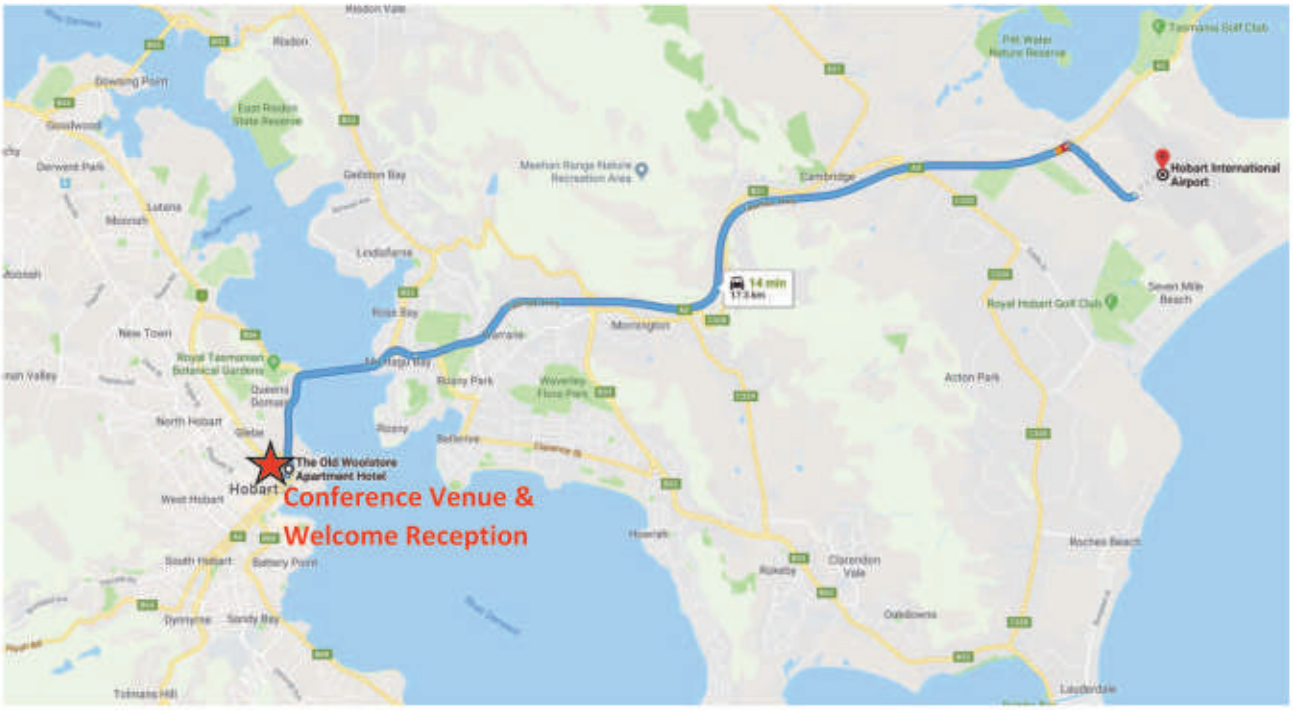
| | |
|---|---|
| 8:30 | Session 5 |
| | Opening announcements |
| | Presentation of papers 25-30, 15 minutes each |
| | Mentor Summary |
| | Sponsor messages |
| | |
| 10:17 | Keller sponsored morning break and refreshments 30 minutes |
| | |
| 10:47 | Session 6 |
| | Presentation of papers 31-36, 15 minutes each |
| | Mentor Summary |
| | |
| 12:22 | Lunch 1 hour |
| | |
| 13:22 | Session 7 |
| | Presentation of papers 37-42, 15 minutes each |
| | Mentor Summary |
| | |
| 14:57 | Keller sponsored afternoon break and refreshments 30 minutes |
| | |
| 15:29 | Session 8 |
| | Presentation of papers 43-46, 15 minutes each |
| | Mentor Summary |
| | Announcements and conclusion of presentations |
| | |
| 19:00 | Conference dinner at Mures Upper Deck |
| | After dinner speech by Pip Mills on behalf of the Platinum Sponsor Coffey |
| | Presentation of awards |

### *Friday 9 November: Field Trip to kunanyi/Mount Wellington*

| | |
|---|---|
| 8:15 | Report to Woolstore reception and board bus |
| 8:30 | Bus departs to summit |
| 9:00 | Walking tour from Summit to Chalet |
| 12:00 | Bus departs from Chalet |
| 12:30 | Bus returns to Woolstore |
| 12:30 | Conference concludes |

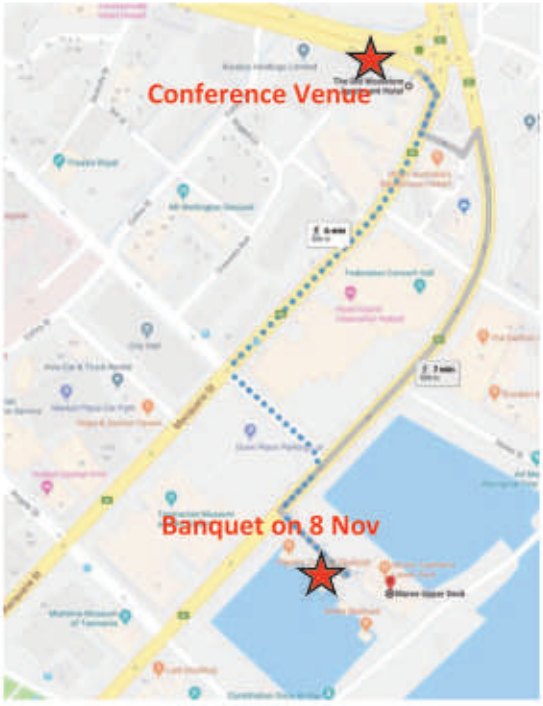
# Travel Guide

## Hobart Airport – Old Woolstore Hotel (Conference Venue): the travel between them costs about $60 by taxi and about $20 by Skybus




## Old Woolstore – Mures Upper Deck

The travel takes about 6 min by walk




## Old Woolstore – Saffron

The travel takes about 5 min by walk

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# COMPARISON OF 2D AND 3D LIMIT EQUILIBRIUM SLOPE STABILITY ANALYSIS WHEN CONSIDERING VARIOUS LOADING CONDITIONS

**Darron Lee, B.E. (Hons)**
*EDG Consulting Pty Ltd, Brisbane, Australia*

## ABSTRACT

Two commercially available limit equilibrium slope stability analysis software packages (*Slide* and *Slide*$^3$) were used to compare the computed factors of safety (FoS) from two dimensional (2D) and three dimensional (3D) models when considering distributed and concentrated surcharges. Available published literature typically only considers the difference in model geometry from 2D to 3D, and generally suggests an approximately 10% increase in FoS when moving from 2D plane-strain to a 3D model. Experience indicates that this indicative increase in FoS is inaccurate when concentrated loads or surcharges are acting on the slope, and that for such cases the increase in FoS can be significantly higher.

A comparison is presented of the computed FoS resulting from 2D analyses and those obtained with 3D analyses when considering various lengths of surcharge. The study investigates the changes in FoS for a homogenous soil under undrained and drained conditions for varying slope heights and angles. The results indicate that the 3D effects are more significant for failure mass with smaller lengths of surcharge due to more pronounced end effects, and that these effects are most prominent in slopes made of cohesive soil.

For cohesive soils, up to a 50% increase in FoS is observed for surcharge lengths less than 1m. For granular soils, up to a 35% increase in FoS is observed for surcharge lengths less than 0.5m. However, for both cohesive and granular soils, the end effects are negligible when the length of the surcharge load exceeds 3m and no significant increase in FoS is observed.

