Australian Geomechanics Society

IAH AUSTRALIA

ISSN 0818-9110

GROUNDWATER & EXCAVATION

PROCEEDINGS OF THE 2015 AGS/IAH SYMPOSIUM
HELD IN
AUSTRALIAN NATIONAL MARITIME MUSEUM, DARLING HARBOUR, NSW
ON NOVEMBER 13TH 2015

ORGANISING COMMITTEE:
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ENGINEERS AUSTRALIA

Published by The Australian Geomechanics Society,
National Secretariat,
P.O. Box 955, ST IVES, NSW 2075

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Geomechanics is the application of engineering principles to the earth sciences to improve continually the accuracy, efficiency, cost-effectiveness and safety of construction projects both above and below ground, including the recovery of the earth's mineral resources. It remains an imprecise discipline due to the infinite variety of conditions in the earth's crust but correspondingly offers a fascinating and rewarding field of research and practice.

The Australian Geomechanics Society was founded in 1970. Its origins lie in the National Committee of Soil Mechanics of the Institution of Engineers, Australia, established in 1953 and the call for a corresponding society in rock mechanics. In 1973 the society was expanded to include the third discipline of engineering geology and has remained substantially unchanged since that date.

The society is affiliated to the International society of Soil Mechanics and Foundation Engineering (ISSMFE), the International Society for Rock mechanics (ISRM) and the International Association for Engineering Geology and the Environment (IAEG).

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Hydrogeology is an interdisciplinary profession which combines chemical, physical and biological knowledge to understand the relationship between geology and occurrence and movement of groundwater in the unsaturated and saturated zone. Similar to geomechanics it is an imprecise discipline as the complex geological conditions underground and physical and chemical processes make it challenging to interpret and analyse.

The International Association of Hydrogeologists (IAH) was founded in 1956 and it has since grown to a world-wide membership of more than 4000 individuals. It is a scientific and educational charitable organisation for scientists, engineers, water managers and other professionals working in the fields of groundwater resource planning, management and protection. Its aim is to raise awareness of groundwater issues and work with national and international agencies to promote the use of groundwater to ensure ready access to safe drinking water. IAH also promotes the protection of aquifers against pollution, the improvement of aquifer storage and the management of groundwater resources to assure the sustainability of groundwater-dependent ecosystems.

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2015 AGS/IAH Symposium

Recent Developments and Experiences with Groundwater and Excavation

Friday 13 November 2015
Australian National Maritime Museum, Darling Harbour, Sydney

8:30 *Registration*
9:00 *Opening address*

Excavation (Part I)

9:05 **Keynote Lecture**
Prediction of groundwater impacts for excavations
Ross Best (Coffey)

9:35 **Fibre reinforcement of CSM walls to enhance strength, crack resistance and seepage cut-off**
Adrian Russell (UNSW)

9:55 **Excavation, structural stabilisation and groundwater management by jet grouting on Sydney harbour foreshore**
David Chadwick (Keller Ground Engineering)

10:15 **Performance assessment of cut-off walls subject to tidal pressure variation**
Antony Orton (Coffey)

10:35 *Questions*
10:55 *Morning tea*

Excavation (Part II)

11:15 **Use of deep soil mixing for excavation retention and groundwater control**
Chris Lyons (Arup)

11:35 **Deep excavations in soft clay on Brisbane Airport Link Project**
Henry Zhang (PB)

11:55 **Some design and construction issues in deep excavations and shoring design**
Jim Yang (Hyder)

12:15 **Meeting the challenges of complex excavation interactions**
David Oliveira (Jacobs)

12:35 *Questions*
13:00 *Lunch*

Groundwater (Part I)

13:40 **Keynote Lecture**
Building dewatering in the Botany Sands and the Aquifer Interference Policy
Boyd Dent (NSW Office of Water, NOW)

14:10 **Utilisation of deep groundwater barrier walls using soil bentonite and biopolymer slurries in geotechnical and environmental applications**
Philippe Vincent (Menard Bachy)

14:30 **Contaminant flow in groundwater in Hawkesbury sandstone – experience from major basement excavations**
Malcolm Dale (EIA)

14:50 **Groundwater inflow assessment for deep basement excavations: a case study**
Ben Rotter (Coffey)

15:10 *Questions*
15:25 *Afternoon tea*

Groundwater (Part II)

15:45 **Hydrogeologists and geotechnical engineers – lost without translation**
Steven Pells (Pells Consulting)

16:05 **Design groundwater levels and depressurisation of the Cleveland St underpass**
Gareth Swarbrick (PSM)