# COMPARISON OF PREDICTED AND OBSERVED SEISMIC PERFORMANCE OF KEKERENGU AND TIROHANGA BRIDGES DURING KAIKOURA 2016 EARTHQUAKE

**Jawad Arefi, Richard Young, Nik Stewart**
*Beca Ltd, Christchurch New Zealand*

## ABSTRACT

On November 14, 2016 at 12:02 a.m. local time, the $M_w$ 7.8 Kaikoura earthquake occurred along the east coast of the upper South Island, New Zealand. The earthquake affected a relatively large area and significant impacts occurred to the horizontal infrastructure in the region. This paper focuses on the effects of the ground shaking on two bridges - Tirohanga Stream Bridge and Kekerengu River Bridge along State Highway 1 (SH1). As a result of this earthquake, a new bridge and associated embankments have been constructed at the Tirohanga site and the Kekerengu Bridge has been repaired. One year prior to this earthquake, the same two bridges were the subject of a geotechnical and structural seismic assessment initiated by the New Zealand Transport Agency (NZTA) as part of a programme for assessing the seismic performance of bridges on national strategic routes. This paper compares the predicted seismic performance of the bridges prior to the earthquake and their observed performance during the Kaikoura earthquake. It provides lessons learned for young geotechnical engineers to consider for seismic assessments of existing structures and valuable insights into their performance, and how uncertainties can be accounted for.

# IMPROVEMENT OF AN EFFICIENT SEMI-ANALYTICAL MODEL FOR THE SHEAR STRENGTH OF ROUGH ROCK DISCONTINUITIES

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## ABSTRACT

The shear strength of rock joints is known to be scale dependent, which is often referred to as the "scale effect". A new method has recently been proposed to solve the long-known issue of scale effect on the shear strength of large discontinuities (Casagrande *et al*. 2018; Buzzi and Casagrande 2018). This method, stochastic in nature, uses the roughness information available from visible traces to create N synthetic rock surfaces from a rigorous random field model. The shear strength of these N surfaces is then estimated using a semi-analytical model and a distribution of shear strength, with a mean and a standard deviation is produced. This approach was validated at small scale by Casagrande *et al*. (2018) but it was found that the semi-analytical model under-estimates the shear strength at low values of normal stress, which is explained by a number of simplifying assumptions made in regard to asperity shearing. This paper explores strategies to improve the model without compromising its computational efficiency and the resulting improvement in shear strength prediction.

# GEOTECHNICAL DESIGN AND CONTRUCTION METHODOLOGY OF A DEEP BASEMENT CUT NEXT TO SENSITIVE BUILDINGS

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## ABSTRACT

The Maritime Apartment building is a proposed 16 level building over 2 basement levels to be constructed on a steep site with neighbouring buildings on 3 sides. The primary challenge of this site is limiting movement at the western boundary, which is within 1 metre of a 5 storey sensitive historic building located at the crest of the slope. The basement structure retains approximately 13 metres and has been designed in collaboration by the structural and geotechnical engineers. Coffey has undertaken geotechnical analysis to assess the design loads and soil-pile interactions. To limit deflections the basement soldier piles are very stiff and are supported with a capping beam, diaphragm slab and associated wing wall. However, poor pile drill rig access to the top of the site and the requirement to install the perimeter soldier piles and pile cap before excavation presents constructability issues. By working closely with the main contractor a temporary works methodology was developed that was both constructible and ensured the stability of the site and neighbouring structures. The proposed solution comprises the construction of a geogrid reinforced ramp to the top of the site where a temporary platform founded on piles would be constructed to support the pile drilling rig. A detailed monitoring plan was prepared to mitigate the risks during construction.

# INFLUENCE OF SITE INVESTIGATION BOREHOLE PATTERN AND AREA ON PILE FOUNDATION PERFORMANCE

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## ABSTRACT

Site investigations are the largest element of technical and financial risk in civil engineering works, with insufficient testing often causing cost over-runs, construction delays, foundation failure and over-design. However, there is little research on where best to place boreholes with respect to the foundation. Typically, if the structure location is known, then boreholes are placed at the centre, or otherwise at the corners, although some studies indicate that there may be benefit to randomising the sampling location. This study aims to determine the best of a series of sampling schemes, where each scheme involves varying degrees of randomness, as well as to examine the effect of investigation area relative to the building footprint.

The optimal sampling scheme is determined from Monte Carlo analysis, where a random, variable, single layer, 3D virtual soil is generated. From this, it is possible to carry out a variety of virtual site investigations, determine true foundation performance, and determine the magnitude of structural damage resulting from insufficient investigation. Total cost, calculated from a combination of construction, investigation, and failure costs, is used as the objective function to be minimised.

# PROBABLE LOSS ESTIMATION OF INFRASTRUCTURE DAMAGE DUE TO LANDSLIDE HAZARD: AN EXAMPLE OF GEOTECHNICAL RISK ASSESSMENT

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## ABSTRACT

With the rising cost of impact from natural hazards on public horizontal infrastructure (e.g. water supply networks), better management of natural hazards is required. The main options for managing the impacts from such events are risk acceptance, avoidance, mitigation and transfer (i.e. through insurance). Each of these options have a monetary cost. An optimal approach generally comprises a combination of options, which vary between asset types, locations and infrastructure owner requirements. To understand the costs and effectiveness of the risk management options, risk assessments are conducted to assess the likely damage and the associated reinstatement cost. This paper summarizes a case study that applied a model developed to assess the impact to council assets from seismic and co-seismic events (e.g. liquefaction and landslide) in order to estimate the probable loss. This paper focuses on the landslide hazard and risk analysis component. Using mapped historic landslides, the susceptibility of the geology and slope profile for future landslides can be quantified. This produced a landslide hazard factor which was grouped into a qualitative hazard descriptor. The output for the landslide hazard analysis was geospatially referenced to attribute assets to the modelled landslide risk. Through stochastic risk modelling, the total asset portfolio loss was modelled.

*Keywords:* Natural hazards, landslide hazard, asset management, risk assessment, landslide, insurance, geospatial modelling, stochastic modelling, loss modelling

# REMEDIATION OF CONTAMINATED MARINE SEDIMENTS USING MUDCRETE – A CASE HISTORY

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## ABSTRACT

Remediation of the second-highest priority contaminated site in New Zealand has provided an opportunity to remove and stabilise contaminated marine sediments from the Calwell Slipway Basin, Port Nelson. Other drivers for the project included restoring navigability and extending an existing reclamation. The new reclamation was constructed with dredged marine sediments mixed with Portland cement and power activated carbon to create mudcrete. Mudcrete increases the strength of the sediments and minimises leaching of contaminants. Environmental and engineering design components are discussed including bench and production trials, and results achieved during construction. Geotechnical design was governed by seismic loading and the potential for liquefaction of the existing reclamation fill and marine sediments beneath the mudcrete.

# DESIGN AND CONSTRUCTION OF MULTI STOREY BUILDING FOUNDATION PILES IN LIQUEFIABLE GROUND IN CHRISTCHURCH, NEW ZEALAND

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## ABSTRACT

A five storey office building is being constructed at St Andrews Square in Christchurch. The building is founded on soft and liquefiable ground and is located 60 m from the Avon River. The ground conditions are variable both throughout the soil column and across the building. Due to the size of the building and the structural system, column loads are very high and vary considerably across short distances. Ground improvement, shallow foundations and deep foundations were considered. Due to the physical and environmental constraints of the site and construction advantages a bored pile foundation was chosen. The bored piles are designed to carry large vertical loads enabling wide column spacing which is favoured in office style buildings. The contractor also founded a tower crane on the piles to help with super structure construction.

The construction methodology involved open-hole technology which is relatively new in the NZ market. A partial length of temporary casing was used with the remainder of the pile open-hole augered using a combination of bentonite and synthetic polymer fluids for side wall support. It required international support on the fluid technology and pro-active risk management from the contractor and onsite staff. This type of pile is quick to construct which allowed part of the superstructure construction to begin before piling was completed. Design considerations including learnings from the Canterbury Earthquakes, pile capacity, negative skin friction and total and differential settlement are presented. The construction supervision required from the consultant in order to achieve Construction Review PS4 sign off is discussed.