16:25 **Hydrogeological assessment for a land reclamation dewatering operation**
Kim Chan (GHD)

16:45 **Groundwater control in design and construction of deep basement excavation in Singapore**
Sher Bhullar (ARUP)

17:05 *Questions*
17:20 *Closing address*
17:35 *Close*

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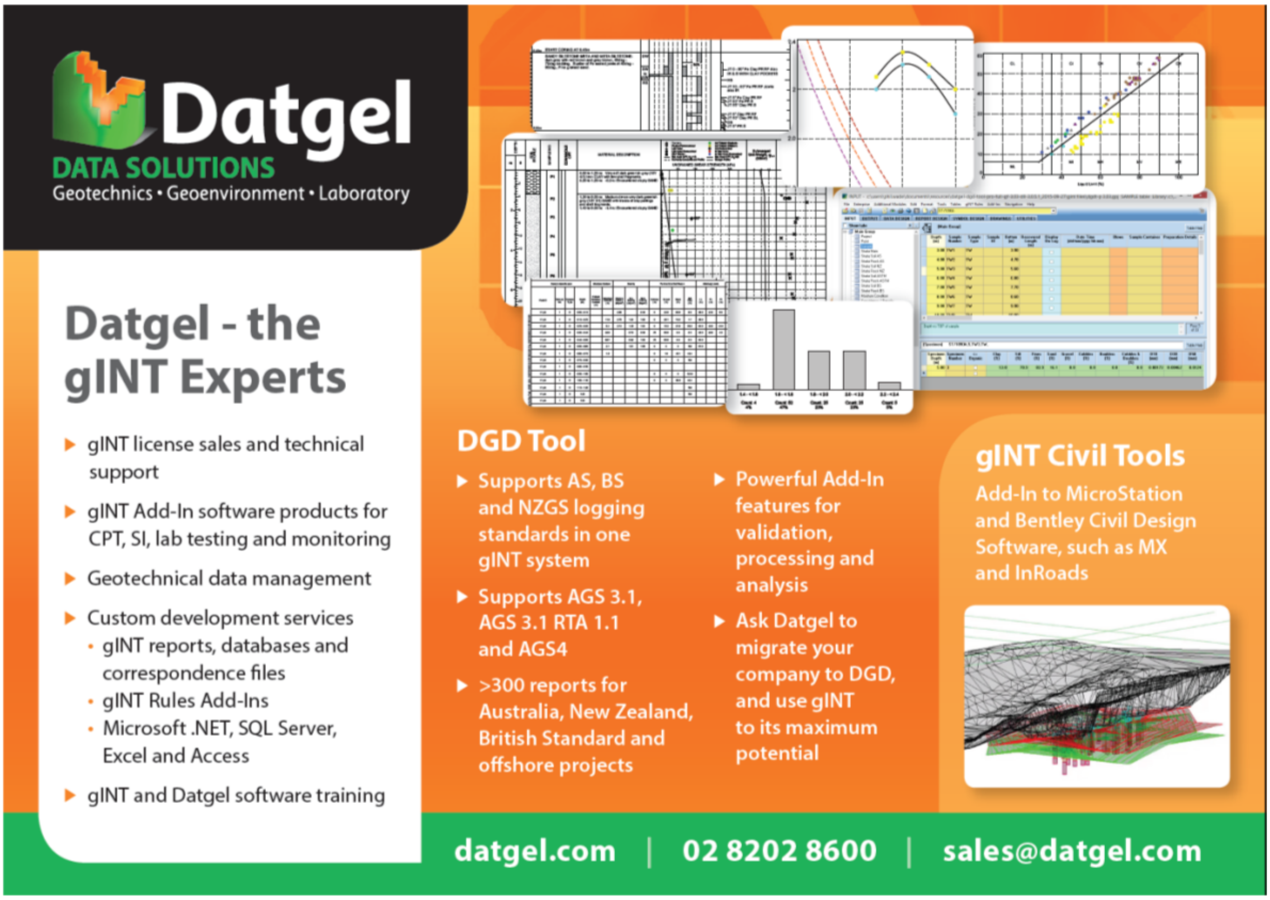
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Symposium – Friday 13 November 2015

GROUNDWATER AND EXCAVATIONS

PREFACE

This document contains papers for the 19th annual symposium organised by the Sydney Chapter of the Australian Geomechanics Society and the NSW branch of the International Association of Hydrogeologists. It is hoped that the symposium will keep practicing geotechnical engineers, engineering geologists, hydrogeologists and other engineering professionals informed of recent developments in this field. It also recognises the need to gather together the experience of those practicing throughout Australia and to allow transfer of knowledge and sharing of their experiences.

These symposia continue to be one of the best forms for bringing together the key stakeholders of the Australian geological, geotechnical and groundwater community. The main objective of the symposium, held on 13 November 2015, is to advance the knowledge in design and construction towards safer excavations, more cost effective shoring practices, accurate groundwater modelling and better management of groundwater issues in urban and infrastructure environment.

Contributors include academics, practicing consultants, designers, suppliers and contractors. The papers present novel design and construction technologies for the performance monitoring and prediction of groundwater flow in excavations, groundwater management, the state-of-the-art practices, innovative technologies as well as new research results and case histories on construction.

This symposium is the cooperative effort of many authors and qualified reviewers. The editors and organising committee wish to thank the authors, who have generously contributed their time to prepare the various papers and the colleagues of the authors, who have assisted with time, secretarial, drafting and other facilities. Appreciation is also extended to our sponsors for their support. Without them the Symposium would not be possibly the best ongoing forum for the Australian Geomechanics and groundwater community.

Cholachat Rujikiatkamjorn, Sam Mirlatifi, Katarina David, Adrian Hulskamp, and Mark van Uden
On behalf of the AGS/IAH Symposium Organising Committee,
The Australian Geomechanics Society, Sydney Chapter, and
The NSW branch of International Association of Hydrogeologists

Annual Seminars of AGS Sydney Chapter

No.	Date	Topic	Chairman & Organising Team
1	1997	Pavement Design Beyond 2000	A Leventhal
2	1998	Recent Developments in Piling Practice in Sydney	P Andrews
3	1999	Flexible Retaining Walls: Design to Prevent Failure	P Andrews and P Hewitt
4	2000	Computer Methods	P Hewitt and J Carter
5	2001	Excavation Retention	T Walker and P Hewitt
6	2002	Landslide Risk Management	B Walker and T Walker
7	2003	Geotechnical Instrumentation and Construction Works Compliance Testing	G Scholey and T Walker
8	2004	The Engineering Geology of the Sydney Region – Revisited	G Scholey, M Parmar, G Young and G McNally
9	2005	Geotechnical Aspects of Tunnelling	H Buys and T Gourlay
10	2006	Soft Ground Engineering	H Buys, R Moyle and P Hewitt
11	2007	Engineering Advances in Earthworks	R Moyle, R Lindbeck and H Liu
12	2008	Foundation Design and Construction	R Moyle, R Lamont and B Ewers
13	2009	Geosynthetics – New Materials for Modern Infrastructure	B Ewers, H Buys and H Liu
14	2010	Seismic Engineering- Design for Management of Geohazards	C Rujikiatkamjorn, J McIlveen, R Lamont and M Haysler
15	2011	Coastal and Marine Geotechnics- Foundations for Trade	C Rujikiatkamjorn, J McIlveen, G Blumberg, J Smith and C Y Tey
16	2012	Advances in Geotechnical Aspects of Roads and Railways	H Khabbaz, C Y Tey, O Stahlhut and C Rujikiatkamjorn
17	2013	Retaining Structures: Recent Advances and Past Experiences	H Khabbaz, C Rujikiatkamjorn, M van Uden, C McColgan and S Mirlatifi
18	2014	Resilient Geotechnics	H Khabbaz, C Rujikiatkamjorn, S Mirlatifi, C McColgan and M van Uden
19	2015	Recent Developments and Experiences with Groundwater and Excavation	C Rujikiatkamjorn, S Mirlatifi, Katarina David, A. Hulskamp, and M van Uden

TABLE OF CONTENTS

[All papers have been refereed in accordance with the full DETYA review process, unless stated otherwise.]

PREDICTION OF GROUNDWATER IMPACTS FOR EXCAVATIONS

Ross James Best
Senior Principal, Coffey Geotechnics Pty Ltd

ABSTRACT

Groundwater inflow and levels associated with excavations are important considerations for construction and operation of the completed development. Drawdown associated with excavation has potential to result in settlement, impacts on vegetation and ecosystems and the distribution of existing groundwater contamination. Inflows to excavations need to be dealt with including possible need for treatment prior to release to the surface water system.

The paper presents methods which can be used to address a range of groundwater issues associated with excavation drawing upon closed form analytical methods. The methods presented are illustrated with examples drawn from practice.

Topics discussed include:

- Prediction of maximum groundwater level over the design life of a project
- Prediction of the rate of groundwater inflow to an excavation
- Prediction of groundwater level drawdown associated with excavation.