# KAIKŌURA EARTHQUAKE RECOVERY, DESIGN OF A 13M HIGH GEOGRID REINFORCED, NO FINES CONCRETE GRAVITY SEAWALL IN A HIGH SEISMICITY ENVIRONMENT

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## ABSTRACT

The North Canterbury Transport Infrastructure Recovery (NCTIR) Alliance was formed to deliver the repairs to the national road and rail transportation corridors after the Mw7.8, Kaikōura earthquake which occurred on 14 November 2016. At Ōhau Point, located approximately 26 km north east of the Kaikōura CBD via road, approximately 241,000 $m^3$ of landslide debris buried the rail, road and adjacent coastline.

Between February 2017 and July 2018 a new seawall was designed and constructed to support the coastline around Ōhau Point. This 900m long structure incorporates five ton concrete blocks and geogrid reinforcing with cement stabilised backfill.

The most complex section of this seawall is around a rock outcrop known locally as Shag Rock where the seawall is up to 13m high. The constraints and challenges in this area include maintaining access along the existing state highway one (SH1) road above the wall and ecological constraints. A complex no fines concrete gravity wall (NFC G-Wall) was designed and constructed to buttress the slope and seawall. This structure, and the wider fill and earth platform which supports the widened roadway, is designed to slide as a block under 0.76 g horizontal acceleration.

This paper presents the results of the FLAC modelling which was completed to analyse and design the 13m high geogrid reinforced NFC G-Wall at NCTIR site 6. It also describes the pragmatic observational approach which was taken for the seawall design, highlighting the seismic sliding mechanism and issues that arose during design and construction of the seawall.

Keywords: mass, gravity, retaining wall, no fines concrete, seawall, Kaikōura, earthquake, FLAC, seismic, displacement, sliding, NCTIR, observational.

# LIQUEFACTION EVALUATION IN STRATIFIED SOILS

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## ABSTRACT

The Canterbury Earthquake Sequence of 2010-2011 (CES) induced widespread liquefaction in many parts of Christchurch city. 55 case history sites around Christchurch have been studied to assess the liquefaction characteristics of Christchurch soils. Initial studies identified a correlation between soil stratification and liquefaction manifestation during the CES. Furthermore, comparisons with the simplified method show an under-prediction of liquefaction at sites that manifested liquefaction and an over-prediction for sites that did not. To further investigate these observations, an effective stress analysis was employed to study the effect of soil stratification on the development and manifestation of liquefaction, and to investigate the impact that neglecting these effects has on the predictive capabilities of current simplified methods. The analysis showed that the system response of soil deposits (i.e. the dynamic interaction between soil layers) played a key role in the development and manifestation of liquefaction during the CES.

# CHALLENGES IN CONSTRUCTION MONITORING – ADAPTING TO UNFORSEEN CONDITIONS: A CASE STUDY IN RICCARTON, CHRISTCHURCH, NEW ZEALAND

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## ABSTRACT

Geotechnical investigations are limited by the data available through subsurface investigations, which are typically isolated borings, providing snapshots of the subsurface profile. Difficulties can arise were the encountered profiles fail to identify isolated subsurface features. We present a case study of this situation during construction of a Multi-Unit Residential Building (MUB) in Riccarton, Christchurch, New Zealand. Initial investigations encountered interbedded silt and sand with gravel below 5.3 m and one location with peat soils, which were deemed an isolated feature. A gravel raft and concrete slab foundation was therefore designed. While excavating for construction, a linear peat feature was encountered, extending across the building footprint. The remedial solution for this required careful consideration and consultation with the owners and stakeholders. It was deemed appropriate to excavate and replace with ballast to minimise construction delays, however this presented challenges associated with dewatering, liquefaction and creation of sand boils at subgrade level caused by operating machinery. Concurrent to construction of the MUB gravel raft, consideration was given to the suitability of the foundations of the adjacent garage. The peat deposit trended towards the garage footprint and would likely contribute to the same construction challenges. To provide better understanding prior to construction commencing, additional investigation was undertaken in the garage footprint, which raised further uncertainty and ultimately triggered a foundation re-design to a pile supported solution. This project highlighted the difficulties faced within geotechnical investigations, and the importance of construction monitoring in conjunction with additional investigation to minimise project cost and time delays.

# LOGISTICAL AND TECHNICAL CHALLENGES OF THE GEOTECHNICAL INVESTIGATION FOR THE NEW BRIDGE OVER THE CLARENCE RIVER AT HARWOOD

**James Care**
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## ABSTRACT

The new bridge over the Clarence River at Harwood forms an integral part of the Pacific Highway upgrade in northern NSW and is currently under construction by the Acciona-Ferrovial Harwood Joint Venture (AFHJV). The proposed bridge extends 1.5km between abutments, spans the Clarence River with a water span of approx. 560m and is founded on 2m to 2.4m diameter driven hollow steel tubular piles to over 60m depth in some areas.

The underlying geology of the site consists of 30 to 40m of soft estuarine silts, clays and loose to medium dense sands underlain by saturated basal sands, gravel and cobbles up to 25m in thickness. Historical ground investigation information has thus far failed to provide confidence in the characterisation and engineering properties of this basal gravel and cobble layer due to limitations with conventional SPT, CPT and drilling techniques.

A non-conforming ground investigation (GI) scope was proposed to support the bridge detailed design phase undertaken in parallel with the field works. This paper presents a perspective on the challenges of developing a ground model within this complex geological sequence and is was addressed by a diverse, state-of-art GI campaign. It also presents the logistical challenges encountered during the campaign and how alternative approaches such as geophysical methods and sonic drilling can bolster engineering design as well as the efficiency of an investigation program.

# HOW TECTONIC GEOMORPHOLOGY CAN BE USED TO FIND A HIDDEN FAULT ZONE: A CASE STUDY OF THE TE TATUA O WAIRERE FAULT ZONE, NEW ZEALAND

**F. Spinardi, V. G. Moon, A. Pittari, W. P. de Lange**

## ABSTRACT

A series of complex fault systems have recently been discovered within the Hamilton Basin, New Zealand. Though the first zone was unexpectedly exposed during construction excavations, other zones have been discovered due to their influences on the local geomorphology. In this paper we present evidence for tectonic geomorphic features that were first observed via high-resolution LiDAR images of the Hamilton Basin, then confirmed by geologic and geomorphic mapping. Exposed fault traces show evidence of significant fault splaying within the soft sediments and tephra deposits contained within the basin, causing the fault zones to cover a wide area and create a geomorphic system of complex linear ridges. At Stubbs Road, tectonic geomorphological features including rectangular drainages, stream knickpoints, aggradational/degradational zones, linearly aligned ridges and drainage systems, and abandoned river channels and outlets were observed in the LiDAR and bathymetric data of the Waikato River and surrounding area. Field investigations revealed offset geological outcrops concurring with geomorphic features found in both the LiDAR and bathymetric data. At this site the Waikato River begins bending 82° from N to NE. Electrical resistivity data reveal a discontinuity in the geological material and seismic reflection indicates a fault crossing the river. These features are evidence for the Te Tatua o Wairere Fault Zone and are being presented to exemplify the use of tectonic geomorphology in aiding in the discovery of tectonic structures that are either concealed due to poor exposure within young, unconsolidated material, or that contain planes that have yet to daylight.

# LOCALISED FAILURE OF CLIFF TOP WAITEMATA GROUP RESIDUAL SOILS, AN APPROACH TO REMEDIATION

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## ABSTRACT

Cliff top soil failures are a common occurrence along the coastal margin of the Auckland Urban Area. With the continued development of this space for residential infill housing the impact of localised slope failures have increased. As the majority of development along the coastal margins are privately owned, any remediation measures proposed must be cost effective for individual landowners, constructible and provide a robust engineering solution to meet local authority requirements. WSP Opus and Earth Stability Limited have remediated numerous localised shallow slope failures along Auckland's coastal margin through the use of soil-nailing and the installation of drainage within the overlying residual soil mantle.

Due to access, budgetary and health and safety constraints, geotechnical investigations undertaken for cliff top properties are typically limited to the areas adjacent to the failure and terrain evaluations. The prominence of terrain evaluations in the development of geotechnical models has facilitated the use of WSP Opus's UAV capability to determine any underlying factors driving slope failure. Shallow slope failures are often the initial driver for the landowner to engage geotechnical specialists, however as geotechnical practitioners and stability contractors, the underlying cause of slope stability issues along the cliff line cannot be ignored.