BUILDING DEWATERING IN THE BOTANY SANDS AND THE AQUIFER INTERFERENCE POLICY

Boyd B. Dent[1], Greg Russell[2] and Richard T. Green[3]
[1]Hydrogeologist-Aquifer Interference, [2]Regional Hydrogeologist, [3]Leader Coastal Management Team, DPI Water, NSW Department of Industry

ABSTRACT

The Department of Primary Industries (DPI) Water is responsible for the management of groundwater across NSW. The management of groundwater extraction impacts including those associated with dewatering for building developments which predominate in Sydney within the Botany Sands Groundwater Source is one of the primary roles of the agency. There are an increasing number of residential and commercial developments that need to accommodate construction below the water table for basements and other functions. These have to be built in a way that mitigates adverse impacts on other building developments or other groundwater users, sensitive ecosystems or structures. Parts of Sydney's development are remarkably high-density and construction must be well planned to prevent such effects as unintentional groundwater mounding, obstruction of natural flows by the completed building, and potential basement inundation caused by periodic elevated water levels.

In order to demonstrate sustainable development principles, the Aquifer Interference Policy (AIP) requires the proponent to account for all groundwater take during both construction and occupation. This may include the proponent taking measures to avoid or prevent the take of groundwater where possible and include mitigation or avoidance strategies to reduce take of water. The proponent should demonstrate that adequate arrangements will be in place to ensure the minimal impact considerations of the AIP are met. The information needed for assessments of the groundwater impacts of proposed developments under the AIP requires a comprehensive evaluation of the hydrogeological environment. This information is required to allow DPI Water to balance the management of the groundwater resource with facilitating sustainable development.

In some instances, the use of secant piled cut-off walls to enclose an entire site may not be the optimum solution without other engineering measures because the walls effectively work like dams to groundwater flow. Alternate methods of construction might be more appropriate and facilitate flows both beneath and around structures. The dewatering considerations are not limited to individual properties as there are significant interferences from major infrastructure projects, as well as other nearby concurrent building developments, which need to be accommodated at the same time. This paper discusses requirements for proponents and their consultants that relate to the assessment of dewatering proposals in Sydney's Botany Sands Groundwater Source, which is part of the Greater Metropolitan Region Water Sharing Plan area.

FIBRE REINFORCEMENT OF CSM WALLS TO ENHANCE STRENGTH, CRACK RESISTANCE AND SEEPAGE CUT-OFF

Adrian R. Russell[1], Mark Chapman[2] and Hossein Taiebat[1]
[1]*Centre for Infrastructure Engineering and Safety, School of Civil and Environmental Engineering, The University of New South Wales, Sydney, 2052, Australia*
[2]*Wagstaff Piling Pty Ltd, Brisbane, QLD, 4000, Australia*

ABSTRACT

Cutter soil mix (CSM) walls are created by mixing soils while in situ with cement and bentonite slurry to produce a soil mix with modest tensile and compressive strengths. CSM walls may be stabilised using internal steel beams and ground anchors. Presented here are results of a CSM wall field trial in which polypropylene fibres were added to a soil mix. One objective of the trial was to explore whether or not fibres have the potential to increase wall resistance to bending and reduce the quantity of steel needed to provide stability. Another objective was to explore whether or not the fibres provide a reduced tendency for crack formation and thus the potential for enhanced seepage cut-off. The trial involved mixing fibres into a 4 m deep single CSM wall panel using a conventional mixing procedure employed by Wagstaff Piling. 24 hours after placement a 20 tonne excavator was used to remove the wall panel. Samples were collected and tested 28 days and 2 years later to assess unconfined compressive strengths, indirect tensile strengths and flexural tensile strengths. The fibre orientation distribution in the soil fibre mix was also assessed. The testing confirmed that the mixing technique resulted in a uniform orientation distribution of fibres and significantly improved strength characteristics. The testing also showed that the fibres made the CSM wall mix very ductile and prevented brittle failure. Adding fibres to the CSM material enabled larger bending deformations to be tolerated before major cracking and failure occurred. Also presented is a hypothetical design of a fibre reinforced CSM wall to show that steel quantity can be reduced while maintaining stability and crack prevention, leading to significant cost reductions.

EXCAVATION, STRUCTURAL STABILISATION AND GROUNDWATER MANAGEMENT BY JET GROUTING ON SYDNEY HARBOUR FORESHORE

David A Chadwick[1] and Derek L Avalle[2]
[1]Southern Region Manager, [2]Senior Engineer
Keller Ground Engineering Pty Ltd, Sydney, Australia

ABSTRACT

A former town gasworks site on Sydney Harbour's foreshore has been the subject of site remediation to address residual industrial contamination. Jet Grouting was undertaken under a Design & Construct contract to form a temporary retaining structure behind and under the full length of a 19th Century seawall, thereby facilitating the excavation and ex-situ remediation of contaminated materials at the site and ensuring long-term stability of the seawall. In addition, existing heritage buildings were underpinned with Jet Grouting to ensure the structural stability and integrity of these structures during the excavation phase. The excavation was up to 7m deep and 6m below sea level. Jet Grouting was undertaken under strict settlement and deflection controls, with a target permeability no greater than $1x10^{-7}$m/s. The works were performed by installing over 300 Jet Grout Columns ranging from 1.2m to 2.5m in diameter. Jetting was partially carried out from within the confines of existing heritage structures, while the bulk of the external works was carried out from within an environmental odour control enclosure. The confined nature of the site and its access limitations required the effective co-ordination of Jet Grouting with other site works.

PERFORMANCE ASSESSMENT OF CUT OFF WALLS SUBJECT TO TIDAL VARIATION

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ABSTRACT

Cut off walls constructed in coastal settings are subject to external tidal variations in water pressure. A method to exploit this tidal variability to check the performance of cut-off wall construction is presented supported by analytical and numerical modelling results. The method described allows progressive assessment of performance of the wall during its construction. The approach is illustrated with reference to two case studies: one for a major building project and the other for an environmental control measure.

Use of Deep Soil Mixing for Excavation Retention and Groundwater Control

***Chris Lyons*[1], *Sergei Terzaghi*[2]**

[1]*Associate;* [2] *Principal, Arup, 1 Nicholson Street, Melbourne VIC 3000;* chris.lyons@arup.com*, 04 2817 7067*

ABSRACT

Several buildings at St George's Hospital were damaged as a result of the 2010/2011 Canterbury earthquake sequence. Four new buildings are being constructed, which when completed, must remain operational following a similar seismic event.

Arup provided design services to Hiway Geotechnical, for the use of Deep Soil Mix (DSM) columns below the buildings to mitigate the effects of liquefaction and provide support and groundwater cutoff for a 4m deep basement excavation. With a groundwater table within 1.0m of the ground surface and a ground profile consisting of loose sands which were susceptible to instability and piping, the DSM columns provide an alternative to typical sheet pile solutions.

Based on previous research by Arup, the design also made use of ground improvement effects in the soils between the DSM columns. On-site trials and testing verified the ground improvement, enabling cost savings compared with traditional DSM column layouts and other ground improvement solutions. DSM columns also provided advantages over sheet pile which have installation issues and don't provide the same level of versatility.

The adoption of DSM enabled several design issues to be addressed with one construction technique, providing construction cost and programme time savings.

This paper presents the main geotechnical challenges for the site, describes how various elements of the DSM columns were designed to address these issues and summarises site observations and performance during construction including observations of wall movement.

DEEP EXCAVATIONS IN SOFT CLAY ON BRISBANE AIRPORT LINK PROJECT

Henry Zhang[1], Hong Zhu[2]
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ABSTRACT

This paper presents a case history of a 22 m deep excavation in deep soft clay on the $5.6 billion Brisbane Airport Link Project, one of the biggest infrastructure projects in Australia. A 25m dep cut and cover tunnel was constructed using a bottom up sequence to connect twin driven TBM tunnels at Toombul. Diaphragm walls with two layers of slabs and two layers of horizontal steel struts were adopted to support the deep excavation and to control the ground movements and ground water drawdown in order to ensure a safe excavation and to protect the adjacent existing residential buildings, utilities and North Coast Railway. Two-dimensional (2-D) finite element analyses were conducted during detailed design to predict the retaining wall displacement, ground settlement behind the wall and pore water pressure variation during construction and in the long term. Inclinometers, settlement markers and piezometers were installed to monitor the behavior of the diaphragm walls and the retained ground, pore water pressures during construction. The monitoring data is compared with the design predictions and comments offered on the success of the deep excavation and accuracy of predictions.