The use of soil-nails to enhance the stability of a slope has long been established, but is typically constrained by site geometry to primarily provide support perpendicular to the slope. Therefore, it must be communicated to the client that soil nailed remediation of slope failures are not intended to prevent global cliff failure or lateral regression adjacent to the soil nailed section.

# DEVELOPMENT OF AN EARLY WARNING SYSTEM FOR RAINFALL INDUCED SLOPE FAILURE AFFECTING RAILWAY IN A POST-EARTHQUAKE SETTING

**Zeb Paterson**
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## ABSTRACT

Following the 2016 M7.8 Kaikōura Earthquake approximately 30-40 large scale landslides inundated sections of the rail transport corridor. Onsite experience and international literature suggest earthquake damaged slopes are generally more susceptible to rain induced landslides, however the specific increased susceptibility for the Kaikōura area needed to be assessed. Moreover, rail operators needed to know what conditions were likely to result in slope failure and potential blockage of the track or impact to a train.

A record of slope failures that have occurred in Kaikōura since the earthquake was used to assess the susceptibility of the local slopes to rainfall induced failure. A correlation between total rainfall volume, assumed soil moisture and slope failure was established based on assessment of over 600 records of slope movement. Probabilistic thresholds were established based on the rainfall-slope failure relationship that was found for the Kaikōura area. Forecasting of expected rainfall volumes in relation to antecedent rainfall conditions enabled development of a predictive tool that is being used by rail operators to decide when to delay or cancel rail operations due to increased risk of slope instability.

# DESIGN OPTIMISATION OF TEMPORARY WORKING-PLATFORMS

**Amelia Gilbert-Milne, Kasia Zamara, Martin Larisch**

## ABSTRACT

Temporary working-platforms have significant cost implications in the construction industry. Working-platforms are required on almost every infrastructure project either for piling-rigs or for mobile/crawler-cranes, to lift up and install structural components. The cost associated with the material and the resource needed to build working-platforms is significant. Further, these costs increase if a platform fails and a crane or rig falls over. Incidents of this nature are not uncommon in the industry. In global literature there is little research into temporary working-platforms. Therefore current design methods are considered to be conservative by practitioners and thus expensive to build. This paper describes a study that has been carried out to investigate the performance of a temporary working-platform. The platform has been designed and built with monitoring instrumentation installed. Instrumentation includes pressure cells, shape accel array and settlement plates which will be used to monitor platform performance during typical construction operations. The project set-up and preliminary data from the instrumented platform trial are summarised in this paper. This research will aid in future design optimisation of safe, cost effective working-platform construction.

# COMPARISON BETWEEN PANDA PENETROMETER TESTING AND TRADITIONAL TESTING METHODS IN NZ – A MORE BEARABLE PROCEDURE

**Katarzyna Anna Zamara, Amelia Gilbert Milne, Martin Larisch, Liam Wotherspoon**
*Brian Perry Civil Ltd (NZ)*

**Liam Wotherspoon**
*University of Auckland (NZ)*

## ABSTRACT

Lack of site investigation data is a common problem that geotechnical engineers face on a daily basis. Whilst typically permanent works would involve a scope and budget for site investigation, lack of information on subgrade geotechnical parameters is a common issue for temporary work designs such as crane platforms. Panda Penetrometer is a Variable Energy Dynamic Cone Penetrometer that has recently been used in New Zealand for geotechnical data collection. A study has been undertaken to evaluate Panda penetrometer application as a quick and cost effective site investigation method. Due to limited information available on Panda Penetrometer performance in New Zealand's soil conditions, a series of locations have been selected and the tests were run to compare standard tests methods such as: CPT, drilled boreholes with SPTs and shear vanes against Panda Penetrometer results. This has been undertaken to confirm the accuracy of the recorded properties. Scope of works and the preliminary findings of the comparative study have been reported in this paper.

# CASE STUDY REVIEW OF SEISMICALLY INDUCED LAND DAMAGE MITIGATION USING STONE COLUMN GROUND IMPROVEMENTS IN CHRISTCHURCH, NZ

**Kieran Foote and Dr Jan Kupec**
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## ABSTRACT

The major earthquake sequence from 2010 to 2011 caused significant damage to residential and commercial properties in Christchurch, New Zealand. Damage to major civil infrastructure, as a result of seismically induced liquefaction, lateral spreading and the associated settlements is often considered to be severe. The rebuild of infrastructure within the Christchurch area required significant ground improvement works to reduce the potential for seismically induced land damage from future earthquake events.

This paper will provide a background on the effects of seismically induced land damage and detail the use of stone column ground improvement works to reduce or mitigate liquefaction potential through ground densification. Three case studies within the Christchurch area where stone columns have been used for ground densification, with differing site conditions and installation methods will be critically reviewed and appraised, including a review of the design assumptions and lessons learned from observing construction works. The theoretical effectiveness of stone column ground improvements at these sites will then be analysed and discussed using construction compliance testing. The paper will then discuss key advantages and shortcomings of stone column ground improvements in differing soil conditions found in Christchurch and how this may apply to other parts of New Zealand.

# IDENTIFICATION AND MITIGATION OF RISKS IN AN AUCKLAND TUNNELLING PROJECT

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## ABSTRACT

A thorough understanding of ground conditions and associated risks is one of the primary roles of geologists on engineering projects, and allows clear communication and mitigation of potential risks. A wide spectrum of risks was encountered on the St Marys Bay and Masefield Beach Combined Sewer Upgrade project, consisting of 3 shafts, a storage tunnel, and a marine trench and outfall in a high-profile suburb of central Auckland. Although much of the terrestrial alignment is expected to be constructed in good East Coast Bays Formation rock, key ground risks include lenses and layers of harder volcaniclastic conglomerate in the marine environment and an alluvial channel and sources of contamination along the main storage tunnel. A further challenge is the communication of the risks to a concerned and influential public and the fact that parts of the project area are close to or within sites of significance to local Maori tribes. Existing infrastructure dating back to the middle of last century and documentation of design and as-built structures pose another potential risk in the project area. A review of historical data, combined with 2 phases of ground investigation, lab testing and hydrogeological analyses, all visualised in a 3D model, has enabled us to represent and communicate a range of complex risks and aid in their mitigation.

# A CASE STUDY ON UTILISATION OF UNDRAINED STRENGTH ANALYSIS TO DESIGN AN UPSTREAM EMBANKMENT ON SOFT TAILINGS

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## ABSTRACT

A case study is presented illustrating utilisation of Undrained Strength Analysis (USA) principles to design an upstream earth dam constructed on soft tailings to retain bauxite residue. A series of geotechnical investigations comprising cone penetrometer tests using piezocone with dissipation tests (CPTu) was carried out to ascertain the subsurface profile of the embankment footprint and to assess undrained strength ratios and permeability of soft soil layers. Targeted vane shear tests were carried out at selected CPTu locations as confirmatory tests. Additionally, laboratory tests including consolidated undrained (CU) triaxial tests and oedometer tests were performed on selected soil samples to further assess soil permeability and compressibility. Based on the outcomes of the investigation, a geotechnical model was developed for the proposed embankment which was then analysed for stability using both limit equilibrium and finite element methods. Staged construction of the embankment was modelled incorporating SHANSEP principles to account for strength gain in soft soil layers during staged construction due to consolidation. During the construction, subsequent geotechnical investigations and monitoring were carried out to assess the actual strength gain in soft soil layers and to refine stability models accordingly. At the conclusion of the project, a good agreement was observed between the predicted and observed behaviour of the embankment.