SOME DESIGN AND CONSTRUCTION ISSUES IN DEEP EXCAVATIONS AND SHORING DESIGN

Qijing Yang
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ABSTRACT

This paper presents, firstly, a critical review of the current codes of practice on design and construction for retaining structures. The key factors impacting on the design and construction of shoring system is examined and discussed in detail. The importance of groundwater pressure on the design of a retaining structure is highlighted, which is as much as three times of the active soil pressure. Some design issues with respect to the SLS and ULS load combination and associated analysis are discussed through practical examples. A real case history in Sydney due to a burst water main behind the retaining wall is presented to demonstrate the significance of the groundwater pressure on deep excavation shoring design. A detail design approach is proposed as to how best the retaining wall structures could be designed to take account of the accidental water pressure induced by a burst water pipe. It is the Author's opinion that this proposed approach will provide useful guidelines to the future retaining structure design.

MEETING THE CHALLENGES OF COMPLEX EXCAVATION INTERACTIONS

D.A.F. Oliveira[1]
[1]Principal Geotechnical and Tunnelling Engineer at Jacobs and Visiting Research Fellow at the University of Wollongong, Australia.

ABSTRACT

Design of buildings on and around existing underground infrastructure is becoming more and more necessary as land within the Sydney CBD and surrounds becomes a greater commodity and below ground space is being further utilised. In mining, many underground mines need to go deeper to be economically feasible, experiencing higher stresses and challenging conditions than ever experienced before in addition to complex geological settings with significant three-dimensional effects and multiple mining fronts. As a result, such complex and dynamic environment poses significant geomechanical challenges for the planning and design of such projects. The successful design of such projects is therefore fully dependent on a good understanding of what generates the complexity and the consequent impacts. Forecasting and predictive analyses are typically not needed for investigating such complexity and targeting cost-effective, sustainable and resilient solutions. Such analyses often involve large scale and complex 3D models that should be combined with experience based design and understanding of the fundamentals. This paper presents some discussions on how to address complexity with 3D modelling and present some modelling techniques that are useful to achieve reasonable results. Examples of model confirmation are also given to illustrate how some degree of confidence is gained based on available monitoring data and/or observations combined with local experience.

UTILISATION OF DEEP GROUNDWATER BARRIER WALLS USING SOIL BENTONITE AND BIOPOLYMER SLURRIES IN GEOTECHNICAL AND ENVIRONMENTAL APPLICATIONS

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ABSTRACT

Menard Bachy has carried out over the last 15 years a large number of groundwater containment structures utilising a wide range of techniques. One particular technique is the Soil Bentonite (SB) wall which is one of the most efficient, cost effective and environmentally friendly solution to implement in-situ cut off (low permeability) walls. SB walls have been utilised historically for a wide range of applications including confinement of contaminated ground water around landfills, toxic tailing ponds but also for the improvement of performance of dams and other types of water retention structures. In the delivery of complex projects SB walls have also been utilised in combination with other mechanical and hydraulic structures such as PVC membranes, hydraulic gates, leachate collection trenches, and sumps but also sheet piles and other retention systems.

For the particular case of sites presenting environmental challenges, involving soil and groundwater pollution, a strategy requiring both removal and treatment of the source of the contamination as well as control of the contaminated groundwater plume acting as the pollution carrier is required. In the case of urban excavations where treatment is complicated by access and impact on community contamination confinement is often preferred. In any case, the adopted strategy needs to take into account the future use of the site, combined solutions involving both the reduction of the source of pollution and control of the pollution carrier generally offer the most sustainable outcome.

This paper presents a range of projects performed in Australia and overseas utilising different forms of SB walls. A particular focus is given on project methodology, site validation and trial testing but also production and quality control. The paper also provides a comparison of the environmental impact that different cut off wall techniques have and how they compare with SB type walls.

CONTAMINANT FLOW IN GROUNDWATER IN HAWKESBURY SANDSTONE – EXPERIENCE FROM MAJOR BASEMENT EXCAVATIONS

Malcolm Dale
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ABSTRACT

The geology and hydrogeology of the Hawkesbury Sandstone is well documented in relation to the construction of deep excavations and water resources. Less well known is the impact of structure/defects and bedding in relation to contaminant migration into excavations.

The Triassic Hawkesbury Sandstone is a quartz sandstone, cut by many igneous dykes and characterised by dominant NNE and ESE trending fault/joint zones. The sandstone can be divided into sheet, massive and mudstone facies (Hebert, 1983). In vertical section, the sheet (or cross bedded) and massive facies make up 95% of the formation (Pells, 1998). Tammetta and Hewitt (2004) indicate the hydraulic conductivity of the sandstone is related to defect characteristics, which is influenced by depth and in situ stress and ranges from a mean of 0.1 m/day near surface to 0.002 m/day at 50 m. Many studies also document the changes in vertical and horizontal permeability of the sandstone (AGL, 2013).