# MANAGING GROUND RISK FOR MAJOR RAIL ELECTRIFICATION PROJECTS

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## ABSTRACT

The United Kingdom has embarked on a series of major rail electrification projects, for example the Great Western, Midland Mainline, Transpennine and the North West. The schemes require the installation of thousands (over twenty thousand on Great Western alone) of new deep foundations to support the overhead line equipment (OLE) foundations, which are primarily laterally loaded cantilever structures. This paper discusses geotechnical aspects of such proposals, from cradle to grave and is based upon the difficulties of obtaining quality geotechnical information within the confines of an operational railway corridor to inform design and construction risks. The paper details the necessary desk study sources of information that are available on such schemes (that are not necessarily initially appreciated), the recommended strategy of ground investigation with respect to types and spacings. Also detailed in specific recommendations in reducing risks in areas of very poor deposits with respect to the standard method of 'allocating' foundations in accordance with the electrification system design requirements. This paper also expands on foundation technical innovations within the UK, that can offer substantial economies in civil engineering construction to proposed New Zealand and Australian rail infrastructure upgrades.

# EFFECT OF BIOCHAR ON THE GEOTECHNICAL PROPERTIES OF SATURATED SAND

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## ABSTRACT

Biochar is a carbonaceous material produced by heating any organic biomass in oxygen-free environment through pyrolysis process. Biochar has several properties that make it an environmentally friendly material. For instance, given its aromatic nature, biochar is highly recalcitrant, so it has great potential to sequester carbon and reduce greenhouse gas emissions. In addition, due to its highly porous nature with high specific surface area can be effectively used for the removal of contaminants from soil and ground water. Since most of the research on biochar applications are about their use as soil amendment, it is important to assess its effect on soil properties from geotechnical point of view. To date, little work has been done in this field. In this study, the effect of biochar addition at varied amounts (3% and 5%) on the liquefaction resistance of loose saturated sand is investigated through simple shear tests. The results show that the addition of biochar increases the liquefaction resistance of sand by delaying the generation of excess pore water pressure and restraining shear strain development. In addition, the results for sand with 5% biochar are compared with those for sand with 5% fines content (silt), and the difference between them is considerable; implying that the mechanism by which biochar increases liquefaction resistance is different from just adding fines to the sand. To provide an insight to the improvement mechanism, the interaction between biochar and water is studied by rheology tests and ESEM analysis. The results presented in this paper provide evidences that this material has potential as an alternative to mitigate soil liquefaction and subsequently mitigate carbon emission and promote plant growth.

# THE HUMBLE DCP – STAY HUMBLE

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## ABSTRACT

The Dynamic Cone Penetrometer (DCP) was developed in Australia in the mid-1950s. At this time, pavement design procedures were created, based on correlations between DCP and California Bearing Ratio (CBR). Fast forward 60 years, and you will see designers and contractors blindly specifying and undertaking testing, then using DCP values to assess CBR, bearing capacity, pile capacity and soil strength.

This paper discusses the limitations of this tool, which will assist designers in selecting when and where DCP testing may be appropriate. A recent case study is presented which demonstrates the limitations and also encourages effective use of the DCP alongside other site investigation techniques. With an appropriate understanding of its place, the humble DCP can remain a time and cost effective option within the suite of tools available to engineers.

# CASE STUDY: IMPACT OF JET GROUTED COLUMN VARIABILITY ON A BASE BLOCK IN SAND

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## ABSTRACT

To construct an underground rail dump station at a port on a land reclaimed island in Australia, diaphragm walls and a base block designed of overlapping jet grout columns was used, aiming to allow excavation without dewatering. The base block varied between a depth of 8.9 and 19.4 m (surface RL ~6 m AHD) with material mainly consisting of sands. Proximity to the harbour provided a groundwater head boundary, with typical levels of 2 m AHD. Jet grout columns were designed with diameters between 2.1 and 2.7 m and a trial at the site was performed prior to construction. Failure of water tightness tests prior to excavation resulted in a second layer of jet grout columns being installed immediately below the original base block. During excavation of the material within the dump station gaps in the base block led to boiling of the sand, often before the base block level was exposed, preventing further excavation or construction. Ultimately an external dewatering and reinjection system was required to allow further excavation and construction of a concrete base slab on top of the base block. Investigation post construction by PSM highlighted the importance of jet grout column trial interpretation, the influence of column diameter, tilt and position variability and the consequence of small gaps in the base block. Monte Carlo techniques, based on observed as-built column variability, were used to demonstrate the impact of variability on the continuity of the base slab. These indicated that near perfect construction was required if the project objective was to be achieved.

# PAVEMENT MODEL TESTS TO INVESTIGATE THE EFFECTS OF GEOGRID AS SUBGRADE REINFORCEMENT

**Chamara P.G. Jayalath[1], Chaminda Gallage[1], Manicka Dhanasekar[1], Biyanvilage S. Dareeju[1], Jothi Ramanujam[1] and Jeffrey Lee[2]**

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## ABSTRACT

The stabilization of weak subgrade is essential before placing the pavement structural layers. It is well known that geogrids can be used to reinforce the weak subgrades, however, the verification using local materials is needed to convince road authorities. In this study, two identical model pavements: one without composite geogrid and the other with composite-geogrid reinforcement at the interface of the subgrade-base layer were prepared in a steel box with length, width and height of 1m, 1m and 1.2m, respectively. The 500mm thick subgrade (Black soil) was prepared to achieve CBR value less than 3% and then 200mm granular layer (Type 2.3) was compacted on top of the subgrade to achieve 91% of its maximum dry density. The model pavements were instrumented with Linear Variable Displacement Transducers (LVDTs), soil pressure transducers and moisture sensors. Both pavement models were subjected to repeated loading (more than 110, 000 cycles) at the centre using a 200mm diameter plate to simulate the maximum tire pressure of 550kPa. The test results showed that the inclusion of composite geogrid at the base-subgrade interface can significantly reduce the rutting depth of granular pavement on weak subgrade (CBR < 3 %). At 50mm rutting, the approximate Traffic Benefit Ratio (TBR) of 5 could be achieved by using composite-geogrid-reinforced subgrade. Furthermore, the pressure transmission to subgrade was significantly reduced by the composite geogrid at the interface.

# DIGITAL ENGINEERING IN IDENTIFYING POTENTIALLY SETTLEMENT AFFECTED STRUCTURES FROM ADJACENT TUNNELING AND EXCAVATION

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## ABSTRACT

Potential settlement of structures from tunnelling and excavations have typically been manually identified through comparison of structures footprint against settlement modelling. This time-consuming exercise requires manual re-processing after every alteration in the settlement model and is prone to human error. As a part of large scale tunnel and excavation works, Golder Associates and PSM developed a digital engineering solution to automatically identify structures that are predicted to be affected by settlement, and its magnitude. The tunnels stretch for over a dozen kilometres through inner Sydney with half a dozen box cut excavations, the settlement model of which can now be re-analysed in less than half an hour.

Vertical displacement from green field settlement was modelled, and Surfer used to output contours of the modelled settlement. These contours were intersected with the footprint of the structures along the route and the value of the greatest intersecting contour attached to the footprint. As a part of the settlement effects analysis adjacent basements were also classified into proximity zones using horizontal and vertical distance of basements to box cut excavations and the tunnel walls. The 3D CAD models of the box cut excavations and the centreline of the tunnel were brought in and the angle and distances to the basements along the alignment calculated.

The scripts were created with the Extract, Transform and Load software FME, and the python package ArcPy. This solution is highly flexible and able to be adapted to other settlement effect analyses.

# CULTANA SEAWATER PUMPED HYDRO-ELECTRIC ENERGY STORAGE PROJECT – GEOTECHNICAL OPTIONEERING DESIGN

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## ABSTRACT

The Cultana Seawater Pumped Hydro-Electric project is located 10km south-west of Port Augusta in South Australia. The objective is to provide between 100MW and 250MW of dispatchable peak electricity to the National Electricity Market grid in South Australia, as well as providing a range of grid support and ancillary services.

This paper outlines the geotechnical concept design carried out during the optioneering stage of this project. The aim of the geotechnical optioneering stage was to provide a preferred option for each of the four major structures on this project.

- 40m deep bunker style powerhouse nearshore and an inlet / outlet structure with strict requirements on water inflow and outflow speeds to protect marine fauna;
- Installation of a 3.4 km onshore transfer pipeline subject to large surge loads;
- Penstock down the ridge on a steep approximately 220m high slope or tunnelled under the slope;
- Reservoir subject to daily rapid water drawdown;

Some of the key technical features associated with these structures included:

- The ground conditions across the site, and therefore at each of the four structures, was different;
- Powerhouse retention system comprised a 40m deep "peanut" shaped diaphragm wall housing three turbines. The diaphragm wall panels worked in a hoop system to resolved lateral forces into compression thereby eliminating the need for permanent rock anchors. The diaphragm wall is located predominately on sand dunes, with bedrock encountered at 37m depth and groundwater level at 1m below ground level;
- Transfer pipeline proposed to be constructed using open excavation with temporary shoring. A shallow sandstone caprock layer and/or cemented bed was encountered suggesting excavations may require rock blasting or hydraulic excavation;
- A crushed sandstone with clay core reservoir wall design has been selected, however the reservoir will be subject to daily rapid drawdown making the clay core design and minimising water ingress through the dam walls challenging;
- Penstock construction was a key safety in design issue. The additional energy created with a tunnel through the slope needed to be traded off against the additional cost of the tunnel. Surge loads on the penstock foundations were also considered. Access for excavation machinery and piling rigs was critical in deciding which foundation design to adopt.

This paper will discuss design options for each of these structures and those selected for the feasibility stage business case (optioneering stage). Each option was selected based on hydraulic considerations, cost effectiveness, constructability and safety in design.

# ASPECTS OF THE REGIONAL TECTONIC AND STRUCTURAL GEOLOGICAL MODEL OF THE TRANSMISSION GULLY PROJECT IN WELLINGTON, NEW ZEALAND FOR ROCK CUTTING SLOPE DESIGN

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## ABSTRACT

The rocks of the Torlesse Composite Terrane in New Zealand are highly anisotropic and as such local to district scale geological structure patterns tend to orientate with respect to crustal anisotropy. Accordingly study of the tectonic setting and regional scale faulting is an important tool when evaluating structural domains for rock slope design in quarries and cuttings for road, rail and land development projects.

This approach has been adopted for rock cutting design at Transmission Gully in New Zealand which is a project to build a new 27 km, four lane motorway along SH1 north out of Wellington. The Transmission Gully alignment is dominantly located in Torlesse rocks and crosses several regional scale faults. Structural data for slope design was mostly from borehole imaging with some mapping. To guide engineering geological evaluation of local structural domain models a regional tectonic and structural geology study was undertaken to help predict cutting-scale structural patterns and guide interpretation of the borehole dominated structural database. This paper summarises key aspects of the study and illustrates how this approach is integral to managing design and construction risk.

# GEOTECHNICAL SITE INVESTIGATION: OBSERVATIONS OF SITE ACCESS, SITE SUPERVISION AND SERVICE PROVING BEST PRACTICES

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## ABSTRACT

As geotechnical site investigation becomes inherently more challenging to complete due to site access constraints, elevated project risk profiles and increased public awareness, the importance of sound planning and execution is vital. The intent of this paper is to provide engineers tasked with managing and delivering site investigations with an overview of personal observations of what could be considered industry best practices (Melbourne) in mitigating potential risks associated with service strikes when planning site investigation, especially for high profile projects. Rigorous site access processes, targeted service clearance, including Non Destructive Excavation (NDE), and proficient site supervision are essential for site investigations on large scale infrastructure projects. The creation of larger Joint Ventures, Alliances and project teams has resulted in the development of more stringent safety processes, more thorough permits and heightened safeguards aimed at reducing risks, both perceived and actual, associated with ground breaking activities. With stakeholders and client becoming increasingly more risk averse, there is a greater reliance on engineers to complete site work without incidents or attracting the attention of the public eye.

# THE INFLUENCE OF RUBBER CRUMBS ON THE CYCLIC DEFORMATION BEHAVIOUR OF WASTE MIXTURES

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## ABSTRACT

The practical application of waste materials such as steel furnace slag (SFS) and coal wash (CW) is becoming more prevalent in many geotechnical projects. While the inclusion of rubber crumbs (RCs) from recycled tyres into mixtures of SFS and CW not only solves the problem of large stockpiles of waste tyres, it can also provide an energy-absorbing medium that will reduce vibration and track degradation. However, the high compressibility of rubber materials may subject track systems to increased deformation if they are included, which is why an engineering insight into the effect that rubber crumbs have on the cyclic deformation of SFS+CW+RC mixtures is imperative. In this study the influence of RC contents on the cyclic deformation, i.e. total and resilient deformation was investigated based on drained cyclic triaxial tests. The results reveal that with the inclusion of RC, the total axial strain increases, the volumetric strain becomes more contractive, and the resilient deformation of the SFS+CW+RC mixture increases while its resilient modulus decreases. By comparing with traditional subballast, the waste mixture with 10% RC was found to be the optimal waste matrix for subballast in view of controlling deformation while maintaining sufficient resilient modulus.

# THE DESIGN, MONITORING AND ANALYSIS OF A TRIAL EMBANKMENT OVER SOFT ALLUVIAL DEPOSITS FOR THE TAURANGA NORTHERN LINK: A CASE STUDY

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## ABSTRACT

The Tauranga Northern Link (TNL) is a designated 6.9km long, 4-lane road alignment for State Highway 2, and also includes a 2km extension north on Takitimu Drive and a new onramp from 15th Avenue near Tauranga. The ground model is complex and across the valley floors up to 20m of geologically recent soft alluvial sediments were encountered. Analysis of laboratory oedometer testing results was undertaken to determine suitable preliminary consolidation parameters for design. Primary and secondary settlement calculations were completed using in accordance with Terzaghi 1-dimensional consolidation theory. Preliminary calculations indicated that without mitigation measures, post-construction consolidation and secondary creep settlements would exceed the NZTA Bridge Manual serviceability limit state performance criteria. To refine the design, a trial embankment was constructed adjacent to the Wairoa River to enable back-calculation of actual consolidation parameters for the soil units using the Asaoka method and Terzaghi's theory of consolidation. Construction and ongoing monitoring results are discussed as a case study within this paper, along with comparison of the predicted versus actual settlement results and design parameters.

# EMERGENCY RESPONSE PROCESS FOR SLIP REMEDIATIN ALONG THE STATE HIGHWAY 4, NEW ZEALAND

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## ABSTRACT

State Highway 4 (SH4) is approximately 240km long, 2-lane highway connecting Whanganui to Te Kuiti in the lower North Island, New Zealand. A major storm event in June 2015 lead to over 43 landslips affecting an approximately 85km section of highway between Whanganui and Raetihi. Twelve of these slips resulted in considerable damage to the highway corridor. As part of the Network Outcomes Contract (NOC) for the Manawatu-Whanganui region, Beca Ltd was commissioned by Higgins Group Holding Ltd (Higgins) and the NZ Transport Agency (NZTA) to provide engineering services, including emergency response, geotechnical investigation, design and construction monitoring of the remedial measures for the slip sites.

Initial emergency response was undertaken to restore access to the affected communities. This was followed by site prioritisation to identify the sites which required in-depth investigation and design for remediation (known as 'Category B' sites). Site-specific ground investigations were undertaken at these sites to assess the ground and groundwater conditions and likely failure mechanisms. Remedial options in the form of reinforced, embedded and gravity retaining structures, earth fill buttresses and road re-alignment were developed. Detailed design and construction of the preferred options were undertaken over an approximate 18-month period.

This paper presents the processes adopted to remediate the slip sites through close consultations between the client, consultant and contractors as well as the local stakeholders and the local council. It discusses the geotechnical aspects of the design solutions, and presents the main lessons learnt and recommendations for further improving the collaborations between all parties involved in NOC contracts.