With urban renewal, many old industrial sites are being redeveloped for residential purposes. The developments are often multi-storey with multiple basement car parking levels. Investigations of groundwater contamination at these sites often requires installation of monitoring wells to below the basement depth to assess the potential risk to human health and the environment.

The migration of contaminants particularly hydrocarbon compounds can migrate into the defects in the unsaturated zone and may form light non aqueous phase liquids (LNAPLs such as petrol) in the fractures or dense non aqueous phase liquids (DNAPLs such as chlorinated solvents or coal tar) that sink below the water table.

Contamination assessments in Hawkesbury Sandstone should identify the various facies and target particular bedding planes and defects for groundwater sampling. Identifying the presence of major joint sets in vertical boreholes can be more problematic and may result in a poor understanding of the vertical migration. Often this can only be fully appreciated during excavation. In many areas, the water level measured, also represents a phreatic surface due to the location of the site within a catchment.

This paper provides examples showing how contaminant migration is driven by the vertical permeability in sub-vertical defects/joints and by the horizontal bedding planes between the various sedimentary facies in the sandstone.

GROUNDWATER INFLOW ASSESSMENT FOR DEEP BASEMENT EXCAVATIONS: A CASE STUDY

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Abstract

Approvals for proposed building developments in Sydney are granted by the consent authority with input on groundwater-related matters from NSW Office of Water. Developments with deep basements require approval for construction dewatering. NSW Office of Water input considers the requirements of the NSW Aquifer Interference Policy, including assessment of the excavation's "groundwater take" and potential impacts associated with dewatering.
In order to adequately assess the potential impacts associated with construction dewatering, and to design appropriate construction dewatering systems, it is important to accurately estimate groundwater inflow rates to deep basement excavations during construction.

This paper discusses and compares established methods to assess groundwater inflows to deep basement excavations, including analytical, analogue and numerical approaches. A case study for a proposed development in Sydney is used to demonstrate differences in estimated inflow based on these approaches, and highlight the benefits and disadvantages of each approach. Consideration is given to geological structures, basement design, and uncertainty in conceptual models and aquifer parameters that can complicate accurate assessment.

HYDROGEOLOGISTS AND GEOTECHNICAL ENGINEERS – LOST WITHOUT TRANSLATION

Philip Pells and Steven Pells

Pells Consulting and University of New South Wales

ABSTRACT

Fundamental to structural, geotechnical, hydraulic and groundwater engineering are coherent, functional, mathematical theories that obey the laws of physics and thermodynamics. Whether explicit, or intuitive, and though they be simplifications of a complex reality, it is these theories that set engineers apart from lay persons.

Like all practitioners, hydrogeologists have developed categorisations of common phenomena to make their tasks easier, of which two that are ubiquitous in hydrology are:

1. The notion of 'aquifers', and their inverse; 'aquicludes' and 'aquitards'
2. The notion of 'confinement', and its inverse; 'connectivity'.

These relate to geology, and mathematics, and are enticing because geology is complex and mathematics can be difficult. While the categorisations have been helpful, where the only consideration is groundwater production, they are deceptions when it comes to assessing depressurisation impacts. In addition they are not scientifically quantifiable with satisfactory precision.

The categorisations form a heuristic, where:

"heuristics are simplified rules of thumb that make things simple and easy to implement Their main advantage is that the user knows they are not perfect, just expedient, and is therefore less fooled by their powers. They become dangerous when we forget that." (Taleb, 2012)

In this paper, we trace the etymology of the classification of 'aquifers' and 'confinement', and the development of the current hydrogeologist's heuristic. We show how this leads to a contagion of error when considering depressurisation impacts. We also deal with other words and concepts that are particular to hydrogeology, being Specific Storage, Hydraulic Diffusivity, Specific Yield, Specific Retention and Transmissivity, and which often mystify civil engineers with conventional training in soil mechanics. By translating these hydrogeology terms to those understood by engineers we hope to help communications between these closely aligned professionals.

DESIGN GROUNDWATER LEVELS

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ABSTRACT

Successful design of structures located within or below the groundwater table requires assessment of the variation of groundwater levels over the design life. Currently the methods used for prediction of future water levels are poorly developed usually relying on extrapolation of a limited period of on-site monitoring or reliance on other historical records that may bear little relevance to the site.

Adoption of overly conservative water levels can have a very significant impact on design and construction costs. Therefore, an accurate assessment is required to achieve a design that achieves the optimal balance between risk and cost.