# GPGPU-BASED 3-D HYBRID FEM/DEM FOR NUMERICAL MODELLING OF VARIOUS ROCK TESTING METHODS

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## ABSTRACT

In the field of geotechnical engineering, the number of applications of combined/hybrid finite-discrete-element method (HFDEM) to both the lab-scale and field-scale problems has increased recently. In author's research group at university of Tasmania, 2-D/3-D HFDEM code has also been successfully developed [e.g. Liu et al. 2015, Int. J. Geotech. Eng. 9:115-131] and applied to some geotechnical engineering problems such as rock blasting, fracture processes in a series of lab-scale rock testing methods and asperity degradation and gouge grinding during direct shearing of rough rock joints. However, since the HFDEM code was implemented by sequential programming, its main application mentioned above was limited to 2-D problems owing to the computationally expensive nature of HFDEM. To overcome this situation, the parallel programming scheme using "general-purpose-graphic-processing-unit (GPGPU)" and "CUDA (Compute Unified Device Architecture) C" was recently incorporated into the HFDEM code and significant speed-up has been achieved. This paper briefly describes the theory and newly incorporated features of the GPGPU-based HFDEM code along with some important issues which have not been addressed clearly in the previous publications using HFDEM. Then, this paper demonstrates some examples of 3-D numerical modelling of rock fracture process using various lab-scale rock testing methods such as quasi-static Brazilian test, quasi-static uniaxial compression test, dynamic Brazilian test using Split Hopkinson Pressure Bar (SHPB) apparatus. Through these demonstrations, the applicability of the newly developed 3-D HFDEM code is shown.

# LESSONS LEARNT FROM DEWATERING CHALLENGES IN CHRISTCHURCH

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## ABSTRACT

Foundation and infrastructure construction in Christchurch often involves groundwater management which is executed as dewatering. By virtue of these works being temporary the design responsibility often falls to the contractor, and on many occasions for smaller projects dewatering systems are specified and installed without input from experienced engineers or personnel, and without oversight from designers. This practice evolved due to the varying plant and equipment that contractors have available, and uncertainties involved in specifying dewatering systems. Depending on the chosen dewatering method and the quality of installation and operation, dewatering can pose significant risks to the surrounding buildings and infrastructure.

This paper outlines typical dewatering methods for horizontal and vertical infrastructure construction in Christchurch. Based on the author's experience as a designer and while undertaking construction observations the common issues with dewatering will be discussed through two case studies, where improper dewatering installation led to ground subsidence and instability, and caused significant damage to adjacent infrastructure.

A review of each case study indicated that each share common organisational contributions and construction issues, which in turn have led to the poor performance. The paper will specifically discuss the timing of the dewatering drawdown period, knowledge and background of the persons responsible for dewatering, and appreciation of dewatering risks by the project stakeholders. Lessons learned are drawn for engineers designing and supervising projects involving dewatering. These lessons include appropriate limitations on dewatering for specifications, and the key stages of dewatering setup where site supervision is required.

# GEOTECHNICAL PROFICIENCY TESTING FOR FIELD-BASED SOIL EXPANSIVITY ASSESSMENT: DO WE NEED IT?

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## ABSTRACT

The intention of this study was to assess whether proficiency testing, as outlined in ISO/IEC 17043:2010 could be beneficial for field assessment of soil properties testing, similar to the laboratory 'interlab' system.

The geotechnical profession is unique amongst engineering disciplines, as project-specific specialised quantitative testing is not always used to establish material properties used for analysis and design. For the numerous smaller projects, in particular, plasticity, for example, is typically assessed on-site through experience as opposed to laboratory testing. This experience is specific to each consultant and, in conjunction with no requirements for inter-consultant comparison, presents the position where industry-wide consistency is unknown.

The study undertook a proficiency test on soil plasticity logging between various geotechnical consultants using the procedure outlined in ISO/IEC 17043:2010 section 4.4. Participating consultants received a uniform soil sample for logging by at least two staff members. The participating companies and engineers were kept anonymous throughout the study. The participants were also asked to interpret the soil class according to AS 2870:2011. Results were collated and compared to a laboratory tested control sample to assess logging and interpretation consistency.

The implications of any variance between participants and laboratory tests were also explored. Whilst plasticity was the parameter chosen for investigation, the results of the exercise provide an insight into whether proficiency testing by a regulatory body or professional organisation would benefit the industry and its customers. Processes that reduce the inconsistency and variance in the field based assessment of soil performance characteristics could reduce the risk of excessive conservatism or the risk of underestimating plasticity and underspecifying foundations.

# FINITE ELEMENT MODELLING OF UNSATURATED SOIL BEHAVIOUR FOR DESIGN OF RETAINING STRUCTURES FOR THE TORRENS RAIL JUNCTION PROJECT, ADELAIDE

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## ABSTRACT

The Torrens Rail Junction (TRJ) is where the interstate freight railway crosses the Outer Harbor passenger railway, located in the Park Lands, Adelaide. The original rail junction posed a productivity constraint to the strategically important Perth to Melbourne rail freight line, with freight trains forced to give way to Outer Harbor passenger trains at the junction. The TRJ project comprised a grade separation of the rail lines by lowering the Outer Harbor rail line below both the interstate rail line and the adjacent Inner Ring Route (Park Terrace). The lowered Outer Harbor rail line extends for a length of approximately 1.5 kilometres supported by an approximately 8m deep cantilever pile wall.

The project is underlying with River Torrens alluvium. The River Torrens alluvial deposits transition to alluvial fan sediments of the Adelaide Lower Outwash Plain. These materials typically comprise of stiff to hard clay soils with local interbedded sandier horizons. These clays are typically unsaturated above the groundwater table and are highly reactive.

The technical solution for the earth-retention systems proposed the use of an economical, practical and compliant design. To achieve this, the retaining wall design approach proposed differed from normal design practice to consider effects of suction and unsaturated soil mechanics principles.

Numerical methods were employed to analyse soil-structure interaction. The analysis considered staged construction, effects of volume change in clay soils due to unsaturated condition including variations from an initial equilibrium condition to a new equilibrium suction (wetting), effects of swell pressures and the beneficial effects of suction in the shear strength of clays when assessing lateral earth-pressures against retention structures and local/global instability.

As this design approach was novel, the proposed methodology was compared to a full-scale pile wall trial, undertaken by the Department of Planning, Transport and Infrastructure (DPTI), Government of South Australia, to verify the design approach. The results using the proposed design methodology indicate the numerical models could reliably predict both deflection and structural reaction at all construction stages.

# GEOTECHNICAL INTERPRETATIONS USING VISUAL TACTILE METHODS

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## ABSTRACT

Every engineering project has a scope, timeframe and budget. The budget or scope for a geotechnical investigation is generally a fraction of the whole project's budget. For small projects, due to limited time frames and budgets, the scope at each site is often limited to only one borehole with in situ testing and materials to be logged using visual tactile methods by a trained engineer/geologist. Using limited investigation data presents challenges to determine geotechnical design parameters and the engineering design of foundation systems. This paper presents a process for establishing geotechnical design parameters in the absence of laboratory testing for small projects such as telecommunication towers. Geotechnical design parameters are derived using well established correlations and engineering experience.

# MINE SUBSIDENCE ASSESSMENTS AND REVIEW OF SELECTED GROUTING REMEDIATION PROJECTS IN THE NEWCASTLE AREA

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## ABSTRACT

Widespread mining has been undertaken beneath developed areas of Newcastle and it's surrounds since the early 1800s, and continues to the present day.

Local geotechnical consultants are regularly asked to assess the risk of mine subsidence for proposed developments, and to provide 'worst credible case' subsidence parameters in the event of a future subsidence event. Where the risk of subsidence is considered too high for the proposed structure, ground improvement is usually adopted which includes remedial grouting works, in order to limit the risk of future subsidence to acceptable levels.

The uncertainties associated with grouting of the old mine workings beneath sites in and around Newcastle has in the past been seen as a big risk for prospective developers, with the potential for expensive overruns associated with grout volumes making them reluctant to commit to developments underlain by mine workings. The introduction of a Government backed Newcastle Mines Grouting Fund has now provided a safety net to developers in the event that grout costs are more than anticipated. This safety net has provided developers and financiers more confidence to proceed with developments, but the need to understand the likely quantities of grout required to remediate sites continues to be an important consideration for both Government and developers alike.

This paper presents data for numerous local projects where remedial grouting works have been undertaken for large developments. Common methods of investigation and assessment of the condition of the mine workings are discussed. The focus of the paper, however, was to compare the volume of grout required to remediate selected projects with knowledge of the mine conditions to develop an empirical approach to evaluate the quantities of grout for future projects in the Newcastle Coalfields.

# ISSUES WITH GEOTECHNICAL INVESTIGATIONS, DESIGN AND CONSTRUCTION IN REMOTE LOCATIONS

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## ABSTRACT

This paper discusses the complexities of providing geotechnical design parameters for rock anchors and shallow foundations for an access stairwell at the 20 m high, vertical walled, To Sua Ocean Trench in Samoa.

Restricted by an absence of relevant published geotechnical information, local resources and equipment, as well as on-site testing limited to shallow subsurface investigations and visual site observations, the geotechnical design parameters are constrained to conservative estimates.

Hand auger borehole testing with associated in situ strength testing (Scala penetrometer and shear vane testing) was completed in the surficial soils at the top of the trench, rock samples were collected for UCS testing (where accessible) from the vertical walls, and Scala penetrometer testing was completed through the water at the base of the trench. Additionally, geological mapping and detailed evaluation of the rock face was undertaken.

Without cored borehole investigations, rock strength data and evaluation of the presence and prevalence of defects within the rock mass, recommended geotechnical design parameters are conservative assumptions, analogous with published values for weathered, relatively porous, basalt rock form internationally recognized standards. Consequently, geotechnical designs are less cost-effective and assumptions require verification during construction.

# IMPROVEMENTS TO TENSILE STRENGTH MEASUREMENT OF HARD ROCKS

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## ABSTRACT

Geomaterials commonly refer to both natural materials of geological origin (e.g. soil and rock), and manufactured and processed geo-like materials (e.g. bricks, crushed stone aggregates, asphalt, pavement, solid waste, dredged material, etc.). Hence, geomaterials cover a wide range of materials for which geotechnical parameters must be obtained to enable the reliable design of buildings and footings, highways and railways, tunnels, earthern embankments, open pit and underground mines. Although the literature is replete with test methods and standards to estimate the strength of geomaterials, many of these test methods have not been advanced for decades, rely on simple apparatus, when more advanced test methods and equipment are becoming available, and are inadequate for the requirements of modern infrastructure.

On the other hand, unlike for metals, the ratio of compressive strength to tensile strength, or so-called the brittleness index, is significantly large in geomaterials, particularly in hard and brittle rocks. To avoid their tensile ruptures and to guarantee the stability of foundations, structures and deep underground openings, therefore, accurate and reliable measurement of the tensile strength of brittle geomaterials is of the most critical importance. In this study, first, some of the widely accepted testing techniques in the literature for the tensile strength measurement of geomaterials is reviewed and their reliability and validity to hard and brittle rocks are investigated. Then, based on some preliminary experimental studies, two new testing methods are introduced as alternative tensile strength test methods for hard and brittle rock-like materials.

# THE USE OF EARLY-WORKS EMBANKMENTS IN SOFT SOIL AREAS TO OPTIMISE DETAILED DESIGN: GATEWAY MOTORWAY CASE STUDY

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## ABSTRACT

This paper presents a case study on the use of early-works preload[1] embankments in soft soils areas to provide information to optimise detailed design. The Gateway Upgrade North (GUN) project involved the widening of the existing Gateway motorway from four to six lanes with some areas of re-alignment. Early-works for the motorway upgrade involved construction of sections of embankment located in areas of soft soils. From a geotechnical perspective, the early-works were essentially instrumented trial embankments constructed 9 to 12 months ahead of the main package and therefore provided an opportunity to observe embankment and wick drain performance and back-analyse soft soil consolidation parameters used for the detailed design for the final motorway construction.

Data from settlement plates, vibrating wire piezometers and inclinometers was used in conjunction with site investigation and laboratory data to assess consolidation parameters of highly compressible Holocene-age alluvial clays. Asaoka's method and Terzaghi's theory of one-dimensional consolidation were used in the back analysis of primary consolidation parameters. Secondary settlement was also observed allowing back analysis of secondary compression parameters. Using consolidation parameters derived from the back analysis, design parameters were allocated to relevant geological units which were then applied in settlement modelling for critical sections in the detailed design.

Assessment of the early-works embankment monitoring data enabled a more robust prediction of embankment behaviour during and post-construction. This resulted in a more cost-effective and optimised embankment design with higher confidence in predicted post-construction settlements.

# REVIEW OF OVERCORING TESTING TO MEASURE IN SITU STRESS FOR TUNNEL PROJECTS IN SYDNEY

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## ABSTRACT

The magnitude and direction of *in situ* stress is important to the design and performance of an underground project. A number of techniques are available to estimate *in situ* stress in rock, with borehole deformation strain cells (a form of overcoring) and hydraulic fracturing being the most common used in investigative boreholes in civil projects in Australia. An assessment of recent stress measurements obtained from the overcoring technique for tunnels in Sydney indicates lower results for the magnitude of the horizontal stress, when compared to available published data on the Sydney horizontal stress field by hydraulic fracturing. Overcoring stress testing involves drilling a pilot hole in a borehole and measuring strains while overcoring. The calculation of the *in situ* stress further requires laboratory testing of the overcored rock sample to measure Young's modulus and Poisson's ratio. An iterative calculation is undertaken to determine the *in situ* stress in the rock. The intrinsic aspects of the overcoring testing method are discussed to assist in interpreting the stress field for tunnelling.

# RESOLVING MAJOR DISCREPANCIES BETWEEN PREDICTED AND MONITORED SETTLEMENTS OF A HIGHWAY EMBANKMENT ON SOFT SOIL

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## ABSTRACT

This case study discusses settlement predictions and how they compare to monitored settlements at an embankment constructed over soft soil forming part of the Woolgoolga to Ballina Pacific Highway upgrade on the north coast of New South Wales. The embankment height ranged from 3.4 to 7.7 metres with wick drains installed across most its 410-metre length. Settlement predictions ranged from 125 to 300 millimetres with a predicted construction and waiting time of 1.5 years. Settlement plates, inclinometers, magnetic extensometers, hydrostatic profile gauges and vibrating wire piezometers were installed to monitor settlements, pore pressures and embankment stability. It was found that after 3 months of construction and 9 months of combined construction and consolidation monitoring the soft soil had reached 95 to 100% consolidation, however the monitored settlement had exceeded predictions by up to nearly 300% in some areas of the embankment while in other areas the monitored settlement was less than 20% of prediction. Site investigation data was scrutinised and back-analysis was performed to match the monitoring data in a one-dimensional consolidation model. Back analysed parameters were compared to design parameters and possible reasons for the discrepancies in settlements and consolidation rates were discussed.

# A TRANSIENT PRESSURE ANALYSIS FOR WELLBORE STRENGTHENING

**Yang Liu[1, 2, 3], Ping Chen[1], Tianshou Ma[1], Bisheng Wu[4], Xi Zhang[3], Bailin Wu[3]**
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## ABSTRACT

Wellbore strengthening treatments have been widely applied to improve formation bearing capacity and to mitigate lost circulation during drilling fractured formations with narrow mud-weight window. However, the mechanisms and mechanics of wellbore strengthening are still not completely understood since the fluid-solid coupling process between plugging zone and drilling fluid is previously simplified. In this paper, a fully coupled numerical model that includes rock elastic deformation, fluid flow and plugging mechanics is employed to study the evolution of plugged fracture system after wellbore strengthening. The numerical result is in good agreement with the published ones, verifying the accuracy of the present model. Symmetric bi-wing fracture geometry is considered to investigate the near-wellbore stress distribution and internal pressure profile in fracture before and after wellbore strengthening. The numerical results indicate that the hoop stress can be enhanced in compression after plugging the fractures. The evolution of fracture opening and internal pressure in fracture suggest that wellbore strengthening treatment can prolong the time to reach the fracture growth state. The existence of the plugging zone can also significantly change the normal stress distribution. In addition, the impact of plugging zone permeability on its shear failure pattern is analysed, and the relations of wellbore pressure and plugging zone failure time to the controlling parameters are discussed in detail. The limitations of the present model are also pointed out.