This paper discusses the pitfalls associated with these methods and presents some examples of failure to select appropriate design groundwater levels. Other methods are discussed than may be employed to provide an alternate and potentially more accurate assessment of design water levels so that the risk of adopting poor design levels may be reduced in the future.

HYDROGEOLOGICAL ASSESSMENT FOR A LAND RECLAMATION DEWATERING OPERATION

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ABSTRACT

The Kingston Foreshore Redevelopment was an urban renewal project in the suburb of Kingston on the southern shore of Lake Burley Griffin in Canberra. It involved reconfiguration of the foreshore by the excavation of part of the existing foreshore and the reclamation from the lakebed to form a harbour. Conventionally, reclamation process for "wet conditions" involves end dumping of granular fill, with subsequent vibro-compaction or dynamic compaction stabilisation. However, this method would not be possible since local sources of granular fill were not economically viable. Moreover, while the excavated materials from the existing foreshore were expected to be firm to stiff clays, the dumping of these excavated "lumpy" clays into the ponded reclamation areas without compaction, and the reliance upon subsequent preloading for stabilisation, would be difficult and problematic. The more feasible option in the geotechnical context was the "dry reclamation", where the reclamation areas was dewatered and fill placed in the dry. This approach required that the reclamation areas to be enclosed and water be pumped out and discharged into the lake. The selection of a dewatering system would in turn be a function of the hydrogeological model and the level of drawdown required.

This paper focuses on the hydrogeological model and properties of the site that were considered to be critical for the assessment and design of the construction options. The assessed hydrogeological model in the foreshore areas comprises an upper fine-grained alluvium, which acts as an aquitard to restrict the flow of the water from the lake to the underlying gravel/sand aquifer. The gravel/sand aquifer is therefore likely to be semi-confined. Laboratory tests and full scale pumping/recovery tests were undertaken to estimate the permeability and storativity of the gravel/sand aquifer. Back-analysis of the pumping test results indicated that the permeability values derived from various analytical methods such as the distance drawdown analysis and the recovery analysis compared reasonably well with those estimated using the more simplified Hazen's (1911) empirical method, which was related to the particle sizes of the gravel/sand materials. No in-situ permeability test was conducted in the upper alluvial aquitard. The hydrological conductivity of this layer was instead inferred from the dissipation test results obtained from CPTU soundings. It had been shown that the inferred permeability of the upper alluvial aquitard compared reasonably well with published correlations.

A number of dewatering schemes were assessed by undertaking 2D Finite Element Analysis (FEA) to check the viability of various options and sensitivity to changes to soil permeability properties. A summary of the various FEA results is presented.

GROUNDWATER CONTROL IN DESIGN AND CONSTRUCTION OF DEEP BASEMENT EXCAVATION IN SINGAPORE

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ABSTRACT

In a highly built-up city like Singapore, newer developments revolve around constructing deep underground basements due to its limited land space. This constraint constantly challenges engineering methodologies especially in groundwater control and in the design and construction of deep basement excavation works. Most excavations below the natural ground water table will inevitably induce pore pressure reduction and drawdown in groundwater table. Some of the key factors that affect the change in water table are type of geologies, excavation support system and the excavation depth. Control of groundwater during deep excavation can also be attributed to reducing horizontal stress behind the retaining wall leading to pore pressure control, high permeability soil constituents underneath the toe of the wall and leakage through the gaps or openings. In this paper, three case studies are featured where 18m to 25m deep excavations were carried out for underground basement construction in the heart of Singapore City. How the control of groundwater was considered in design and implemented in construction methodologies of deep basement excavations is presented and groundwater behavior observed during the course of excavation in different soil conditions are presented coupled with the field monitoring results.

DEPRESSURISATION OF THE CLEVELAND ST UNDERPASS

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ABSTRACT

Between May and July 2014 the Cleveland St Underpass on the Eastern Distributor, Sydney was successfully resurfaced using open grade asphalt some 15 years after motorway construction. To undertake this work required temporary depressurisation of the surrounding aquifer so that the motorway could be kept dry throughout the work period. Key to the project was rapid depressurisation such that works could be completed during night shift and within tight work hours dictated by RMS minimising disruption to one of Sydney's busiest motorways. Surface monitoring of groundwater levels was also required to ensure the drawdown beneath adjacent structures was within acceptable limits established from review of construction records and historical data. The successful depressurisation of this section of the motorway was the culmination of 4 years of research, modelling, testing, permitting and monitoring. This paper describes the staged approach performed over 4 phases of investigation, testing and monitoring of the novel solution to dewatering that was utilised to make resurfacing possible.